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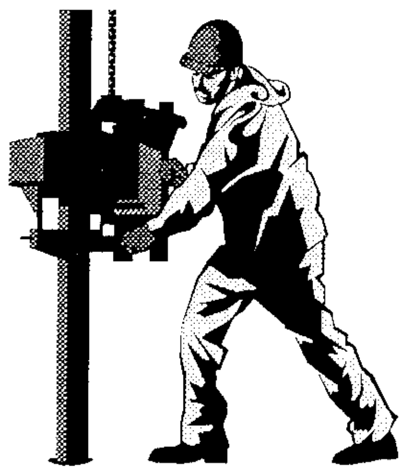

DECEMBER 16 - 18, 1996 - NEW ORLEANS, LOUISIANA, USA.

EDITED BY:

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AMERICAN BUREAU OF SHIPPING

1996 International Workshop on Human Factors in Offshore Operations

December 16 - 19, 1996
New Orleans, Louisiana

Edited by:

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Mr. Rodger D. Holdsworth
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New York, New York, 10048

ISBN ?????

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Co-Chairs: Dr. Jere Noerager - Exxon Production Research Company
Dr. Jay Weidler - Brown & Root Inc.
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Group Leader: Dr. Ove Gudmestad - Statoil

Co-Chairs: Mr. John F. Moore - Shell Offshore Inc.
Ms. Linda Bellamy - Save Consulting
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Co-Chairs: Mr. Jack Holt - Exxon Production Research Company
Dr. Michael B. Moreno - Moreno and Associates
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Group Leader:	Dr. William Moore - American Bureau of Shipping
Co-Chairs:	Mr. David A. Jones - Primatech Inc. Prof. Karlene Roberts - University of California Berkeley Mr. Rodger D. Holdsworth - Primatech Inc. Dr. Edward Wenk Jr. - University of Washington Mr. Peter Velez - Shell Offshore Inc. Mr. Ron Newton - Peak Inc.

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Group Leader:	Mr. Gerry Miller - G. E. Miller & Associates
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F **SCIENCE AND APPLICATION WORKING GROUP** - *"Implementation and Application of HOF in Safety Management"*

Group Leader:	Dr. James Jenkins - Science and Engineering Associates
Co-Chairs:	Dr. Paul Baybutt - Primatech Inc. Mr. Harold Blackman - Lockheed Idaho Mr. Tony Blackmore - Health and Safety Executive (UK) Ms. Linda Bellamy - Save Consulting Mr. Phil Brabson - Four Elements Mr. Erik Holnagel - Halden Institute for Energiteknikk Mr. Barry Kirwin - University of Birmingham Mr. John Stiff - Novel Denton and Associates

Working Group Support Papers:

"A Strategy for Management of Human Error" by: Dr. James P. Jenkins - Science and Engineering Associates, Inc.

"Human Factors in Process Safety and Risk Management: Needs for Models, Tools and Techniques" by: Dr. Paul Baybutt - Primatech Inc.

"An Agenda for Improving Safety Culture" by: Mr. G. A. Blackmore - Health and Safety Executive (UK)

"Evaluating Risk Assessment Approaches in Oil Spill Prevention Applications" by: Mr. Nathan O. Siu, Mr. Steven D. Novak and Ms. Susan G. Hill - LMITCO Report, June 16, 1996

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Dr. Charles Smith - Research Program Manager, U. S. Minerals Management Service (MMS)

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- National Energy Board, Canada
- United States Coast Guard
- United States Department of Energy
- United States Department of Transportation, Pipeline Safety
- United States Minerals Management Service

Executive Summary

Since the introduction of the Safety Case program in North Sea, the API RP 75 Safety and Environmental Management Program (SEMP) standard and similar risk management efforts, process safety has achieved unparalleled support and commitment by the offshore community. Still, most will agree that the level of offshore accidents and injuries attributed to human error is high. The recent ship collision into the popular New Orleans Riverwalk shopping complex the day before this workshop was a strong reminder to the participants how frequently and how close to home human factors is to us all. As such, it could be argued that the 1996 International Workshop on Human Factors in Offshore Operations held in New Orleans, Louisiana was long overdue. It is time for professionals, industry, government and institute representatives to discuss the status of human factors offshore. We need to review what have we done in the past, what are we doing now and what can we do in the future to lower the risk and the number of human factors related incidents and near misses we continue to see in offshore operations?

The supportive remarks, keynote addresses and theme papers presented by government leaders, representatives from regulatory and certification agencies, and management of several international oil companies clearly demonstrated the importance of human factors issues to both industry and government. Six topics were selected to establish the status of human factors spanning the life cycle of an offshore facility including design, fabrication and installation, field operations, management systems, standards and regulations and science and application. Each group was successful in capturing the state of the art utilized in offshore facilities from preliminary design to decommissioning. The issues discussed by each working group during the course of the workshop brought out the use and benefits of HOF established in other industries, advances in HOF offshore and barriers blocking further progress.

All six (6) working groups enjoyed a balanced number of representatives from industry, government and institutions who pro-actively discussed the issues related to each topic of discussion. Exchange of information and points of discussion were based upon state of the art white papers written by working group leaders and co-chairs in attendance and submitted to each participant at the opening of the workshop. From the beginning of deliberations, each white paper was enhanced by the participants to capture the true essence of each topic and clearly established industrial and research needs, guidelines and recommendations for the future development and improvement of human factors in the life cycle of an offshore facility. The importance of integrating human factors into facility design were discussed not only at the preliminary design phase but throughout the design process up to construction and fabrication. The role of HOF in the fabrication, installation and modification phases of offshore facilities began where the design group left off. Lively discussions related to fabrication and installation included organizational and safety culture/safety climates, management aspects, supervisor's roles, working environments, accident reporting, the role of the individual worker, training, design influences, quantification of human errors and more. Despite the limited amount of knowledge and good practice available related to use of HOF in improving offshore drilling, workovers, production operations and maintenance, an abundance of enthusiastic dialogue was generated touching many areas offshore management and polices and actual operations related to field operations. Topics of discussion included use of HOF in the management of contract crews, shift change and work schedules, auditing techniques for field operations incorporating HOF, adequacy of the human working and living environment as it affects operations, human error classification schemes to predict error and improve behavioral safety processes, management of change in upstream exploration and production, behavioral techniques and communication between operations personnel.

One of the many questions asked during the course of the workshop was "How do we integrate HOF into our management systems at the top and front line of our operations in such a way that we can effectively improve our safety culture and appreciably reduce risk?". Practical applications of HOF integration into all levels of management system documentation for all elements of process safety and environmental management were discussed at length. Risk assessment, Management system models, tools and techniques for safety management were only a part of the topics discussed as well as safety, corporate culture and corporate character. The group discussing further development of HOF standards, specifications and guidelines also entered into interesting and spirted discussions. Representatives from the North sea, Canada, Southeast Asia and the United States communicated various points on key issues and discussed the role of different organizations including Federal Agencies, Trade Associations, Professional Associations and Individual Companies. The Science and Technology group generated several papers on various methodologies utilized in the field of HOF as well as various approaches to designing and developing HOF models, analytical, quantitative and qualitative solutions to specific applications. Many questions were fielded by all of the working groups that lead to specific problems for future development and or research.

Scope

The scope of this workshop was to provide a cooperative workshop on the use of Human and Organizational Factors (HOF) in the Management of Safety and Environmental Hazards for Offshore Operations and Facilities. The goal of the workshop was to define the state-of-the-art of the engineering and management practice of HOF and Behavioral Safety to reduce the likelihood of offshore incidents, on the job injuries, environmental hazards, and improve safety, quality, reliability, economics during the design, construction, and operation of offshore facilities. The workshop involved international participants representing HOF assessment and management strategies, and included corporate, institute and government leaders, HOF specialists, human factors engineers, safety professionals and practitioners with special knowledge in the effective application of HOF in facilities design and implementation in the workplace.

Introduction

It is generally believed that as many as 90% of offshore accidents and injuries can be attributed to human error. Human factors - the human-machine interface in particular-greatly influence the safety and reliability of offshore facilities and operations. One of the most effective methods of reducing the risk of accidents and improving quality and reliability is through human factors engineering.

Human and Organizational Factors (HOF) have been successfully applied in various industries to reduce accidents caused by human error. Those same HOF standards and methodologies can also be used to reduce offshore accidents. Improvement of standards, regulations and programs to educate the offshore community in the numerous recent advancements in HOF engineering and application, both on and offshore, cannot be overemphasized. Engineers, managers and operators need a better awareness and understanding of HOF in the design, construction and operation of facilities before full utilization and benefits can be achieved. In addition, further efforts in research and development are needed to provide for missing HOF elements specific to offshore operations.

This workshop was designed to provide guidance and promote collaboration on the use of HOF in the management of safety and environmental hazards for offshore operations and facilities. Experts reviewed the progress in various HOF applications, identified current problems associated in introducing HOF into design and the workplace, and prioritized the important research and development topics in the field of HOF and behavioral safety.

Workshop Overview

The format of the 1996 Workshop in New Orleans, like previous workshops on other topics in past years, was unique in that it carefully balanced the two and a half (2-1/2) day workshop with presentations on the state of the art of Human and Organizational Factors and working group sessions in which discussions on research and development needs were held. A total of two (2) Supporting Remark presentations, six (6) Keynote Address presentations and four (4) Theme Paper presentations were delivered. The manuscripts of these presentations are included in this volume.

With respect to the working group sessions, there were six groups established which covered the following areas related to HOF in offshore operations:

1. Design Working Group; Position White Paper - *"Reduction of Human Error Through the Application of Human and Organizational Factors in Design and Engineering"*
2. Fabrication and Installation Working Group; Position White Paper - *"The Role of Human and Organizational Factors in the Construction Fabrication and Installation of Offshore Production Facilities"*
3. Field Operations Working Group; Position White Paper - *"Improving Offshore Drilling, Workovers, Production Operations and Maintenance Through Practical Application of Human and Organizational Factors"*

4. Management Systems Working Group; Position White Paper - *"Application and Integration of Human and Organizational Factors into Management Policies, Procedures and Practices to Reduce Human Error and Improve Safety and Productivity"*
5. Standards and Regulations Working Group; Position White Paper - *"Further Development of Standards, Specifications and Guidelines Related to Human and Organizational Factors to Reduce Human Error in Offshore Facilities and Operations"*
6. Science and Application Working Group; Position White Paper - *"Implementation and Application of Human and Organizational Factors in Safety Management"*

Each working group started with the presentation of a white paper which identified the research and development needs, opportunities and important ongoing projects, and barriers to the progress and application of human and organizational factors in offshore operations. The position white papers were given to each participant prior to the working sessions. During the working group period, the participants were encouraged to visit more than one session to maximize their contributions to the different aspects of human and organizational factors. In addition supporting papers were submitted to some working groups focusing on specific topics of concern. For the final session of the working groups, the participants were changed to prepare lists of prioritized action items for the final workshop assembly.

The atmosphere of the workshop was extremely positive and upbeat. All participants felt that HOF technology is undergoing significant progress and that the tools are available to formally integrate HOF throughout the life cycle of an offshore facility, including existing facilities. There are many areas that require in terms of fundamental research, the availability of qualified professionals, publicly available information these issues are still the major problem. More fundamental studies coupled with practical HOF solutions to issues unique to offshore operations are needed to understand and control human factors related failures. The science, technology and application of human factors is progressing but in small increments. Several new HOF methodologies have been introduced to the offshore and marine industries that may improve significantly the universal use of human factors. It goes without saying that management needs more information before committing to full integration of HOF into all aspects of offshore facilities design and operations. The commitment starts with working together in researching and developing HOF programs to a common end.

Acknowledgment

The organizing committee would like to extend their most sincere gratitude to the Department of Interior - Minerals Management Service (MMS) and the American Bureau of Shipping for their contributions beyond sponsoring this event. The support of their staff and facilities was greatly appreciated. The major government, institutional and industrial sponsors are also acknowledged for contributions which made this event possible. The industrial participants with booth exhibitions are greatly appreciated for their effort in bringing their information to the workshop. During the Workshop, University of California graduate students were asked to assist in facilitating the work of each working group and two Primatech staff, Ms. Cynthia Hawthorne and Ms. Lisa Longoria were asked to handle the logistics and administration of the workshop. Their efforts are gratefully acknowledged. Finally, the organizing Committee congratulates each of the participants for their active participation in the working group sessions with questions, comments, and suggestions. As to the request for holding the next Human Factors workshop within the next three years, it will be made known to the concerned parties.

Prioritized List of Research and Development Needs in Human Factors for Offshore Operations

The Way Forward: High Priority Research and Development Initiatives

High priority Research and Development (R&D) initiatives defined during this workshop could be organized into six areas:

1. Guidelines and standards
2. Training
3. Information and communications systems
4. Management systems
5. Pilot projects
6. Research

The emphasis developed during this workshop was on development - appropriate utilization and testing of existing technology. It is apparent that there is a large body of information and experience (technology) from other industries that awaits application to offshore platforms. 'Pilot' applications of some of this technology by both industry and government groups have clearly indicated its potential effectiveness and benefits in improving both the economics and safety of offshore platforms. The existing technology needs to be properly and wisely adapted from other allied industries and areas to offshore platforms.

The first five initiatives are identified as development initiatives. It was assessed by the workshop participants that there is adequate existing technology to begin addressing these initiatives. The remaining initiative identifies research related efforts in which it was assessed that there is insufficient existing technology to adequately address these topics or aspects.

The workshop presentations, discussions, and papers clearly indicated that there are some significant efforts being made by some industry and governmental groups to implement advanced methods to better understand and manage human and organizational factors (HOF) in platform design, construction, maintenance, and operations. The primary objective of the R&D initiatives defined during this workshop was to take full advantage of these developments and experiences, accelerating their further acceptance and use by all members of industry and government. The secondary objective of the R&D initiatives was to promote a better understanding of the three professional disciplines most often associated with HOF: 1) Human Factors Engineering, 2) Behavioral Science, and 3) Process Safety. Thus, these R&D initiatives were generally seen as those that were clearly justified and of high priority to allow a reasonable pace of implementation of HOF technology by industry and government.

Many of the R&D topics identified are cross-cutting in that they were cited and discussed by several of the Work Groups. The Work Group discussions repeatedly emphasized that there is a single common factor among the diverse functions, systems and activities discussed in each of the work groups: the people that design, construct, operate, and maintain platforms. Thus, the R&D initiatives cited here are fundamentally 'generic' in that they can apply equally to each of the phases in the life-cycle of an offshore platform.

Guidelines and Standards

The R&D topics included in the Guidelines and standards initiative area are summarized in Table 1. Most of the work in this initiative is intended to make use of existing guidelines and documents, interpreting and adapting them properly to offshore platforms. While several operators have developed excellent guidelines and standards for their use, it is clear that development of these guidelines and standards needs to be on a industry-wide basis. These guidelines and standards need to be sanctioned both by industry and government if full benefits of the guidelines and standards are to be realized. Joint industry - government sponsored projects and projects conducted under the auspices of trade associations (e.g. American Petroleum Institute), professional societies (e.g. Society of Petroleum Engineers), and organizations knowledgeable and experienced in Human Factors Engineering, Behavioral Science, and Process Safety were suggested as mechanisms to accomplish this work.

Table 1 - R&D Recommendations for Guidelines and standards

• Guidelines for incorporation of HOF considerations into design of new platforms	• Guidelines for incorporation of HOF considerations in contracts and specifications and selection of contractors
• Guidelines for incorporation of HOF considerations into reassessment of existing platforms	• Guidelines for training personnel in HOF principles and considerations
• Guidelines for design of platform systems (structures, equipment, personnel, procedures) that will be more tolerant of HOF related deficiencies	• Guidelines for the qualitative and quantitative analysis of platform systems to adequately incorporate HOF
• Guidelines for improved incorporation of automation into drilling and production systems	

Training

Given the wealth of existing technology and experience in HOF in the safety of engineered systems, training was identified as one of the most important development efforts. The training needs to be performed by properly qualified and experienced trainers. The training programs should take advantage of the formats and methods developed by other industries (e.g. those developed by the American Ergonomics Society). The training programs should emphasize an understanding and knowledge of HOF fundamentals and practical skills in application of these fundamentals. Case history based methods and pilot projects were two training approaches that were suggested by the workshop participants as being highly effective. Development of multi-media self-study courses and periodic short-courses were indicated to be highly desirable training mechanisms.

Table 2 - R&D Recommendations for Training

• Training programs for offshore engineers in HOF considerations and principles	• Training programs for platform safety auditors and assessors in HOF considerations and principles
• Training programs for platform operators in HOF considerations and principles	• Training programs for managers of offshore operations in HOF considerations and principles

Information & Communications Systems

In all life-cycle phases and activities associated with improving the safety of offshore platforms through the improved management of HOF indicated an important need for improved information and communications. Information on incidents and near-misses was seen as very useful in providing early warnings of safety and HOF related degradation. However, this information needed to be developed and communicated in such a way as to avoid counterproductive legal and punitive activities. Information on accidents needed to be developed to provide more definitive information on the HOF aspects of these accidents and to provide information on how offshore platforms could be improved to reduce the incidence and severity of HOF related accidents. The lack of appropriate and timely feed-back to engineers and designers throughout the life-cycle of platforms was repeatedly cited as a primary source of HOF related problems. It is clear that several accident and near-miss information systems have been developed, but the general observation developed by the workshop participants was that these systems do not adequately capture the HOF aspects. Thus, work is needed to improve these existing systems. In addition, there is no central industry communications system to allow sharing of experiences and developments. An effective information development system must incorporate an equally effective communications system so that the knowledge can be shared, understood, and used to improve the safety of offshore platforms.

Table 3 - R&D Recommendations for Information & Communications Systems

• Development of an industry wide system for reporting, assessment, recording, and communication of information on incidents / near-misses during the life cycle of platforms (with emphasis on the HOF aspects)	• Development of an industry wide system for reporting, assessment, recording, and communication of accidents during the life-cycle of platforms (with emphasis on the HOF aspects)
• Development of industry - government forums to permit discussion of evolving safety challenges	• Development of industry - government forums to encourage feed-back from construction, maintenance, and operations to design engineers

Management Systems

One of the most pervasive topics of discussion during the workshop involved development of management systems for industry and government to adopt, implement, and continuously improve HOF related initiatives intended to improve the safety of offshore platforms. It was observed in one of the workshops:

> *"The difficulty with a voluntary approach however, is that so far, left to their own the vast majority of the offshore companies to date have not placed any focused effort on the use of HOF standards, specifications, or guidelines in the design and operation their offshore facilities unless forced to by a regulatory agency of some form. This may be due to lack of knowledge about HOF, a concern over what is perceived to be yet another costly and time consuming burden imposed on them by others without a demonstrated cost benefit, a belief that they are doing all that is necessary now, or a deliberate choice to exclude HOF from their design efforts. Whatever the reason(s), the fact remains that the offshore industry currently is not voluntarily adopting HOF as a part of their design and operation team."*

Clearly, there are some companies that are leading and adopting advanced HOF assessment and management methods and procedures. The majority of these companies can identify the economic and safety benefits derived from these measures. However, these companies are a minority in the entire industry. Further in the face of mandated down-sizing and cost-cutting, and benchmarking based on current costs, several of the leading companies have cut-back their HOF related activities.

If any initiative is to survive in both the short-term and long-term, then there must be economic incentives that can provide the resources to justify maintenance of that initiative. Work is needed to develop sensible and positive management systems to encourage further development of HOF related initiatives for offshore platforms. Table 4 identifies the management system development initiatives that were discussed during the workshop. Because of the necessity for sustainable and practical management systems, it was emphasized that these developments need to involve both industry and regulatory interests, including financial and insurance aspects.

Table 4 - R&D Recommendations for Management Systems

• Develop metrics to evaluate HOF performance during the life-cycle of platforms to provide encouragement and direction for continuous improvements in safety	• Develop positive management systems by industry and government to encourage implementation of advanced methods to better manage HOF in platform operations (the carrot)
• Develop methods and procedures to allow better evaluation and justification of measures to improve management of HOF in the life-cycles of platforms	• Develop reasonable enforcement systems to help encourage diligent application of advanced HOF management methods by all segments of industry and government (the stick)

Pilot Projects

Pilot projects were cited in several work groups as a means for testing, verification, and training associated with HOF initiatives intended to improve the safety of offshore platforms. As shown in Table 5 these pilot projects could involve all of the life-cycle phases of offshore platforms and involve 'platforms of opportunity' where the pilot project could help benefit a 'real' project or platform activity. Several operators discussed their experiences with performing such pilot projects. These projects provided the foundation for a general application of the understanding developed from the pilot projects. In several cases, it was easy to identify how the pilot project had actually decreased the cost and schedule associated with the 'real' project.

Table 5 - R&D Recommendations for Pilot Projects

• Test application of improved HOF assessment and management methods in design of platform structures and equipment systems	• Test application of improved HOF assessment and management methods in operations of platforms to improve the safety of drilling and workover activities
• Test application of improved HOF assessment and management methods in construction of platform structures and equipment systems	• Test application of improved HOF assessment and management methods in operations of platforms to improve the safety of production activities
• Test application of improved HOF assessment and management methods in maintenance of platform structures and equipment systems (e.g. diving operations, vessel and piping inspections and maintenance)	• Test application of improved HOF assessment and management methods in decommissioning platforms and associated facilities

Research

The primary research efforts identified during the workshop were intended primarily to fill presently recognized gaps in the existing technology on HOF in the safety of engineered systems. Data on HOF on near-misses and accidents is still largely missing and needs to be developed to allow further development of proactive and reactive safety qualitative and quantitative assessment systems and measures. Adequate HOF classification and characterization systems, instrument, and protocols still need to be developed for offshore platform operations. Industry information and communication systems on HOF in the safety of offshore platforms are largely non-existent and need to be developed. In some cases, development of equipment and hardware to improve the safety of offshore platform systems has gone about as far as they can go (e.g. blowouts, fires, explosions), and research is needed on how to further improve the HOF aspects to further control these hazards.

Table 6 - R&D Recommendations for Research

• Develop and verify HOF classification and characterization systems that can be used in analysis, near-miss, and accident information and communications systems	• Develop and verify instruments, protocols, information communications systems that can be used in assessments of near-miss, and accidents
• Develop HOF measurement systems that can be used in qualitative and quantitative safety analysis	• Develop improved HOF based manning and shift guidelines and procedures
• Develop improved methods to characterize and manage 'mega-system' organizational interfaces	• Develop improved methods for selecting and contracting with contractors and sub-contractors
• Develop improved HOF assessment and management systems for rapidly developing hazards (high tempo operations) to platform safety (e.g. fires, explosions, blowouts)	

Supporting Remarks

1996 International Workshop on Human Factors in Offshore Operations
December 16, 1996
Welcoming Address
by
Chris C. Oynes

Good morning. Welcome to New Orleans and the International Workshop on Human Factors in Offshore Operations.

This workshop is the culmination of a lot of work by a number of people, and they deserve a lot of credit for assembling an interesting agenda. They have provided us with an excellent opportunity for the discussion of what role human and organizational factors have in offshore accidents. On behalf of MMS, I want to thank those of you who have taken time from your busy holiday schedules to attend this 3-day program. I'd also like to thank those organizations that have helped MMS sponsor this important workshop. A special thanks also goes to the University of California-Berkeley, and to Primatech for their efforts in organizing the - what appears to be a successful workshop.

Before we get too far along, I thought I would briefly discuss what is going on in MMS, specifically in the Gulf of Mexico. This should serve as a backdrop for the key note addresses that follow.

Nineteen ninety-six has been an exciting and challenging year for the MMS.

- Operations in the Gulf of Mexico Outer Continental Shelf have rebounded from the low levels of drilling and new developments just a few years ago.
- 6000 leases - 3800 platforms - 130+ operators
- Deepwater is one area that has contributed substantially to the resurgence of the Gulf OCS.
- Operators are moving into increasingly deeper water and experiencing good success rates in their exploratory efforts.
- Deepwater development projects are going forward based on very promising production rates.
- Of course, improved technology is contributing significantly to meeting the challenges of the deepwater push.
- Legislation signed in 1996 and supported by MMS has provided the operators with relief from royalty payments for some leases and projects, making marginal developments economic.

One only needs to look at the rig use rate overall in the Gulf of Mexico, and specifically the deepwater count, to confirm the interest in deepwater. The deepwater drilling effort is expanding, with 10 companies represented in the 24 wells currently being drilled in water depths greater than

1000 feet. Shelf activities also continue to diversify due to technology and the influx of independent operators that are able to drill wells and produce hydrocarbons that the larger companies find uneconomic or unattractive.

The increase in deepwater development and associated complexities in the technical, safety, and environmental reviews of deepwater exploration and development projects comes at a time when the shelf infrastructure is also undergoing a transition. There are a tremendous amount of supplemental plans to drill additional wells from existing facilities to develop production from subsalt plays. Several other examples include: previously undeveloped shallow objectives; horizontal wells; and multi-lateral wells.

More independent companies are becoming active in the offshore GOM; some have little or no experience with MMS rules and policies. Infrastructure is also approaching (and in some instances surpassing) its design life, necessitating increased attention to assure operations can be conducted in a safe manner.

With the increased activity, aging infrastructure, and diverse OCS operator base, the industry must be careful to assure continued safe and pollution free operations on the OCS. We all have learned valuable lessons from major accidents throughout the world.

- One of these lessons is the need for a proactive approach to safety management for offshore operations.

- Another lesson is that improvements to safety have resulted as the reliability of equipment has been improved, yet the offshore continues to be affected by significant accidents. Experience clearly indicates that human and organizational factors are responsible for the vast majority of incidents and accidents involving offshore platforms.

In recognition of the importance of human and organizational factors in offshore operations, MMS and others have developed guidelines to begin addressing the human aspect of incidents within their areas of expertise and jurisdiction. The MMS effort, known as the safety and environmental management program, or SEMP, was introduced to industry as a mechanism for putting overall performance ahead of rote equipment resting and reliance in prescriptive regulations.

SEMP is designed to look beyond the compliance mentality that too often is associated with regulations. This non-regulatory program is intended for designing, managing, and conducting OCS operations in ways that emphasize the importance of human behavior in offshore safety and pollution prevention.

MMS looks to this workshop to better understand the role of human and organizational factors in all aspects of offshore operations. We hope to better understand where it fits into the regulatory framework, including the Agency's offshore inspection strategies. We also look to the workshop participants to help identify and focus areas where additional research is warranted.

A quick look at the agenda shows that the next three days have been organized to focus the discussion on those issues considered to be key under the umbrella of human and organizational factors.

One of the documented challenges facing industry regarding the effective integration of human and organizational factors initiatives into safety is getting the affected individuals involved with the program. This workshop could lead to a better understanding of this issue.

Let me close with a few recommendations that I believe will lead to a successful workshop. Active participation in the discussions is key to the identification and understanding of safety concerns. If you have practical examples, information on effective implementation of human factors methods, cost/benefit data, or concerns, please share them with those in the working groups. I encourage you to take advantage of the experts in attendance. Use this opportunity to challenge them and yourselves on how, as an industry, we can improve upon the good offshore safety record. Finally, I hope you will take from this workshop some practical examples of where human and organizational factors methods have improved safety and that you will apply them to your own situations.

Once again, thank you for attending the workshop and enjoy the next three days.

Keynote Addresses

Keynote Remarks
Presented by
Henry G. Bartholomew
Deputy Associate Director
Offshore Safety & Environmental Management
U.S. Minerals Management Service
Herndon, Virginia

The influence of human and organizational factors (HOF) on industrial safety has only recently begun to receive the attention it deserves. Over the next two and a half days, we'll be immersed in a topic that not too long ago was unfamiliar to many of us. We'll hear about the role of human and organizational factors not only in the offshore oil and gas industry, but in the airline, shipping, and other industries, as well. We'll learn from experts representing industry, academia, and government, and we'll exchange ideas in discussion groups covering several aspects of the theme topic.

Peter Drucker, the dean of American business scholars, recently scolded the government for failing to effectively address workplace safety. While readily agreeing that workplace safety is a proper regulatory mission for government, he observed that safety in the American workplace has not improved greatly in the past 25 years. Even with the steady shift from unsafe work to comparatively safe work — for example, from relatively dangerous manufacturing and mining jobs to inherently safe office and service jobs — safety in the American workplace may actually have deteriorated since 1970.

Drucker argued that regulatory agencies have been propelled by the common assumption that the primary cause of accidents is an unsafe environment. Under that assumption, the government has attempted the impossible by seeking to create a risk-free workplace. While conceding that we need to eliminate safety hazards, he contends it is only one part of safety, and probably not the most important part. Drucker concluded that *the most effective way to achieve safety is to eliminate unsafe behavior*. Drucker's conclusion is supported by recent studies indicating that upwards of 80 percent of offshore accidents result from human error, procedural failure, or organizational breakdown.

Our examination of the influence of human factors on safety and productivity comes at a time of rapid change in the offshore oil and gas industry. The U.S. Outer Continental Shelf (OCS) currently produces more than a million barrels of oil a day, about 16 percent of all U.S. oil production, and supplies about one-fourth of all the natural gas consumed in the U.S. If projections are accurate, by 2000 the Gulf of Mexico OCS will be producing upwards of 1.6 million barrels per day and accounting for 25 to 30 percent of domestic oil production.

This follows a decade of industry downsizing and restructuring in which tens of thousands of seasoned workers and managers left the industry. A combination of influences is driving or abetting the current surge. It is the introduction of new technologies and the effects of restructuring, however, that have made possible the industry's response to growing demand. Advanced 3-D seismic technology has greatly improved industry's ability to locate hydrocarbon deposits, and has substantially reduced the cost of finding oil and gas deposits.

New subsea systems and technologies, buoyant structures, floating production facilities, and lightweight, high-strength materials are making it possible to produce in increasingly deeper waters. Producers are discovering and developing new resources in subsalt prospects and finding previously undetected reserves in older, worked-over reservoirs. Extended reach drilling and the growing tendency of companies to share offshore facilities has reduced the need for additional offshore platforms, while helping increase production. Advances in horizontal and sidetrack drilling have greatly improved production rates and reservoir yields, causing some operators to look again at older, even relinquished leases.

Among the beneficial outcomes of industrywide restructuring has been the growing influence of the industry's independent operators. Independent producers, with lower overhead costs, have been successfully producing many older, marginal fields that major oil companies no longer can produce economically. Independents also are playing an increasingly important role in offshore exploration and development. A recent study by Louisiana State University (LSU) found that over the last 10 years independent operators drilled nearly 70 percent of all the exploratory wells drilled on the OCS.

Accompanying the industry's downsizing efforts has been a reduction in the numbers of on-the-job personnel and an expanding role for contractors. Whether employed by majors or independents, more day-to-day operations that traditionally have been carried out by seasoned company personnel are now being conducted by contractors. There are safety concern, however, if contractor personnel lack the knowledge and experience of the veteran hands they have replaced.

To round out this picture of the industry, it's important to recognize that its safety record since the 1969 Santa Barbara Channel oil spill has been outstanding. Thanks to technological advances, the industry today has better, more reliable, and safer ways to find, produce, and transport offshore oil and gas. Rarely does equipment failure alone cause accidents or pollution. And that brings me full circle back to the purpose of this workshop — gaining understanding of the role of human and organizational factors in offshore safety.

As the agency responsible for regulating offshore oil and gas activities, MMS has recognized that as the world and the industry change, MMS must reassess and adjust its regulatory strategy. While our goal of safe and pollution-free offshore operations remains constant, new regulatory objectives are emerging. I want to briefly outline four of those objectives.

1. *Eliminate unsafe behavior.* Our first objective is to eliminate unsafe behavior. Most people would agree that well-trained, conscientious workers do not knowingly engage in unsafe behavior or commit unsafe acts, especially experienced workers in hazardous jobs. Not only must workers know how to perform their jobs safely, but they also need to recognize unsafe acts, their potential consequences, and how to prevent them. Workers may need additional training to work safely. Safe work practices should govern the workplace. When an accident occurs, workers and managers must learn its cause and how to prevent a recurrence. Even when there's a near miss, workers and managers need to know why and how to avoid a repetition.

2. *More flexible, performance-based regulations.* Our second objective is to create a more flexible, performance-oriented regulatory system. MMS safety regulations today focus largely on the installation, operation, and inspection of equipment. They have little to say about human behavior. These regulations have been effective and have contributed to the industry's outstanding safety and environmental record. It may be more effective, however, for MMS to establish performance objectives and challenge the industry to devise suitable, even innovative, ways to meet them. Clearly, certain safety measures are so necessary that any responsible oil and gas operator should be expected to employ them — for example, blowout preventer systems, toxic gas alarms, downhole safety valves, and emergency shutdown systems.

3. *Promote continuous improvement.* The third objective is to promote continuous improvement in safety and pollution-prevention practices. The most far-sighted prescriptive regulatory system cannot foresee all potential problems or prevent all possible mishaps. Indeed overly-prescriptive regulations may inhibit innovation, placing too much emphasis on regulatory compliance and not enough emphasis on safe performance. An enlightened and responsible regulatory system should encourage all means of promoting safety and pollution prevention through design, engineering, fabrication, construction, operations, maintenance, and company policies aimed at avoiding human error and organizational breakdowns.

4. *Fix the problem, not the blame.* That leads to the fourth of MMS's emerging regulatory objectives. I've heard it said that industry and government can never truly be partners in a highly-capitalized, regulated industry such as offshore oil and gas. However, I wonder if we can afford not to be partners when it comes to safety. The last of our emerging objectives, therefore, is to promote an atmosphere where industry and government can work together to fix the problem, not the blame. If we're successful, the U.S. offshore not only will be safer and pollution-free, but enforcement actions and penalties will become the rare exception.

To move toward our common goal of cleaner and safer offshore operations, and to place more emphasis on human and organizational considerations, MMS invented SEMP, the *Safety and Environmental Management Program.* SEMP unifies our emerging regulatory objectives into a single, comprehensive strategy. SEMP is a new approach to managing offshore operations that offers potentially less regulation, not more. SEMP can reduce substantially the risk of accidents and pollution by changing the way we think about safety. SEMP is designed to discourage a compliance mentality in which people wrongly and dangerously believe that regulatory compliance equals safety.

A good SEMP plan starts with top management's firm commitment to safety and pollution prevention. It includes programs for identifying and mitigating hazards. It incorporates safe work practices and management-of-change procedures. It assures that employees and contractors are well-trained. It includes procedures for reviewing accidents and near misses, and a system for correcting problems. Lastly, a good SEMP plan includes procurement policies that strengthen safety practices. To date, the industry's operators have been implementing SEMP in accordance with API's Recommended Practice 75 (RP75), which the industry developed in response to the MMS call for a new approach to safety and environmental protection.

I want to welcome you to this international forum that is bringing together corporate leaders, facility designers, human factors experts, safety engineers, and regulatory and certification officials. During the course of this workshop, we hope to achieve several objectives.

Collectively, we will define the best industry practices governing human and organizational factors in the management of safety and environmental hazards in offshore operations and facilities. We'll identify the influences of human and organizational factors on offshore facilities design, engineering, fabrication, installation, operations, and maintenance. Together, we'll produce a record that describes the current practice and science of human and organizational factors and identifies opportunities for applying human and organizational factors in the management of safety and environmental hazards in offshore operations and facilities.

I hope this workshop will be a wise investment of your time and energy. I encourage you to participate actively in the breakout sessions.

I thank you for your attention.

HUMAN FACTOR ISSUES CONCERNING CLASSIFICATION SOCIETIES

Frank J Iarossi
Chairman
ABS

"Men who go down to the sea in ships" have traditionally displayed a certain fatalism in their acceptance of the risks which accompany their chosen occupation. It is to its credit that our industry no longer accepts such a laissez-faire approach. By constantly raising the standards and tightening the rules, many of these traditional risks have been reduced or eliminated.

But there is much more still to be done. Encouraging and protecting human safety in the offshore industry is a complex task. Our task is even more challenging since the vast majority of catastrophic casualties can be traced to human or organizational failures.

Experience shows that the resulting solutions will inevitably require a delicate juggling act involving such unquantifiable factors as judgment, fatigue, boredom and crisis response. It is for this reason that the audience here today includes experts from such a broad range of disciplines including sociology, psychology, risk management and engineering in addition to the facility operators who must wrestle with the application of all these new elements.

For many years there has been a tendency within the industry to think in engineering, or hardware, terms as though it were possible to produce infallible structures. This meeting is evidence that our industry has recognized and is reacting to the importance of people in the design, construction and operation of marine facilities. I prefer to use the phrase "the human element in the safety equation."

Unfortunately, many legislators and regulators continue to embrace the 'hardware' concept, looking to enhanced design and improved engineering as the preferred response to high profile marine casualties. The Oil Pollution Act of 1990 and its requirement for double hull tankers is merely the most prominent of these hardware initiatives in response to a human failure.

Within our industry there now is a different emphasis, stemming from a realization that many incidents could have been avoided if greater thought had been given to the human element within the safety equation - the software side. The sobering aspect of that realization for the shipping industry has been that billions of dollars in new capital investment may have been avoided if greater attention had been paid to the human elements before the U.S. Congress created the Oil Pollution Act.

Within the offshore sector we have seen signs of revolutionary new approaches to safety. Most of you are familiar with the consequences of the *Piper Alpha* disaster. The UK Government's "safety case" came out of this incident. Although application of these new requirements can run to well over $1M per facility, most agree the safety case approach has proven to be of significant assistance in analyzing and addressing human factors in offshore safety.

Where does class enter into this debate? Let me emphasize that at ABS we do not consider this focus on the "human element" to be something new. We trace our own history back more than one hundred and thirty years to our predecessor organization, the American Shipmasters' Association which was created to certify the competency of shipmasters. Although we view ourselves as leaders in the development of marine technology in support of enhanced safety, we have never lost sight of the importance of the people.

We adhere strictly to the philosophy contained in our mission statement - to promote "the security of life, property and the natural environment primarily through the development and verification of standards for the design, construction and operational maintenance of marine-related facilities." People are integral to this philosophy.

You will note that our statement refers not to "ships" but to "marine-related facilities". Class is best known for its activities in the shipping sector. Within the offshore industry our presence has been limited primarily to floating facilities. Not all offshore structures require class, although I would add as an aside, that it has always seemed inconsistent to me that marine underwriters insist on third party certification of a $5M ship, but will accept the risk on a $500M offshore platform with no comparable validation of standards. As offshore production moves to deeper water, floating facilities will benefit from the services, practical knowledge and experience offered by the classification societies. ABS stands ready to assist.

It is our breadth of experience, and our professional and impartial integrity, which we at ABS can contribute to the discussion on the human element in the offshore sector. We believe we can add a distinct perspective by drawing on our recent experience within the shipping industry and applying some of those lessons to the offshore sector. It is when an industry fails to adopt strong self-regulation, that increased government regulation results.

Within the shipping sector the most recent initiative, on an international level, has been the introduction of the International Safety Management Code. The stated purpose of the ISM Code which will become effective in July 1998, is to provide an international standard for the safe management and operation of ships and for the prevention of pollution. The requirements cover corporate policies and operations as well as each vessel within the fleet to ensure consistency with the company's safety management system.

At ABS we have been deeply involved with the early application of these standards. I can assure you that they are bringing fundamental change to the manner in which international shipping is conducted. I can also assure you that conformance is not merely a question of a quick inspection and the issuance of a certificate. It involves a minimum of twelve and often as much as eighteen months of serious corporate introspection in which every aspect of the management and operation of the company, and of each ship within its fleet, is subject to scrutiny and reevaluation.

And there is no end to the process. Although the initial document of compliance is issued to the company and separate safety management certificates to each ship, the ISM Code demands ongoing compliance with subsequent annual self audits by the company, interim 30 month checks by the certificating body and five year recertification audits to maintain compliance. And compliance will be mandatory. Underwriters, charterers, P&I clubs, flag states and port states are making it quite clear to the shipping industry that compliance with the ISM Code is required as a condition of continued trading.

Where the ISM Code differs from past international regulation which the shipping industry has had to digest, is that it is not a hardware initiative. It is solely concerned with the software or 'humanware' - the people and systems which govern the day to day operations of the company and each of its vessels.

- It is about defining and designating authority to ensure safety and pollution prevention.

- It is about designating people to ensure clear communication between ship and office.

- It is about defining the responsibilities of the shipboard personnel and ensuring each of them is properly trained to perform their duties safely and efficiently.

- It is about having clearly defined plans for dealing with emergencies, for monitoring, reporting and analyzing accidents and hazardous occurrences to ensure proper corrective action.

- It is about establishing sound procedures for maintaining the ship and its equipment in a safe condition.

- And it is about self reliance and self regulation of the auditing system once it has been established.

A couple of points bear repeating. The ISM Code is an international regulation. It is focused on people and operations. It is mandatory, worldwide. And it carries the prospect of effective enforcement.

Is the offshore sector subject to a comparable mandatory "human element" safety regime? Not yet. And I say not yet because, on the basis of our experience within the shipping sector, I am convinced it is only a matter of time. For the moment, regulation is either voluntary, as with the API developed SEMP program, or national, as is happening in the North Sea. Mandatory international standards have not yet been applied. Coastal state jurisdiction remains paramount.

But industry activity is changing. MODUS, semi-submersibles, drill ships, FPSOS, OSVS are not designed to be site specific. And drilling activities in most parts of the world are moving further and further out from the continental shelf to deep water locations. It is highly likely that many of these costly floating facilities will find service in more than one location in the world during their service life.

SEMP (The Safety and Environmental Management Program for Outer Continental Shelf Operations and Facilities) based on the API RP75, bears many similarities to the ISM Code, but also carries some significant differences. They are alike in the general principles which apply, including top level management involvement and responsibility, the application of safety and environmental protection procedures, the need for properly trained personnel, emergency response planning, and a focus on operational procedures.

One of the strongest elements of SEMP, and one which is not mirrored in the ISM Code, is the emphasis which it places on safety management throughout all stages of the platform lifecycle including design, construction, maintenance and operations. This approach, however, mirrors the approach which ABS has traditionally taken to the application of its basic mission.

There are other key differences between the SEMP approach and the ISM regulatory environment. SEMP is a major step in the right direction. But it is not an international standard. it is not mandatory. And it does not have clear enforcement mechanisms. In comparable areas within the shipping sector, we have found these to be critical weaknesses which have often resulted, sooner or later, in increased government regulation.

I believe that the questions which the offshore sector should be confronting are:

How to set sensible, practical international standards so that floating facilities may find employment in various national jurisdictions?

How to demonstrate compliance with these standards?

How to enforce that compliance through out the industry without involving a governmental mechanism?

And I suggest that there is no better place to start considering those questions than by analyzing and assessing the human element within your operations, with this workshop being an excellent first step. I hope that, over these three days, you will be able to initiate the necessary dialog.

Although significant progress has been made towards understanding the full implications of the human element in the safety equation, we know at ABS that there is still a lot of work to be done. It is why we are constantly striving to improve our own knowledge base, so that we can better frame the rules and guidelines which impact the design, construction and maintenance of your facilities.

As you consider these developments I would urge you to include class in your discussions. We have a tremendous reservoir of expertise from which you can draw. And we bring to the process the impartiality of a third party, experienced in determining and implementing reasonable standards and trusted by governmental authorities for the judicious manner in which we have exercised that responsibility.

It is for that reason that I also leave you with a further suggestion. If you accept the challenge to move aggressively towards developing and implementing effective international industry safety standards, and if you can successfully define the structure for an on-going dialog among the various sectors of this industry, ABS would be willing to not only participate within that dialog but also to assist in coordinating the process.

Let me restate our mission which is "**to serve the public interest as well as the needs of our clients** by promoting the security of life, property and the natural environment primarily through the development and verification of standards for the design, construction and operational maintenance of marine-related facilities." The challenges which confront your industry are encompassed in this statement.

The Coast Guard, Offshore Industry, And The Human Element
Rear Admiral Card
1996 International Workshop On Human Factors In Offshore Operations
16-18 December 1996

Slide 1: Title

♦ Good morning. I'd like to thank PrimaTech and the University Of California for organizing this gathering. I am very pleased to see the offshore industry and academia cooperate in such an ambitious event. This does not come as a great surprise; the offshore industry has been a leader in the application of human element knowledge for many years. As many of you know, the Coast Guard has begun to approach safety differently with our Prevention Through People program. We are looking at people as an integral part of the process, rather than as a separate entity. The result is a new and improved focus on the human element that will not only reduce casualties and protect the environment, but will provide greater efficiency and reliability.

♦ The Coast Guard wanted to make sure we included the offshore industry when developing PTP. So we changed the wording in our draft PTP vision statement from "marine transportation system" to "marine operations" in an effort to be more inclusive. Our PTP efforts are aimed at all segments of the marine industries. I want to emphasize that PTP also embraces the technological side of safety. In fact, properly applied technology can improve human performance. Engineers and designers traditionally ask, "Will it work?" PTP asks, "How will it work with people?" It concentrates on the implementation and interaction of technology and people. We have discovered that if we don't account for the people who apply the technology, its positive contributions can be undone. Prevention Through People addresses this issue and brings people into the engineering equations.

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Slide 2: Pillars

♦ PTP was developed as a systematic risk-based approach to safety management. Using a systems approach ensures that all aspects of design, construction, management and operation are addressed. The system components are: management, work environment, behavior of people, and appropriate technology, all based on a solid foundation of rules, regulations and standards. The four pillars contain: (1) **management** which is the organizational commitment and impact upon operations; (2) **work environment** which is made up of the external factors that influence the workers' capabilities, judgment, and effectiveness (note that when we develop standards, design, and build ships and platforms, we are building much of the mariner's work environment); (3) **behavior** which reflects the internal factors that affect personnel, and (4) the application of **new technology** which brings in the ability to move ahead but with human capabilities and limitations in mind.

♦

♦ Our systematic approach requires us to consider and balance the interaction between these pillars. For example, the safe application of new technology is related to management's responsibility to see that the personnel are properly trained and supported. The crew needs to know not only how to operate the equipment and instruments of the vessel, but also how to monitor its operation and recognize problems.

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Slide 3 Piper Alpha

♦ I'm sure that all of you are familiar with the *Piper Alpha* disaster in the North Sea in which 165 of 226 people on the platform lost their lives that night in July 1988. Investigated by the British, the most common cause of death was inhalation of the thick black smoke produced by the oil and gas fires on the platform. But what caused the explosion that initiated this tragedy? A lengthy chain of human and organizational errors led to this accident. Each of the pillars that I just spoke about had at least one failure which contributed to this accident. There was a lack of communication between workers at the shift change about what structures were and were not functional. There were several failures by management, including their failure to adequately train and drill the workers in proper emergency procedures. Lord Cullen, who led the investigation into the disaster, stated in his 1990 report that "The safety of personnel on an installation in regard to hazards at large is . . . critically dependent on the systematic management of safety by operators."

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♦ Somewhat in contrast, was the loss of *Rowan Gorilla 1*. It was an accident with a more positive outcome in that the platform was lost, but all of the people were saved. The MODU sank in a storm while it was being towed from a position off the coast of

Canada to the north sea. The crew of *Rowan Gorilla I* had been regularly drilled in survival procedures and the Marine Board directly credits this training, along with the communication and cooperation between the tow captain and the rig superintendent, for saving the lives of those men and women. While the outcome of this accident was less tragic than *Piper Alpha*, it also could have been prevented.

♦

♦ We each play essential roles in this system and have a great impact on safety and environmental protection. Those of us in government and standard setting organizations provide the minimum level of standards to which ships and offshore units must be built, manned, and operated. Those who design, build, and operate ships and offshore units use these standards as a baseline, but they need to look beyond them to reach higher efficiencies. Both groups must fully evaluate the effects of their actions systematically and with a focus on people. The offshore industry is on the rebound after a long slump. As more floating production platforms, OSV's and MODU's are being built in the coming years we hope that the designers consult with people such as Gerry miller and Bob Bea to incorporate the human element from the very beginning. Shell did this recently when they designed and built their new tension leg platforms. Gerry was consulted and these platforms should be much more cost effective and easier to work on in the long run. As you are building these vessels try to include human element considerations on the marine side as well as the industrial side.

♦

- Engine rooms are another area where the long term savings in maintenance and repair costs can be achieved through more people-oriented design and construction. At IMO, through the design and equipment subcommittee of maritime safety committee, we're working on draft guidelines for engineroom design, layout and arrangements. Many studies have shown that, statistically, the engineroom is the most dangerous area on a vessel. It's also one of the most critical components of effective accident response since it contains the controls for pumps, power and propulsion. Therefore, it stands to reason that a well-designed engineroom will be inherently safer and contribute to the overall safety of the vessel. These guidelines will provide vessel designers, owners, operators and crewmembers with information to enhance engineroom safety. The relevant factors that the draft guidelines will address are: familiarity (the standardization of enginerooms so that crewmembers new to a ship can quickly become proficient in its operation); occupational health; ergonomics; minimizing risk through layout and design; and survivability (which addresses that crew's capability to survive and counteract an engineroom emergency.) There is an active correspondence group on this subject headed up by the coast guard. Please contact Captain George Wright, chief of our Office Of Design And Engineering Standards to participate.

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Slide 4: Strategic Plan

- To guide us in our PTP efforts we have developed, in concert with industry, a strategic plan. This plan contains the vision, principles and goals of PTP which are intended to be universal so that any organization committed to quality management and continuous improvement can find them compatible with their own organizational philosophy. We have also developed an implementation plan with objectives and activities to support the coast guard's role in fulfilling the strategic plan. The vision of PTP is "***to achieve the world's safest, most environmentally sound and cost-effective marine operations by emphasizing the role of people in preventing casualties and pollution.***" This vision is not easy to achieve, but it is attainable. It recognizes that we must balance safety and pollution prevention with economic reality. At the same time, it recognizes that safe, environmentally sound operations are also the most economic in the long term. This approach allows us all to work toward addressing the problems of greatest risk rather than those which are most visible.

Slide 5: Principles

The principles of PTP capture the essential nature of how we will do our work. I'm going to run through all five quickly, highlighting three that are directly applicable to this forum. The principles are:

- *Honor the mariner* - seek and respect the opinion of those who "do the work," afloat and ashore.
- When a ship, rig or other vessel is being designed and built, we need to remember that people will be living and working aboard. They are the ones who use the equipment and therefore they are often the ones most knowledgeable about the ship itself. They

understand "ship safety" because their lives depend on it. We need to use their knowledge appropriately.

- *Take a quality approach* - engage all elements of the marine transportation system to drive continuous improvements.
- One way to do this is by incorporating "lessons learned" into the design process, as i mentioned earlier in reference to MODU construction.
- *Seek non-regulatory solutions* - emphasize incentives and innovation.
- Many folks these days seem to think this means the coast guard is abandoning its regulatory duties. Nothing could be further from the truth. Regulations will continue to provide the minimum standard which all must meet. This principle seeks to recognize and reward better ways to operate without relying only on regulations to force better operations.
- *Share commitment* - recognize and act upon the responsibility of government, management and workers to foster a safe and environmentally sound marine transportation system.
- *Manage risk* - apply cost-effective solutions to marine safety and environmental issues, consistent with our shared public stewardship responsibilities.
- The Coast Guard's implementation plan contains specific objectives for us to fulfill PTP's broad goals. At this point i will tell you a little about these five goals and the specific objectives we have set to meet these goals that are the heart of our tactical implementation plan.

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Slide 6: Know More

- The first goal is to
- *Know more* - significantly expand our knowledge and understanding of the human element and its role in maritime operations and accidents.
- We are developing a comprehensive research & development plan for PTP. There is an existing body of knowledge on ergonomics, or the optimization of human performance, in many different industries which we need to apply to all maritime endeavors including offshore operations and construction. Ergonomics is an important part of PTP. A project to evaluate practical applications of PTP principles on a working ship is in the development stage. Here, we are working with industry to examine what can be gained through common sense solutions like modifying traditional 4-on, 8-off watchstanding practices and other work-rest adjustments. We expect that some of the information from these specific tests can be applied to other segments of the marine industries.

♦

- We are also developing a near-miss database. The data collected under this system could be used with the reliability, availability and maintainability (RAM) database to provide information for better risk management.

♦

Slide 7: Train More

- The second goal is to
- *Train more* - give members of the marine community the necessary skills and knowledge to improve safety and prevent pollution.

We are developing continuing education opportunities for mid/senior management and supervisory staff on human element causes and prevention of accidents. One of our key objectives here is to increase coast guard marine inspectors' knowledge of human factors engineering and other human element issues. We have been holding our first human factors engineering (HFE) courses for marine inspectors at our training center. Though many of the elements taught in the HFE course are not covered by regulation, the awareness of these elements allows us to identify existing problems. The intent of this project is not to add to the plethora of standards in existence, but to improve safety by making the designers and manufacturers aware of the human element-impacts of their products. This also feeds back into "Know More."

♦

Slide 8: Do More

- The third of these universal goals is to
- *Do more* - improve professional performance through a practical application and open communication of human element knowledge within the marine community.

One of the broadest objectives for this goal is to share information. We foresee the sharing of best practices and lessons learned as another way to work together and we are discussing many ways to continue this. Why would we do this? Because we want everyone to learn from other peoples' experiences. There is no need for each of us to reinvent the wheel. One specific project of the Coast Guard is the development of risk-based decision making guidelines. These guidelines will be distributed to all of the Marine Safety Offices and Captains Of The Port for their use. We also foresee that these guidelines will be photocopied for even broader distribution. All of which will help to improve professional performance and provide open communications between many segments of the maritime community.

Slide 9: Offer More

As our fourth goal, we want to

- *Offer more* - provide incentives for improvement in safety management systems.
- One of our objectives under this goal is to institutionalize the Streamlined Inspection Program (SIP). The SIP had its roots here in the Eighth District on OSV's. The recent increase in activity here on the Gulf has raised some issues which we need to address, such as a high turn-over rate of crewmembers, and expansion of the program from OSV's to the U.S. flag fleet in general. It is a challenge, but we remain committed to the concept.
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Slide 10: Cooperate More

- Our fifth goal is to
- *Cooperate more* - work together to address the human element in transportation safety and pollution prevention.

One of the ways we can do this is through coast guard and industry partnerships such as the agreements we have with ABS. In October we signed a similar cooperative agreement with the American Petroleum Institute and the U.S. Chamber of Shipping. Based upon reviews by members of those two organizations of the risks that they face in their daily operations, the first issue that we will tackle will be operational communications and bridge resource management.

Under this goal we're also looking to our safety advisory committees to develop and implement a PTP agenda targeted at their focus area. NOSAC, the national offshore safety advisory committee, has been very active in this arena under the leadership of Don Ray of Transocean Offshore Inc. Don's subcommittee is working on some challenging issues, such as the sharing of safety-related information among competitors. This issue is challenging from not only the perspective on how we do it, but also how we convince competitors to participate.

-

Slide 11: Future

Where do we go from here? The future of the offshore industry is heading to deeper water. In so doing, we will all see more Coast Guard involvement as the types of production platforms switch from the fixed to floating facilities. As I alluded to earlier, it is time to consider the human element as key to the long-term welfare of any offshore activity, and design the vessel accordingly. Design engineers must give consideration to access for routine maintenance and periodic overhauls. It is human nature to avoid or delay performing onerous tasks, so let's not build them into the structure! Similarly, the designs of control rooms, accommodations, and drilling decks should consider the human element first, not last. It's time to build in safety. In so doing we will have ships and offshore units that can endure harsher conditions and are easier to maintain, if we remember to think about how they are used, and by whom. Offshore safety presents each of us with a challenge. We must commit ourselves, our organizations, and our operations to producing a safer, more productive environment. With each of us taking a step up, we will essentially force everyone to our higher level.

LESSONS FROM OTHER INDUSTRIES

Karlene H. Roberts
University of California, Berkeley

In struggling with the issue of how we do things to make the offshore industry safer we might takes lessons from some practices engaged in by other industries. Let me begin by giving you a few examples of situations in which organizations have engaged in risk mitigating behaviors.

First we go to the airlines. As a result of an airliner crash in Portland in 1968 United Airlines (UAL) developed its crew resource management program. This program trains flight deck crews in the elements of small group behavior known to be effective. This includes open communication, reduction of hierarchy in command, flexible decision making, and multiple attention to all aspects of flight, among other things. Today United has expanded this program to its cabin crews and major airlines across the United States have adopted the it at least for its their flight crews. Delta and some other airlines have expanded this sort of training to baggage handlers and other groups of workers.

Last year Boeing Commercial Aircraft Company considered how crew resource management might be applied to the design and construction of its commercial aircraft. Boeing had just completed its first experiment in designing an airplane (the 777 or triple seven) without using paper. Complex team activities will be required to do similar work in the future and the basics of crew resource management may well provide a strategy to obtain more efficient design and construction.

For UAL one result of its use of crew resource management was the handling of the landing of UAL 232 (a DC-10) in Sioux City, Iowa a few years ago. Captain Al Hanes benefitted from this training in a number of ways. He was able to call on all the resources available from his first officer and engineer and from a check pilot who was dead heading with the flight, from UALs maintenance team in San Francisco, and from the Federal Aviation Administration's (FAA) air traffic controllers in Sioux City. He did this by keeping lines of communication open and by encouraging a participatory decision style. All generated ideas were entertained. When UAL later tried to simulate this accident at its Denver training center the outcomes were ALWAYS worse than they actually had been.

Happenstances at Sioux City also helped out. While a DC-10 had never before landed at that airport, less than a year before the mishap the National Guard, the fire department and various hospital personnel had practiced together for just such an incident. They had done so because the airport's manager noted the large number of DC-10s flying over Sioux City on a regular basis. It was good fortune that at the time of the accident shift changes were occurring among the hospital personnel at both hospitals that participated in caring for accident victims. Departing shifts remained in place and were augmented by oncoming shifts.

Next let's take a look at law enforcement, particularly at efforts to mitigate risk in terrorist and hostage situations. The United States has been plagued by a set of disasters in this area, including the situations at Jonestown (not in the United States but involving U.S. citizens), Waco, Texas; and more recently the standoff in Idaho in which a woman and child were killed for little or no reason. The French National Police have developed a strategy for handling such situations that is unparalleled anywhere else in Europe. As a situation develops the police can be in close contact with their ministry (unlike the situation in the U.S. where there is substantial distance between the police and the FBI). They can move quickly to assess the situation and literally from their Rolardex choose a team with complementary skills to address the particular problem with which they are faced.

One of the French National Police successes was a school hostage situation in which a mentally deranged man held school children and their teacher. In this situation the police could quickly put together a team of experts on children, school buildings, deranged people, etc. Thus, the requisite variety of the situation is matched by the requisite variety inherent in the team. Team skills are tailor made to the situation.

Let's think about a success story that might happen if representatives of these two kinds of organizations, the air industry and the police have to work together. Awhile back a dirigible flyer in Palo Alto, California, fell out of his balloon and balloon began to float aimlessly over the Bay Area. The FAA tracked the balloon into the East Bay Regional Park System. Because of the excellent communication between the FAAs regional air traffic control center at Fremont, and the Office of Public Safety for the East Bay Regional Park it was possible to have the park system's helicopter feather the balloon.

Next, let's jump into emergency medical services, particularly the pediatric intensive care unit at Loma Linda University. Emergency medical services are typically characterized by lack of team work and competition. A few years ago a former Navy aviator MD and his colleague with an MD degree and a bachelors degree in social ecology came together and noted that things were not as efficient as they might be in most pediatric and adult intensive care units or in hospital emergency rooms. They characterized these places as places in which trust and teamwork are non existent. Using a World War II U.S. Army developed strategy for engaging in battles (known as OODA loops) they developed a Loma Linda a team approach to emergency care. They infused the team with high skill levels, open communication, decentralized decision making and leadership, and high degrees of trust; and they molded an organizational culture that would promote these factors.

It worked. How do we know it worked? Very few industries have outcome measures that are as clear indicators of success as is morbidity rate. Loma Linda experiences a very low morbidity rate despite the fact that it takes only the toughest pediatric medical cases in Southern California. A helicopter service flies its medical teams to other hospitals which are less skilled in emergency care, picking upo only the most severely injured children

Finally, we can look at U.S. Navy/Marine Corps carrier aviation. Despite the rash of accidents in 1995 the U.S. Navy has experienced a steady decline in class A mishaps per one hundred thousand flight hours since 1955. A class A mishap is a mishap that results in a million dollars in damage or more and/or loss of life. On the overhead we can see this steady decline over the years . We can ask what happened to produce this decline. First it is important to realize the cost of an accident to the Navy which was a definite motivator to the behaviors it engaged in to reduce accidents. As some of you know it costs over a million dollars to train a Navy/Marine pilot and the cost of his toys is about forty million dollars for an F-14D Tomcat or the F/A-18 Hornet.

In 1952 Class A flight mishap rates peaked. Aviator medical screening was begun. In 1954 carriers were redesigned with angled decks to improve landing conditions and the Fresnel lens (the ball) was introduced to aid the landing signal officer (paddles). In 1955 the Aviation Safety Center was established at Norfolk, Virginia, which was later changed to the Navy Safety Center. Aviation physiology programs were initiated at the same time. In 1958 the Replacement Air Group (RAG) concept was introduced as a training aid and human engineering analyses were begun. In 1961 NATOPS (procedures) manuals were developed for each air community, and flight simulation was begun. In 1976 the Chief of Naval Operations (CNO) ordered each aircraft squadron to have a safety officer reporting to the squadron commanding officer, and each aircraft carrier to have a safety officer reporting to the carrier's commanding officer. Squadron and ship safety programs were initiated. In the 1980s risk management programs were initiated. In 1990 crew coordination training was developed and in 1994 human factors programs and review boards were initiated.

Clearly technical improvements contribute to safety. But for the Navy technical improvements have been accompanied by significant people oriented programs. In fact, more of the improvements noted by this organization as contributing to reducing its mishap rate fall in the people than the technical category,

What do all these situations have in common. In her PhD. thesis, Carolyn Libuser, a UCLA PhD. developed a model of risk mitigation (which is protected under copyright law). As indicated in the overhead, it has the following five characteristics which Carolyn identified by looking at the organizations I've just discussed:

1. Process auditing. An established system for ongoing checks designed to spot expected as well as unexpected safety problems. Safety drills are included in this category as is equipment testing. Follow ups on problems revealed in prior audits are a critical part of this.

2. Reward systems. The reward system is the payoff an individual or organization receives for behaving in one way or another. Organizational theory points out that organizational reward systems have powerful influences on the behavior of people in them. Similarly, inter organizational reward systems also influence behavior in organizations. Too often organizations and their regulators reward behavior A while hoping for behavior B.

3. Degradation of quality and/or inferior quality. This refers to the essential quality of the system compared to a referent generally regarded as the standard for quality.

4. Perception of risk. There are two elements of risk perception: 1) whether or not there is knowledge that risk exists and 2) if there is knowledge that risk exists, the extent to which it is acknowledged appropriately and/or minimized. Part 2 is the logical outgrowth of part 1.

5. Command and control. The sub factors of command and control are:

migrating decision making (the person with the most expertise makes the decision;

redundancy (people and/or hardware) i.e. backup systems exist;

senior managers who see the "big picture" i.e. they don't micromanage;

formal rules and procedures a definite existence of hierarchy but not necessarily bureaucracy in the negative sense;

training.

As we can see there are lessons to be learned from other industries. At Berkeley we're continuing to try to learn lessons and engage in organizational risk mitigation through the establishment of a center for risk mitigation research. This center will provide workshops and other learning experiences for operators and managers. It will foster inter industry contacts for lessons learned, and will conduct basic research on risk mitigation across industries.

1996 International Workshop on Human Factors in Offshore Operations

December 16-18, 1996
New Orleans, Louisiana

The Key Human Factor: *Leadership Behaviors*

Norm Szydlowski

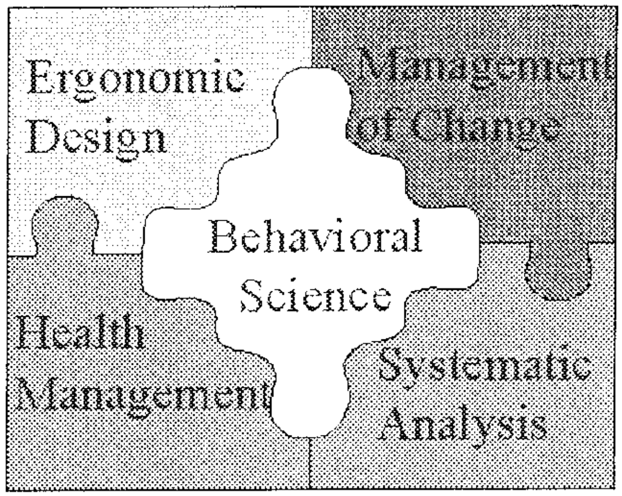
General Manager, Health, Environment, and Safety

Chevron Corporation

What is Human Factors ?

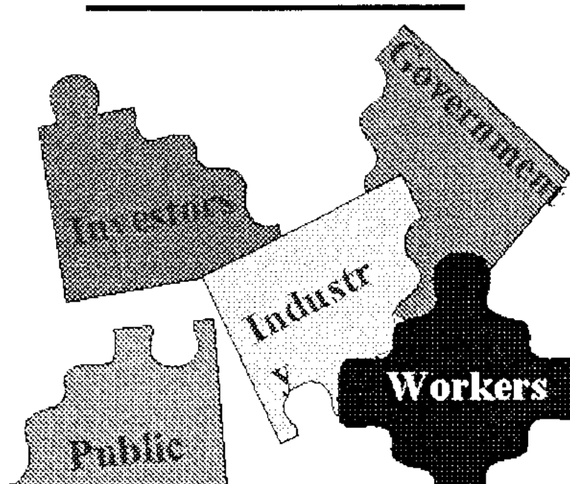
- Ergonomic Design
- Behavioral Science
- Management of Change
- Health Management
- Systematic Analysis

Aspects of Human Factors



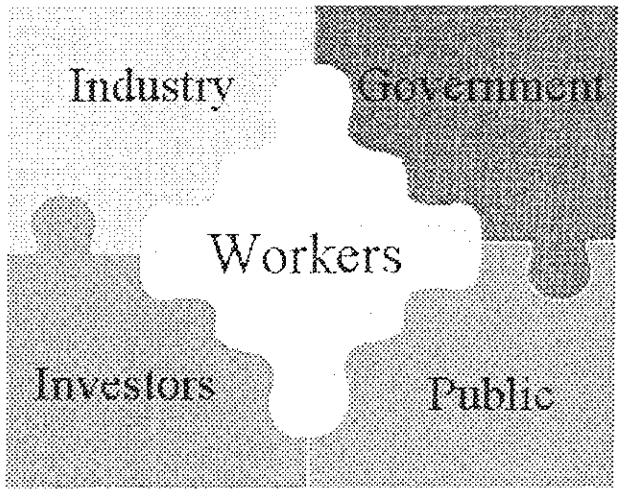
How Does Human Factors Impact Offshore Operations ?

Stakeholders

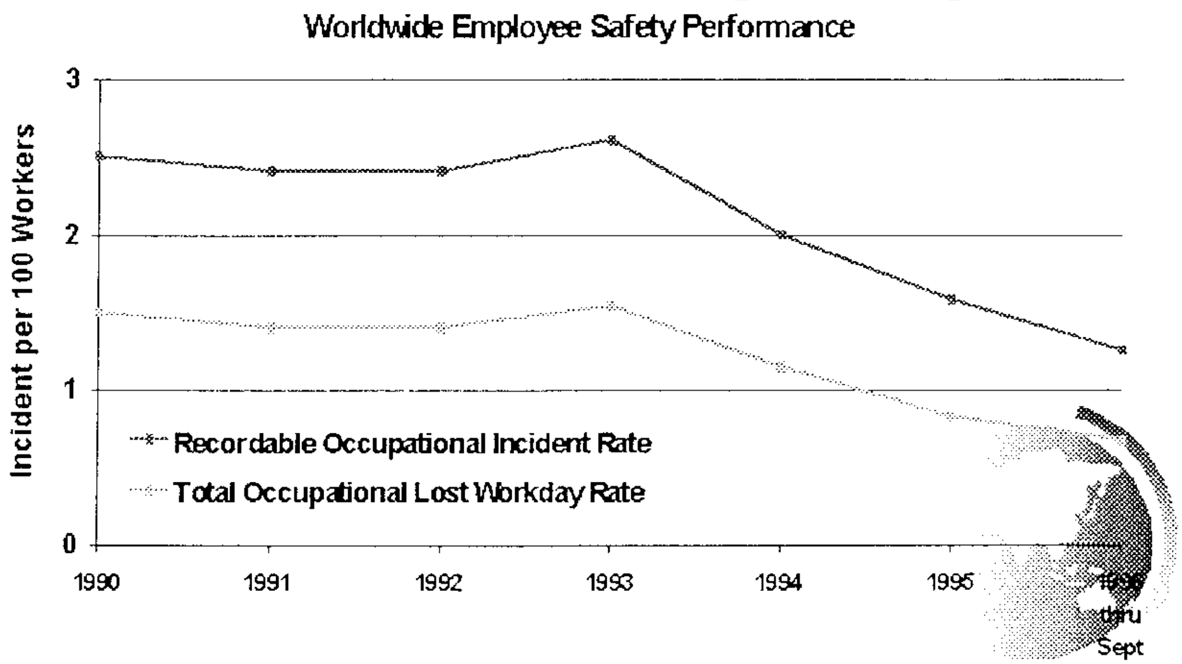


- People design, build, operate, and manage all of the equipment and systems.
- Serious incidents can and do impact all of the stakeholders.

Stakeholders: Incident Free Operations



Overall Employee Safety Performance is Improving...

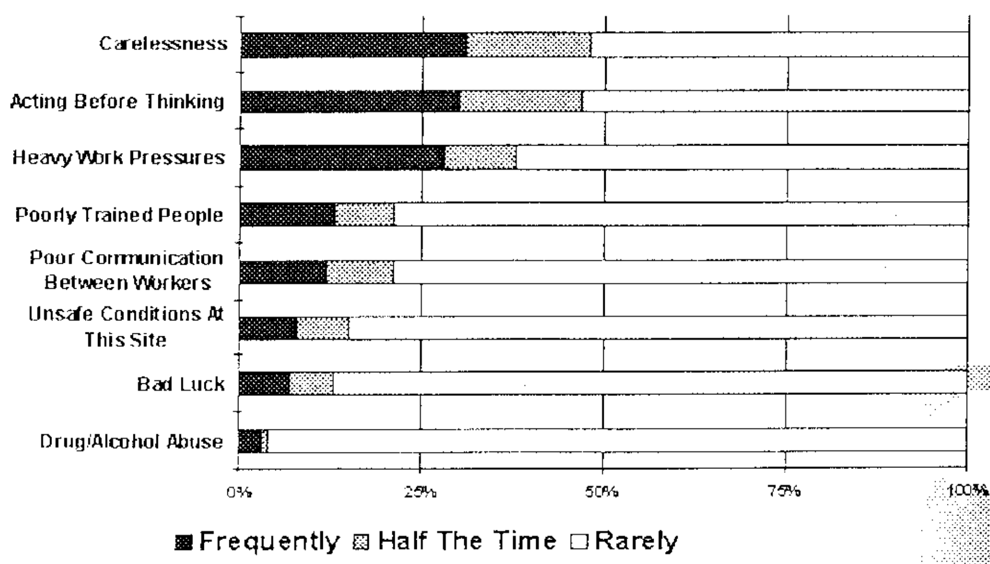


Safety Perception Surveys

Organization	Number of Replies
Chevron Products	**1,521**
Chevron USA Production	**1,126**
GOGB	**651**
CITC	**465**
Chevron Shipping	**221**
Chevron Pipe Line	**175**
Total	**4,159**

Employees Realize That Behaviors are The Leading Cause of Incidents

Accidents perceived to be caused by:

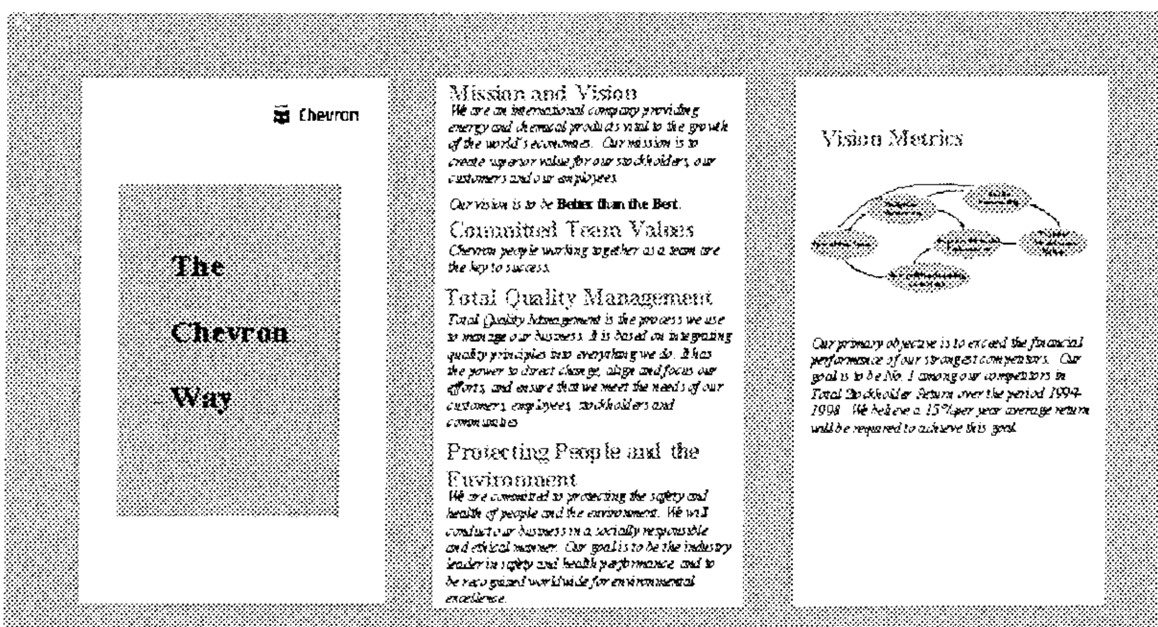


Decisionmaking is Largely Decentralized

Centralized	Decentralized	Decentralized
Corporate Center	Operating Companies	Business Units
Policy making Goal setting Performance monitoring	Implementation Guidance	Implementation Business Planning Action

12/11/96

Philosophy


Chevron

The Chevron Way

Mission and Vision

We are an international company providing energy and chemical products vital to the growth of the world's economies. Our mission is to create superior value for our stockholders, our customers and our employees.

Our vision is to be **Better than the Best.**

Committed Team Values

Chevron people working together as a team are the key to success.

Total Quality Management

Total Quality Management is the process we use to manage our business. It is based on integrating quality principles into everything we do. It has the power to direct change, align and focus our efforts, and ensure that we meet the needs of our customers, employees, stockholders and communities.

Protecting People and the Environment

We are committed to protecting the safety and health of people and the environment. We will conduct our business in a socially responsible and ethical manner. Our goal is to be the industry leader in safety and health performance, and to be recognized worldwide for environmental excellence.

Vision Metrics

Our primary objective is to exceed the financial performance of our strongest competitors. Our goal is to be No. 1 among our competitors in Total Stockholder Return over the period 1994-1998. We believe a 15% per year average return will be required to achieve this goal.

Strategic Framework for Learning

The Chevron Way

Total Quality Management

- Leadership
- Customer Focus
- Strategy Deployment
- Teamwork
- Process Management
- Continuous Improvement
- Learning Organization
- Measurement

Learning Organization

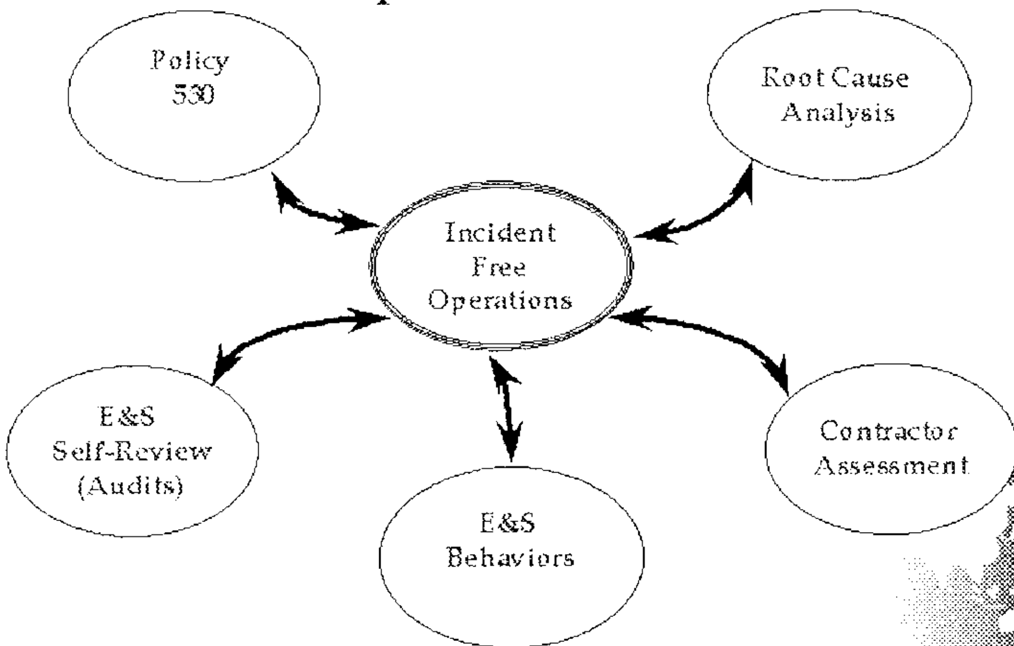
Create an organization that learns faster and better than competitors through benchmarking, sharing and implementing best practices, learning from experience, and continual individual learning and personal growth.

Learning Organization Needs

- Hard Skills
  - Mechanisms, databases, systems, and procedures for sharing
- *Very* Hard Skills
  - Behavioral and cultural changes needed to support learning and using best practices

The tools are important and the behaviors are crucial!

Chevron U.S.A. Production Company
"E&S Implementation Metrics"



Metric Shaping Template

E&S is a
Core Value

Learn from data, reduce incidents

Take action on information collected

Improve quality of information collected

Establish behaviors, measure implementation

Improving Performance

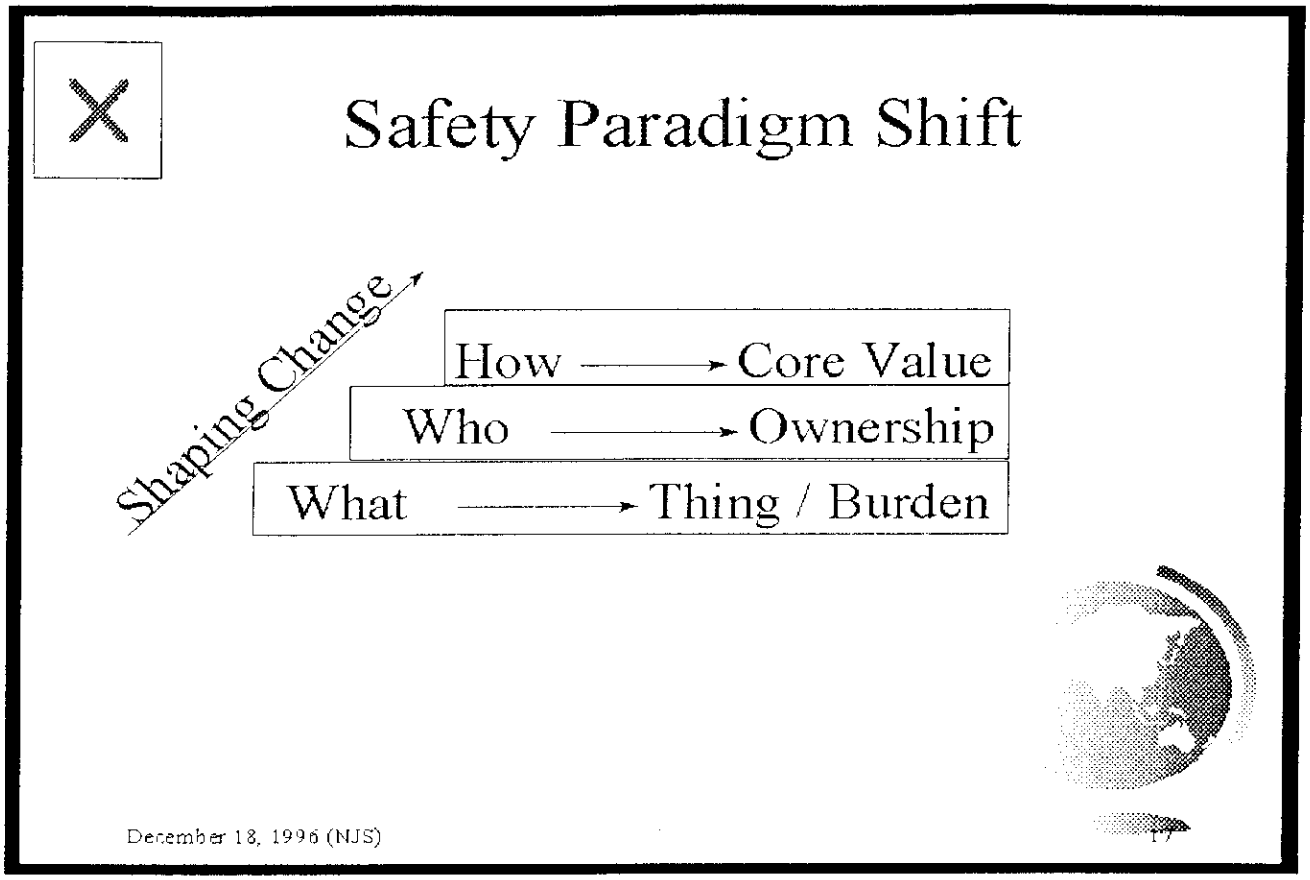
Time

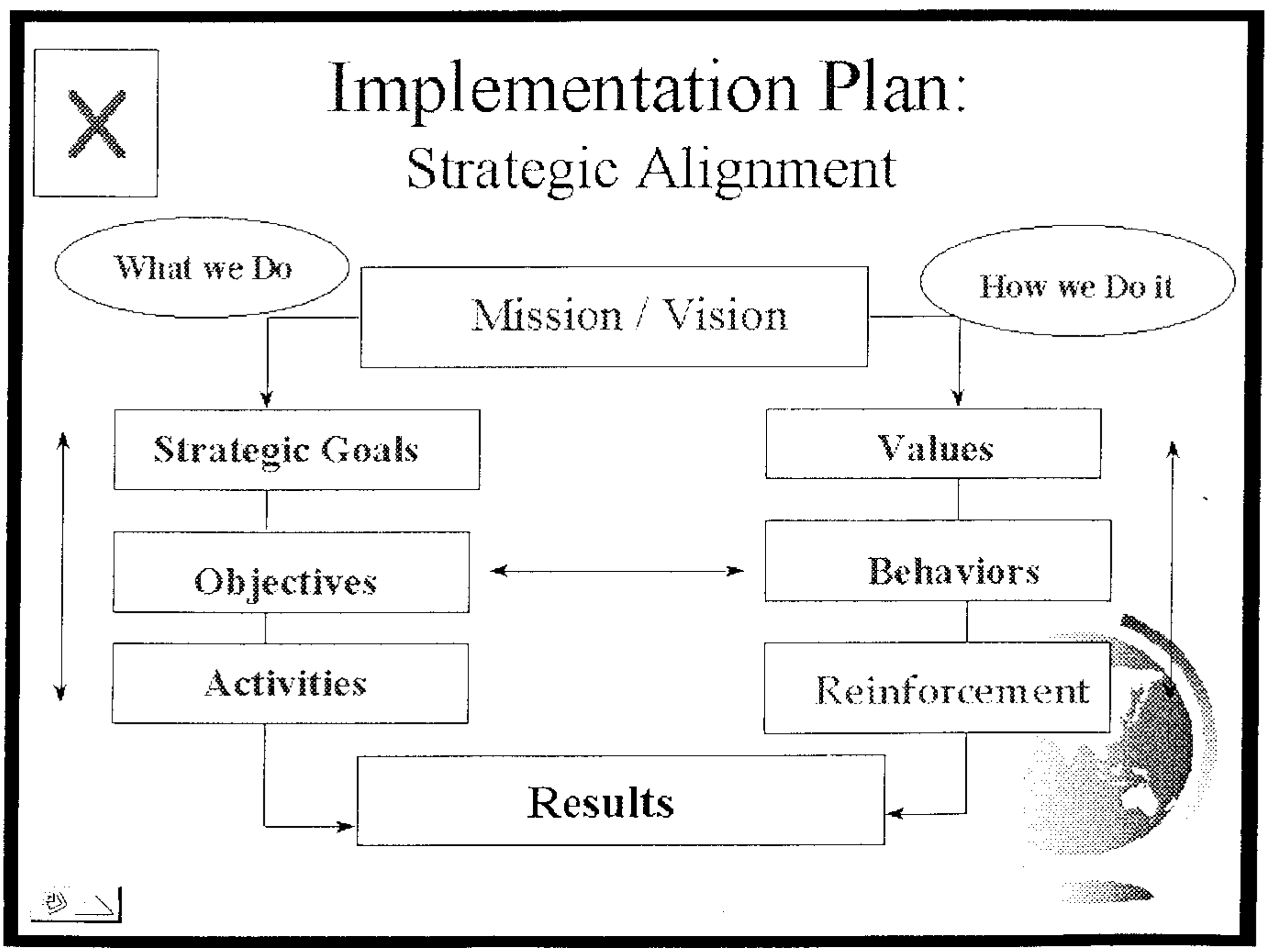
E&S Behaviors Metrics Table

Metric	Year			
	96	97	98	99
• Percent of Profit Centers using worksite behavior reinforcement processes.	80 %	90%	100%	100%
• Number of observations or STOP cards performed.		BU to set	BU to set	BU to set
• Indexed response from current survey tool on E&S leadership behaviors.		65% favor-able	68% favor-able	71% favor-able
• Future Shaping Metric: to define "pinpointed" management and employee E&S behaviors and measure activities.			TBD	TBD

Metrics Team Recommendation: *The Role of Leadership*

- ✦ Managements Role
- ✦ Positive Reinforcement
- ✦ Value-Driven Leadership

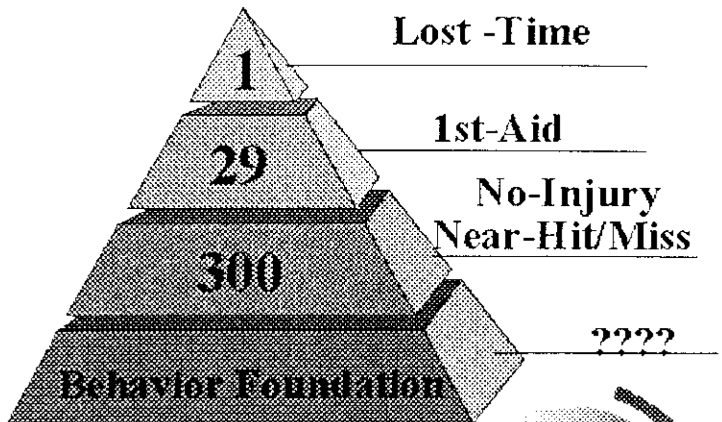

Safety Paradigm Shift
Shaping Change
How → Core Value
Who → Ownership
What → Thing / Burden
December 18, 1996 (NJS)
17


Implementation Plan:
Strategic Alignment
What we Do
Mission / Vision
How we Do it
Strategic Goals
Values
Objectives
Behaviors
Activities
Reinforcement
Results

"Foundation of a Major Injury":

by H. W. Heinrich

- Moral 1: Prevent the Accidents and there can be no injuries.
- Moral 2: Prevent the "at risk" <u>behaviors and conditions</u> and there can be neither accidents nor injuries.



December 18, 1996 (NJS) 19

HUMAN FACTORS WORKSHOP
KEYNOTE ADDRESS

By

Dr M F Pantony

Health and Safety Executive, Offshore Safety Division

In this address I propose to give an outline description of the regulatory regime for offshore safety that currently exists in the UK, describe how it came into being, and how in general it seems to have performed to date and what changes we expect in the coming years. I'll then try to place some of my general comments within a Human and Organisational Factor context. Finally, I'll describe some of the research initiatives that we have taken to try to improve understanding of the role of HOF within the offshore industry in the UK.

The principal element of offshore safety legislation in the UK are the Offshore Safety Case Regulations which came into effect in 1992. The regulations were essentially produced as a direct result of the response to the 1988 Piper A disaster where 167 people were killed following a series of fires and explosions which took place on the installation. The incident itself highlighted the importance of HOF issues to many serious accidents, with apparent inadequacies both in the control of the permit-to-work system and in shift handover procedures being amongst the contributory factors which led to the eventual tragedy. Central to the regulations is a requirement for every fixed or mobile installation operating on the UK Continental Shelf to submit a safety case to the UK Health and Safety Executive. There are 3 main requirements of a safety case.

a) a demonstration that adequate systems are in place for the management of health and safety on the installation and appropriate arrangements for the independent auditing of these systems. Our experience in examining and assessing duty holder's submission with respect to their SMS has already been dealt with by my colleague Tony Blackmore in his theme paper.

b) a demonstration that all hazards which could cause a major accident have been identified. A major accident for the purposes of the regulations is defined as:

    i) a fire, explosion or the release of a dangerous substance involving death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;

    ii) any event involving major damage to the structure of the installation or plant affixed thereto or any loss in the stability of the installation;

    iii) the collision of a helicopter with the installation;

iv) the failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations; or

v) any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity in connection with it.

so as you can see, it is fairly wide-ranging in nature and embraces all of the problem areas that might be expected to be relevant to an offshore installation,

c) lastly an evaluation of the risks from all major accident hazards and a demonstration that measures have been taken (or will be taken) to reduce the risks from such hazards to a level that is as low as reasonably practicable.

Reasonable practicability is a concept central to much of UK safety legislation and it involves computations both of the cost (in terms of time, trouble and money) and the benefits (in terms of risk reduction) of carrying out some potential improvement. Only if the costs are grossly disproportionate to the benefits likely to be received can the suggested improvement be said not to be reasonably practicable.

If HSE is satisfied with the case / the arguments presented to them in these areas, the case will be formally accepted. Unless a safety case for an installation has been accepted by HSE it is illegal for installations to operate or continue to be operated in the UKCS. Within the regulations there are in fact provisions for several different types of safety case; design, operational, combined operations, decommissioning and dismantlement. However with the exception of the design safety case (which is essentially a mechanism for comment and discussion between HSE and the duty holder at an early stage and does not have to be formally accepted) the general principles remain the same. There is also a need to have all operational safety cases re-validated and re-accepted every 3 years, so that the case truly represents the on-going situation with the installation.

Since the first submissions, in May 1993, around 300 different safety cases have been processed and assessed. To date all cases have eventually been accepted by HSE. However this does not mean that assessment has always been straightforward and easy; far from it. In many instances assessment has been a fairly lengthy process, with much interaction between assessors and duty holders, with different elements of the safety cases being queried and challenged and additional analysis/studies being required to deal with specific points. In a number of safety cases, human and organisational factor issues have featured strongly in these discussions. Accepted safety cases have also frequently contained an improvement programme where the duty holder is committed to carrying out specified upgrades to either equipment or studies within a specified period of time.

Once the safety case has been accepted the regulator needs to ensure that the precautions and systems that provide the evidence are being put into practice. The duty holder is bound by law to comply with the performance standards that make up the safety case. HSE uses the safety case and any improvement programme it incorporates as the basis for its continuing strategic inspection programme for the installation.

Having an accepted safety case makes it possible for inspection to be much more focused and effective. The work of preparing the safety case and assessing it identifies the critical safety issues and inspection can concentrate on those. Intervention becomes a much more strategic process, and the workload of inspection is targeted - and therefore less burdensome to the industry. HSE has also refined a range of inspection techniques such as audits and project inspection to aid this process. So for example as well as the SMS audits described elsewhere, surveys examining the extent of problems resulting from non-compliance with procedures amongst some duty holders have also been carried out and recommendations made as to appropriate remedial action. There can be many reasons for non-compliance and the most effective countermeasures need to be carefully evaluated.

The regulatory regime that has been put in place in the UK is frequently described as a 'goal setting' one where employers are required to meet general goals or objectives designed to promote the health and safety of their employees rather than to comply with detailed prescriptive regulations. This goal-setting approach was first proposed in the 1974 Robens Report into UK health and safety legislation. This report recommended that the interests of health and safety are best served by mobilising the commitment and involvement of the two key parties involved; those who create the risks, and the workers affected by them. The role of Government and its regulators should be to set the objectives to be met and then to ensure by subsequent enforcement that those objectives are indeed being met. It should not be the role of Government to set out in detail the means to meet those objectives, as this could stifle innovation and prevent the development of new approaches to health and safety. Also the most effective means of meeting the objectives might vary significantly dependent on the particular circumstances under consideration.

This goal-setting approach was incorporated in the 1974 UK HSW at Work Act and has been steadily adopted for use in regulations governing onshore industries. However for historical reasons the approach largely by-passed regulations for the offshore industry and even as late as 1991 the UK offshore industry still had a compliance philosophy based on a myriad of detailed prescriptive requirements (principally dealing with structural and hardware matters) set out in documents such as SI 289, SI 611 etc. It was only as a result of Lord Cullen's public inquiry into the Piper Alpha disaster that major reform to this system was proposed.

Whilst prescriptive regulations can provide comfort for both the duty holder and the regulator (for both, compliance becomes a question of fact, ticks in boxes) a frequent consequence is that duty holder's management systems are structured not to develop a fully integrated approach to safety but rather simply to achieve compliance with specific requirements which become an end in themselves. The regulator's role may also become mechanistic and unchallenging.

I noted comments from your Minerals Management Service during the launch of the SEMP (Safety and Environmental Management Programs) initiative that their studies showed that traditional prescriptive approaches to safety often resulted in Outer Continental Shelf Operators concentrating more on complying with existing rules rather than identifying and mitigating all risks posed by their operations. These comments exactly mirror our own views and experiences.

It is important not to underestimate the difficulties involved in the implementation of a goal setting regime in an area which has previously been regulated by prescription. Both regulator and duty holder require radically new approaches. Enforcement of goal setting requirements, in particular, test both the professional and technical skills of the regulator to a far greater extent than is the case with prescriptive requirements. At the same time the duty holder must embrace a much more proactive approach to safety and develop systems and procedures to continuously monitor and review his performance.

A further difficulty that has faced us in the UK has been that the move from prescription to goal-setting has had to take place very rapidly. Onshore, the development of goal setting legislation has been incremental since 1975, with changes spread over the last 20 years or so. The challenge for the offshore industry in the UK has been to achieve this full transition in not much more than 5 years.

It is perhaps a tribute to the effort and determination of both industry and ourselves as regulators that the system has ' bedded down' as quickly as it has done. Certainly HSE feels that the safety case system has proved its worth and from independent surveys that have been carried out both of operators and their employees this is a commonly held view. Indeed the safety case approach is now being used in other industries within the UK such as railways and gas transmission. Some relatively minor amendments have recently been made to the Safety Case Regulations addressing areas where additional clarification was seen as desirable in the light of working experience with the regulations. We have also introduced some additional regulations such as the Prevention of Fire and Explosion and Emergency Response Regulations and the Design and Construction Regulations. These are essentially measures which compliment the Offshore Safety Case Regulations providing a clearer structure in certain areas. Given the very significant changes in offshore safety legislation over the past few years we are now looking for a period of consolidation where we monitor the effectiveness of that which is now in place.

So where does this leave us with respect to Human and Organisational Factors. Our own examination of incidents in the UK sector over the past few years involving accidental release of hydrocarbon indicates that about 60% of releases have human error / human factors as a strong contributory cause. So the significance of the issues is clearly important and needs to be examined very carefully.

As I have indicated we try to employ a goal-setting approach to safety, so we are not in the business of setting down detailed prescriptive requirements. To deal with HOF's at a high level we have in place the general requirement that I mentioned earlier to have an adequate SMS in place and for appropriate auditing of that system to be undertaken. We don't tell people the specific shape that their SMS should take but we do provide guidance by way of HSE publications (for example, Guidance Booklet HS(G)65 - Successful health and safety management) as to the sort of features we would expect to see in an SMS and as Tony Blackmore has indicated in his paper we examine their submissions very carefully in this area and if there are aspects of their systems we are unhappy or unclear about, then these matters will be challenged vigorously until we are satisfied that what is in place is adequate for the job required of it.

By and large, this route of non-prescriptive guidance is one that we follow in the other main areas relevant to SC submissions. So for example with respect to hazard and risk evaluation the guidance to the safety case regulations makes clear that an important first step in evaluating the risks is to identify all foreseeable 'initiating events' which could lead directly (or in conjunction with other failed systems) to the hazard being realised and human error is highlighted as an initiating event that needs to be considered. Again, exactly how duty holders effect this consideration is left for them to decide but if they fail to demonstrate that such issues have been taken into account in an appropriate manner in their safety case submissions, they should expect to be required to justify their position and to carry out additional work if no acceptable justification can be provided. This has occurred in a number of instances. As mentioned earlier until HSE is satisfied with the efforts that are forthcoming from a duty holder, acceptance of a safety case will not be granted and the installation cannot operate.

Similarly in terms of the analysis of the adequacy of the evacuation, escape and rescue (EER) arrangements which would be put in place in the event of some developing incident on the installation, guidance which HSE has provided clearly indicates that the analysis should be based on realistic assumptions on human behaviour and performance under stress, in other words that human factors should be properly taken into account.

In essence our attitude is that, we recognise the importance of HOF, we wish such issues to be adequately taken into account in SC submissions, we indicate in general terms both by regulation and by guidance what needs to be done but in terms of detailed compliance we leave it up to the individual duty holders to decide for themselves how best this should be achieved for the reasons that I outlined earlier. Having said that we leave the detailed mechanism of compliance up to individual duty holders, how do we regard industry initiatives such as Codes of Practice and standards such as we have heard discussed here this week. The broad answer is that we welcome them, anything that increases awareness in these important areas is to be applauded. In our system of regulation compliance with an authoritative Code of Practice or standard goes some way to demonstrating that all reasonably practicable measures have been taken. However I think we need to bear in mind the potential danger that if taken too far, industry Code of Practice and standards could in effect become prescriptive requirements under another name. We believe that within general goals there should always be the opportunity for duty holders to do something different, to develop their own initiatives, so long as they can properly justify their approach.

Finally, I'd like to mention some of the research work in the HOF area with which HSE has been or is involved. In OSD we have a substantial annual budget committed to offshore safety research and our own resources are frequently enhanced by industry funding in joint projects. The work is carried out under the guidance of a Research Strategy Board (which has significant industry representation) which determines the overall direction the work should take. This is then further developed in a series of research strategy papers covering areas such as fire and explosion, structural performance, human factors etc.

The programme currently comprises around 400 projects with a total value of about £53M, making it one of the largest programmes in HSE. More than 30% of all projects are funded jointly, with the offshore industry's total contribution to current projects amounting to some £34M. The co-operation between HSE and industry minimises the risk and level of duplication and benefits both parties, thus making it more cost effective. Considerable effort is undertaken in disseminating details of ongoing research and the results of completed research both within HSE and the industry.

The programme:

is undertaken by over 100 different research contractors in the UK and overseas, including private industry, consultants, government laboratories, research institutes, universities and the HSE laboratories;

covers all the main technologies relevant to offshore health and safety;

includes projects to meet the objectives set out in the strategy;

produces results which are used to prepare new or improved technical guidance and to raise industry's awareness of health and safety issues;

is publicised through Offshore Research Focus, a bi-monthly newsletter with a large circulation (4,500 copies) in the offshore industry;

is publicised annually through the Offshore Research & Development Programme Project Handbook published in the Offshore Technology Information series;

is made available to the offshore industry in a series of published Offshore Technology Reports, with a total of over 200 titles now being available.

Activities undertaken in the development of the overall strategy have included a review of the major offshore hazards, consideration of estimates of the fatality rates for each hazard, investigating the ways in which the probability of the associated risks can be reduced, assessing their potential consequences and how these can be mitigated. Account has also been taken of the potential for evaluating and identifying means of reducing the risks and consequences by research.

The research strategy is continually under review in the light of developments both within the programme and the offshore industry. An overall strategy report is produced summarising the individual strategies for the various programme areas, with the intention of informing industry and other interested parties of the future direction of the OSD programme over the next few years. For example, the 1996 strategy contains several new topics which have been developed since the previous version of the strategy was published. Priorities for the future will change and the strategies (and the strategy report) will be modified accordingly.

Research objectives that were set for the human factors area in the current strategy report included:

(a) To investigate and evaluate the adequacy of training and competency assessment, with an emphasis on skills unique to the offshore industry, ie EER and operation of complex safety critical systems.

(b) To determine the magnitude of physical and psychological effects of inhalation of combustion products, in connection with the effects of human performance decrements on EER.

(c) To identify and develop procedures for identification and evaluation (quantitative and qualitative) of safety critical tasks.

(d) To investigate and validate indicators such as lost time injuries, sickness absence and accident data as indices of safety.

(e) To analyse accident/incident data (including databases) to identify and prioritise the factors underlying occupational accidents. These factors would include such features as training, fatigue and or attitudes.

(f) To investigate the relationship between shift pattern, tour length and safety.

(g) To apply ergonomic principles to the identification and presentation of safety critical information.

(h) To increase understanding of group working and communication in safety critical activities, such as PTW systems, team work, crisis management.

(i) To establish the validity of the mapping of onshore human error data to offshore analyses.

(j) To monitor emerging theories of human error and assess their relevance to offshore safety.

For example with respect to (c) we have now agreed with the main industries groups, UKOOA and IADC/BROA a general approach to the identification and evaluation of safety critical tasks and are now looking to take this forward with them into a Joint Industry project where the approach will be developed in detail through case studies on representative installations.

Together with other regulatory bodies from the USA and Canada as well as a number of oil companies, we have also been taking part in the FLAIM (Fire and Life Safety Assessment Indexing Methodology) which is attempting to develop a computerised auditing tool for offshore platforms and marine terminals, with special attention being given to the consideration of human and organisational factors.

Some of our past research projects in this area together with a number which are still ongoing include:

A study of human factors, alertness and shift in the offshore industry which provided recommendations relating to noise levels, sleep quality and shift patterns and how they affect the offshore living and working 'environment'. This informed relevant aspects of the HSE assessment of operational Safety Cases and design Safety Cases.

Resulting from this study a need was identified for a detailed examination of organisational, job and individual factors in relation to performance and well-being, with particular reference to work conditions, safety practices and attitudes, perceived risks and accident rates. In addition, the effects of different shift systems on alertness and mood are being investigated.

A promising method of monitoring an offshore worker's cognitive performance, by means of a programmed, hand-held computer, has been developed and its use is being piloted offshore.

Research on the offshore workforce's perception of risk has resulted in development of a risk perception questionnaire, which is to be refined for ongoing use, and has provided feedback on the workforce's understanding of the Safety Case regime. The individual feedback from members of the workforce has informed employers' feedback of the Safety Case process to the workforce, assisting in addressing a requirement of the Cullen Report.

A methodology has been suggested for identifying limits for hazardous agents which may be present in a Temporary Refuge under fire attach so that survival, long-term health, and ability to escape will not be jeopardised.

Research on risk perception identified the need for further investigation of means for measuring safety climate on installations, determining the role of supervisors in safe working practices and analysing ascribed human factors in accident causation. These issues are being addressed.

Safety Case assessment has defined the need to evaluate human factors assessment techniques for application offshore. This work is ongoing and incorporates development and assessment of a computerised version of HEART (Human Error Assessment and Reduction Technique). The tool should assist both in the preparation of Safety Cases and also be of use for HSE assessors.

Research has shown that the majority of offshore workers who have experienced both types of safety training prefer computer-based methods to a conventional approach. It has also been shown that trainees function better in training programmes that allow them to be active learners, and are more likely to be able to transfer the information to the workplace.

The project on selection and training of OIMs for crisis management acted as a 'trailblazer' for obtaining industry co-operation and rapid feedback of findings to the industry in suitably anonymised form

Those mentioned are merely a sample from a fairly lengthy list of projects. If anyone is interested in obtaining either a fuller list of related projects or more details of any particular projects shown or even a list of projects in some of the other research topic areas such as fire and explosion modelling then we will be pleased to arrange for the information to be sent to them.

So, to sum up:

We, in the UK, are convinced of the importance that appropriate consideration of human and organisation factors has to play in improving offshore safety.

We believe that in the past for various reasons attention to these issues has not always been as great as should have been the case.

Within our Safety Case Regulations we have general goals which mean that operators have to address HOF issues in their safety case submissions.

We consider that this sort of goal-setting approach backed up with appropriate informative guidance is preferable to detailed prescriptive regulation for the reasons that I outlined earlier.

We believe however that there is considerable scope for the development of industry Codes of Practice and standards in this area providing that the potential problems of over-prescription are always kept in mind.

We consider that HOF is an area which would clearly benefit from a much greater research input and with this in mind we are supporting a raft of research initiatives.

Theme Papers

Human and Organization Factors in the Safety of Offshore Platforms

Robert Bea, Rodger Holdsworth, and Charles Smith

INTRODUCTION

Experience clearly indicates that human and organization factors (HOF) are responsible for the vast majority of incidents and accidents involving offshore platforms.[1,2] In fact, this is true for most modern systems including buildings, refineries, power plants, and airplanes. Study of platform accidents shows that about 80 % of the accidents are due to HOF and about 80 % of the accidents occur during operations (Fig. 1).

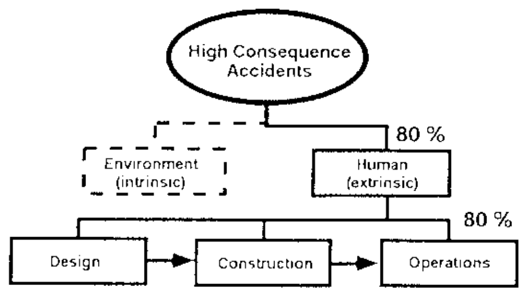


Fig. 1 - Causes of high consequence accidents

Table 1 summarizes results from a study of several hundred well documented case histories of major accidents involving offshore platforms. These findings show that the primary concerns for platform safety should be centered in interactions of humans and organizations with equipment during operations that can result in blowouts, explosions, and / or fires. Operations are frequently burdened with problems inherited from errors developed in design and construction. While individuals can be blamed for initiating accidents, the prevalent contributing and compounding factors associated with the initiation and escalation of accidents are related to organizations.

TABLE 1 - LP / HC PLATFORM ACCIDENT CAUSES

20 %	80%	Involves
•		platform structure
	•	platform equipment & facilities
•		environmental hazards
	•	human & organization factors
•		design / construction sources
	•	operation / maintenance. sources
•		storms, collisions
	•	blowouts, fires, explosions
•		contributed & compounded by individuals
	•	contributed & compounded by organizations

To most people that have worked offshore, this is no news. To many, mention of human factors immediately suggests TQM (Total Quality Management), ISO (International Standards Organization) standards, and traditional QA (Quality Assurance) and Quality Control (QC) measures. What we are addressing in this article is intended to go beyond these measures. We are primarily concerned with low probability - high consequence (LP/HC) accidents. We want to attack the root causes of these accidents.

A first issue that often is raised as one begins to address HOF is "what is human error?" We have chosen to generally avoid the term 'error' because it raises concerns and defenses associated with 'blame.' What we are interested in is how human and organization factors can be better managed to reduce the incidence and effects of errors that can lead to LP / HC accidents. We understand that all errors can not be eliminated. But, because we want to make substantial improvements in the safety of offshore platforms, we understand that HOF must be addressed to go beyond TQM, ISO, and traditional QA/QC measures.

We also understand that in the vast majority of cases and platforms it is because of humans that there are not many more LP / HC accidents. People intercede with the platforms and their systems to keep them safe. It is for this reason that there are generally of the order of 100 to 1000 incidents or near-misses for each LP / HC accident. We are interested in understanding how to improve the ability of humans to control and manage platforms, how to make these platforms less prone to the effects of errors (intrinsic safety), and how to enhance the platforms' capabilities to provide early warnings and protection for operating personnel.

The next issue that generally is raised is "who has responsibility for management of HOF?" Is this an issue for 'management' or does it involve other functions such as operations and engineering? We propose that it involves all of these functions and activities. It is top down and bottom up. Successful experiences with improved management of HOF indicates that management must provide the resources and organization environment that permit and encourage HOF developments. But, the long-term driving energy for improved management of HOF must come at the 'sharp end' of the organization - involving those that have day-to-day responsibilities for operations. It must involve both industry and government. Further, we propose that consideration of HOF needs to placed at the core of engineering. In their traditional forms, pure engineering 'fixes' no longer suffice.

In recognition of the importance of HOF, new guidelines for offshore operations have been developed. These include the U.S. Minerals Management Service's (MMS) SEMP (Safety and Environmental Programs),[3] and the American Petroleum Institute's RP 75 and associated RP 14J.[4] Similar guidelines have been issued by the International Maritime Organization (International Safety Management Code) and other government agencies such as the Health and Safety Executive in the U. K.[5] These new guidelines cite the key HOF that should be addressed. But, there is little information on the how's, when's, what's, and who's of improving management of HOF.

In a similar vein, and in recognition of the importance of HOF in operations of offshore platforms, the MMS and other national and international regulatory agencies, industry, and classification societies organized the **1996 International Workshop on Human Factors in Offshore Operations**. This workshop addressed key topics and experiences in management and evaluation of HOF in platform safety. The workshop was organized around a series of keynote and theme presentations and six working groups. These working groups addressed HOF in design, construction, drilling, production, and management and regulations. The topics included:

- Reduction of human error through the application of HOF in design and engineering.
- The roles of HOF in the construction, fabrication and installation of offshore facilities.
- Improving offshore drilling, workovers, production operations and maintenance through practical application of HOF.
- Application and integration of HOF into management policies, procedures and practices.
- Further development of standards, specifications and guidelines related to HOF, and
- Implementation and application of HOF in safety management.

This workshop was intended to address the important HOF problems that are faced by personnel that have daily responsibilities for the safety of offshore platforms.

In the remainder of this article we will summarize some of the key concepts that have been developed regarding improved management of HOF in platform operations. The reader is referred to the Glossary at the end of this paper for our definitions of some common HOF terms.

HUMAN AND ORGANIZATIONAL FACTORS

Any activity that involves people is subject to flaws and defects. These flaws and defects (malfunctions) often are identified as errors. HOF that occur during the life-cycle of an offshore platform can be related first to the individuals that design, construct, operate and maintain an offshore platform. These are the *system operators*. The actions and inactions of these operators are influenced to a very significant degree by four components (Fig. 2): 1) the organizations that they work for and with, 2) the procedures (formal, informal, software) that they use to perform their activities, 3) the structures and equipment (hardware) that are involved in these activities, and 4) the environments (external, internal, social) in which the operator activities are *performed*. Malfunctions can develop within any of the five components and at the interfaces between the components.

Operator Malfunctions

There are many different ways to define, classify and describe operator malfunctions. *Operator malfunctions can be defined as actions taken by individuals that can lead an activity to realize a lower safety than intended.* These are malfunctions of commission. *Operator malfunctions also include actions not taken that can lead an activity to realize a lower safety than intended.* These are malfunctions of omission. Operator malfunctions might best be described as *action and inaction that result in lower than acceptable safety.* Operator malfunctions also have been described as mis-administrations and unsafe actions.

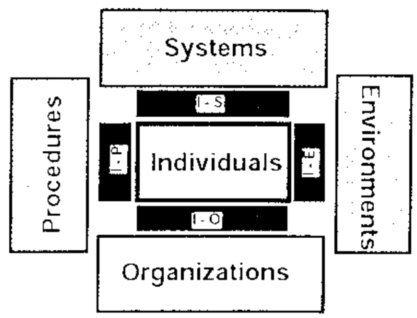


Fig. 2 - Components that influence HOF

Operator malfunctions can be described by types of error mechanisms. These include slips or lapses, mistakes, and circumventions. Slips and lapses lead to low safety actions where the outcome of the action was not what was intended. Frequently, the significance of this type of malfunction is small because these actions not are easily recognized by the person involved and in most cases easily corrected.

Mistakes can develop when the action was intended, but the intention was wrong. Circumventions (violations, intentional short-cuts) are developed where a person decides to break some rule for what seems to be a good (or benign) reason to simplify or avoid a task. Mistakes are perhaps the most significant because the perpetrator has limited clues that there is a problem. Often, it takes an outsider to the situation to identify mistakes.

Based on studies of available accident databases on marine systems and studies of case histories in which the acceptable safety of marine systems has been compromised, the primary factors that lead to human malfunctions are summarized in **Table 2**.[1,2] The sources of mistakes or cognitive malfunctions are further detailed in **Table 3**.

Organization Malfunctions

Analysis of the history of failures of offshore platforms and other marine systems provides many examples in which organizational malfunctions have been primarily responsible for failures. *Organization malfunction is defined as a departure from acceptable or desirable practice on the part of a group of people that results in unacceptable or undesirable results.* Based on the study of case histories regarding the failures of marine systems, a classification of organization malfunctions is given in **Table 4**.

TABLE 2 - CLASSIFICATION OF INDIVIDUAL MALFUNCTIONS
Communications - ineffective transmission of information
Slips - accidental lapses
Violations - intentional infringements or transgressions
Ignorance - unaware, unlearned
Planning & Preparation - lack of sufficient program, procedures, readiness
Selection & Training - not suited, educated, or practiced for the activities
Limitations & Impairment - excessively fatigued, stressed, and having diminished senses
Mistakes - cognitive malfunctions of perception, interpretation, decision, discrimination, diagnosis, and action

TABLE 3 - CLASSIFICATION OF MISTAKES
Perception - *unaware, not knowing*
Interpretation - *improper evaluation and assessment of meaning*
Decision - *incorrect choice between alternatives*
Discrimination - *not perceiving the distinguishing features*
Diagnosis - *incorrect attribution of causes and or effects*
Action - *improper or incorrect carrying out activities*

TABLE 4 - CLASSIFICATION OF ORGANIZATION MALFUNCTIONS
Communications - *ineffective transmission of information*
Culture - *inappropriate goals, incentives, values, and trust*
Violations - *intentional infringements or transgressions*
Ignorance - *unaware, unlearned*
Planning & Preparation - *lack of sufficient program, procedures, readiness*
Structure & Organization - *ineffective connectedness, interdependence, lateral and vertical integration*
Monitoring & Controlling - *inappropriate awareness of critical developments and utilization of ineffective corrective measures*
Mistakes - *cognitive malfunctions of perception, interpretation, decision, discrimination, diagnosis, and action*

The goals promulgated by an organization may induce operators to conduct their work in a manner that management would not approve if they were aware of their reliability implications. Excessive risk-taking problems are very common in marine systems. Frequently, the organization develops high rewards for maintaining and increasing production; meanwhile the organization hopes for safety (*rewarding 'A' while hoping for 'B'*). The *formal and informal* rewards and incentives provided by an organization have a major influence on the performance of operators and on the reliability of offshore platforms.

Many organizations have a very primitive understanding of human factors. A man that has spent his life implementing human factors principles in complex onshore and offshore systems said recently: " many organizations define human factors engineering as select the best people possible, train them the best way possible, and then fire them when they screw up." Failure to wisely use existing technology and knowledge is a very common organization malfunction.

One of the most pervasive problems that has resulted in failures of offshore platforms regards organizational and individual communications. Poor communications result from a breakdown in one or more of the critical elements involved in development of a message by the sender and the decoding of that message by the receiver (Fig. 3). External and internal barriers provide obstacles to effective communications. Without feedback, the sender has little understanding what the receiver has understood.

In the case of the Piper Alpha platform, the break down in organizational communications was represented by the failure of the permit to work system, and the organization's ignoring early warning signals issued by the field operating personnel. Due to incentives provided by the organization, there were tendencies to filter information, making the bad seem better than it was. In development of programs to improve management of HOF, careful consideration should be given to information integrity (collection, communications, and learning), particularly as it affects the balancing of several objectives such as costs and reliability.

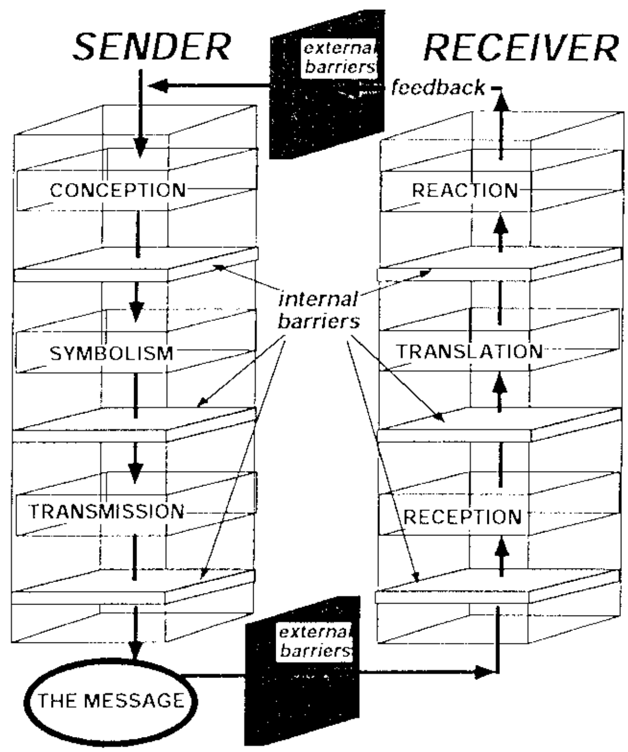


Fig. 3 - Communications elements and barriers

Several examples of organizational malfunctions recently have developed as a result of efforts to down-size and out-source as a part of *re-engineering* organizations. Loss of corporate memories (leading to repetition of errors), creation of more difficult and intricate communications and organization interfaces, degradation in morale, unwarranted reliance on the expertise of outside contractors, cut-backs in quality assurance and control, and provision of conflicting incentives (e.g. cut costs, yet maintain safety) are examples of activities that have lead to substantial compromises in the intended safety of systems.

Experience indicates that one of the major factors in organizational malfunctions is the culture of the organization. Organizational culture is reflected in how action, change, and innovation are viewed; the degree of external focus as contrasted with internal focus; incentives provided for risk taking; the degree of lateral and vertical integration of the organization; the effectiveness and honesty of communications; autonomy, responsibility, authority and decision making; rewards and incentives; and the orientation toward the safety of performance contrasted with the quantity of production. The culture of an organization is a product of its history. Because it is so difficult to change, the culture of an organization is probably the most challenging HOF issue to address.

Hardware Malfunctions

Human malfunctions can be initiated by or exacerbated by poorly engineered systems and procedures that invite errors. Such systems are difficult to construct, operate, and maintain. **Table 5** summarizes a classification system for hardware (equipment, structure) related malfunctions.

TABLE 5 - CLASSIFICATION OF HARDWARE MALFUNCTIONS
Serviceability - *inability to satisfy purposes for intended conditions*
Safety - *excessive threat of harm to life and the environment, demands exceed capacities*
Durability - *occurrence of unexpected maintenance and less than expected useful life*
Compatibility - *unacceptable and undesirable economic, schedule, and aesthetic characteristics*

New technologies compounds the problems of latent system flaws. Complex design, close coupling (failure of one component leads to failure of other components) and severe performance demands on systems increase the difficulty in controlling the impact of human malfunctions even in well operated systems.

Emergency displays have been found to give improper signals of the state of the systems. Land based industries can spatially isolate independent subsystems whose joint failure modes would constitute a total system failure. System malfunctions resulting from complex designs and close coupling are more apparent due to spatial constraints on offshore platforms. The field of *ergonomics* has largely developed to address the human - machine or system interfaces. Specific guidelines have been developed to facilitate development of people friendly systems.

The issues of system robustness (defect or damage tolerance), design for constructablity, and design for IMR (Inspection, Maintenance, Repair) are critical aspects of engineering offshore platforms that will be able to deliver acceptable safety. Design of the structure system to assure robustness is intended to combine the beneficial aspects of redundancy, ductility, and excess capacity (it takes all three). The result is a defect and damage tolerant system that is able to maintain its serviceability characteristics in the face of HOF. This has important ramifications with regard to structural design criteria and guidelines. Design for constructability and inspection, maintenance, and repair have similar objectives.

Software Malfunctions.

Table 6 summarizes a classification system for procedure or software malfunctions. These malfunctions can be embedded in engineering design guidelines and computer programs, construction specifications, and operations manuals. They can be embedded in how people are taught to do things. With the advent of computers and their integration into many aspects of the design, construction, and operation of marine structures, software errors are of particular concern because *the computer is the ultimate fool.*

TABLE 6 - CLASSIFICATION OF PROCEDURES & SOFTWARE MALFUNCTIONS
Incorrect - *faulty*
Inaccurate - *untrue*
Incomplete - *lacking the necessary parts*
Excessive Complexity - *unnecessary intricacy*
Poor Organization - *dysfunctional structure*
Poor Documentation - *ineffective information transmission*

Software errors in which incorrect and inaccurate algorithms were coded into computer programs have been at the root cause of several major failures of offshore platforms.[2,7] Guidelines have been developed to address the quality of computer software for the performance of finite element analyses. Extensive software testing is required to assure that the software performs as it should and that the documentation is sufficient. Of particular importance is the provision of independent checking procedures that can be used to validate the results from analyses. Procedures need to be verifiable based on first principles, results from testing, and field experience.

Given the rapid pace at which significant industrial and technical developments have been taking place, there has been a tendency to make design guidelines, construction specifications, and operating manuals more and more complex. In many cases, poor organization and documentation of software and procedures has exacerbated the tendencies for humans to make errors. Simplicity, clarity, completeness, accuracy, and good organization are desirable attributes in procedures developed for the design, construction, and operation of offshore platforms.

Environmental Influences.

Environmental influences can have important affects on the performance characteristics of individuals, organizations, hardware, and software. Environmental influences include external (e.g. wind, temperature, rain, fog, time of day), internal (lighting, ventilation, noise, motions) and sociological factors (e.g. values, beliefs, morays).

MANAGEMENT OF HOF

There are three fundamental HOF risk management approaches: *1) reduce the incidence and severity of HOF, 2) reduce the effects of HOF, and 3) increase the detection and remediation of HOF.* Experience indicates that a good risk management program will employ all three approaches in a balanced way.

Incidence and Severity Reduction

The first approach is very difficult. It requires fundamental changes in the quality of human resources including how operators are selected, trained, audited, and evaluated. Current experience with major accidents on offshore platforms indicates that in the majority of cases, the particular set of circumstances and breakdowns that resulted in the accident could not have been predicted. Who could have predicted the sequence of events and simultaneous breakdown of 13 critical systems on Piper Alpha that night in 1988? While not lessening the importance of and necessity for proactive management of safety, this recognition highlights the necessity for 'real time' or reactive management of crises.

As a result of a study of how different professional communities manage rapidly developing and life-threatening crises, a few guidelines have been developed on real-time crisis management.[8] The communities that are being studied include commercial and military aviation, emergency room medicine, fire fighting, law enforcement, nuclear power, and oil and gas production and refining. These communities daily face threatening situations that are not predictable or amenable to analysis. Yet, most of these communities face these crises successfully, turning them into near-misses.

A fundamental crisis management approach that has developed from this study is initially focused on an identification of the critical functions that must be maintained to prevent a crisis from developing catastrophic results (**Fig. 4**). Then, the resources that are absolutely necessary to maintain the critical functions are identified. The resources can be organized into three categories: 1) personnel, 2) procedures, and 3) equipment. Personnel resources pertain to the selection, training, and organization of crisis management teams. The procedure resources address how situation awareness is maintained, provides for migrating decision making, how information and alternatives are evaluated, how team work is developed and maintained, and how communications are conducted and maintained. Equipment resources refers to the essential hardware that is necessary to be able to manage the crisis and provision of back-up hardware should the primary hardware fail or not be available.

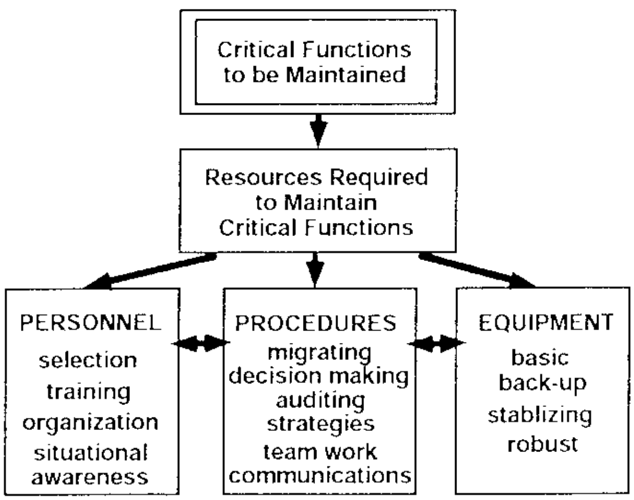


Fig. 4 - Crisis management strategy

A very important part of crisis management regards the change in organization structure that must be accomplished as the tempo of the operations changes from the daily routine to a rapidly developing crisis. Generally, the daily pace of operations is governed by a centralization of authority, bureaucratic practices, hierarchical organization, and an emphasis on individual operating skills. But, as the pace quickens during the development of a crisis, this organization structure must change to one focused on individual teams, their functional skills, decentralized authority, and the utilization of high expertise to implement alternatives, observe their effects, and change the strategy if the observations indicate that the situation is continuing to degrade.

There are two fundamental approaches to improving crisis performance, i.e., increasing the likelihood that the system can and will be brought back to a safe state. *The first is to provide improved system support.* Improved system support includes factors such as improved maintenance of the equipment and procedures; provision of accurate, relevant, and timely information; provision of adequate safe haven and life saving measures; improving communications between the individuals faced with managing the crisis; provision of measures to slow the escalation of the crisis, and the provision of stabilizing measures to help bring the crisis back under control.

The second approach is to provide improved people support. This includes strategies such as selecting personnel that are well suited to address the crises and training these personnel so that they possess the required skills and knowledge and developing crisis management teams that have the requisite variety to manage the crises. Teamwork processes are developed so that the necessary skills and knowledge can be mobilized when they are needed. Risk evolution and situation awareness are emphasized. Programs for continuous auditing, controlling, and re-training to help maintain skills, improve knowledge, and maintain readiness are developed. Strategies and plans that can serve as useful 'templates' in helping manage unique crises are provided and integrated in training and re-training programs.

Effects Reduction

The second approach has proven to be very effective. This can be characterized as engineering or technical fixes that addresses designing, constructing, operating, and maintaining *systems that have inherent stability and robustness*. By stability is meant that as the system is brought to its operating boundaries, that it tends naturally to maintain or increase stability rather than become unstable. By robustness is meant inherent defect and damage tolerance. Robustness is developed from the combination of redundancy (spare components), ductility (ability to redistribute excessive demands), and excess capacity (ability to carry redistributed demands). Platform structure, equipment, and hardware systems will not be ideally designed, constructed, operated, and maintained. Through provision of robustness they should be designed to retain a desirable level of safety even though they are subjected to normal abuse.

Detection and Remediation

The third approach is focused on internal and external assessments and auditing. Quality Assurance and Quality Control (QA/QC) measures have traditionally addressed detection and remediation of hazards and flaws. QA are those practices and procedures that are designed to help assure that an acceptable degree of quality (safety, durability, serviceability, compatibility) is obtained. QA is focused on prevention of errors. QC is associated with the implementation and verification of the QA practices and procedures. Quality control is intended to assure that the desired level of quality is actually achieved. Quality control is focused on reaction, identification of errors, rectification, and correction.

QA/QC measures are intended to assure that a desirable and acceptable reliability of the platform is achieved throughout its life. Quality is initiated with the conception of a platform, defined with design, translated to reality with construction, and maintained with high quality operations. Achieving quality goals is primarily dependent on people. QA/QC efforts are directed fundamentally at assuring that human and system performance is developed and maintained at acceptable levels.

QA/QC strategies include those put in place before the activity (prevention), during the activity (checking), after the activity (inspection), after the manufacture or construction (testing), and after the platform has been put in service (detection). The earlier QA/QC measures are able to detect the lack of acceptable quality, then the more effective can be the remediation.

Of all of the QA/QC measures, the most effective are those associated with prevention. As factors leading to lack of desirable safety are allowed to become more and more embedded in first the design, then the construction, and then the operation of a platform, then the more difficult they are to detect and correct. Personnel selection, training, and verification; the formation of cohesive teams and encouragement of teamwork, and the elimination of unnecessary complexity in procedures and structure - equipment systems are examples of effective QA/QC measures.

Control QA/QC measures consist of procedures and activities that are implemented during activities to assure that desirable quality is achieved. Self-checking, checking by other team members, and verification by activity supervisors are examples of such activities. Inspection and verification QA/QC measures consist of procedures and activities that are implemented after an activity has been completed. Detection QA/QC measures consist of procedures and activities that are implemented after the platform has been put in service to assure that desirable and acceptable quality and safety are maintained.

It is surprising how often correction of flaws and errors is under-estimated. Sufficient provisions often are not made for correcting errors and flaws when they are found, and the fixes become problematic. Detailed planning and evaluations are necessary to properly define what should be done when major errors are detected. Wishful thinking seems to behind much of the problems associated with error correction: "we got by before so why do anything now?"

Effective QA/QC requires certain types of resources: *sufficient time, money, positive incentives, knowledge, experience, insight, respect, and wisdom*. Of all of the resources, knowledge, experience, and positive incentives are the most critical.

Present experience indicates that much QA/QC is not very effective. In many cases, it becomes a 'paper chase' and results in a seemingly endless series of unneeded and perfunctory meetings. QA/QC becomes part of the problem of achieving safety and is not effective at determining what the real problems are and how they might best be solved. Much more attention needs to be given to keeping the good, discarding the bad, and adopting clearly needed improvements in QA/QC processes. This can lead to improving the effectiveness of the QA/QC processes and reducing its costs. Guidelines have been developed to simplify the QA/QC process and increase both its effectiveness and efficiency.[2]

HIGH RELIABILITY ORGANIZATIONS

Even though it may be the most important, the organization aspects of platform design, construction, operations, and maintenance quality are perhaps the most difficult to define, evaluate, and modify. Organizations that are oriented toward achieving high quality and operate relatively free of malfunctions are termed *High Reliability Organizations* (HRO).[9,10]

Studies of HRO sheds some light on factors that contribute to risk mitigation. A variety of HRO ranging from the U. S. Navy nuclear aircraft carriers to the Federal Aviation Administration Air Traffic Control System have been studied. The HRO research is directed to defining what these organizations do to reduce the probabilities of serious malfunctions.

In recent organizational research reported by Libuser and Roberts,[11] five prominent failures were studied including the Chernobyl nuclear power plant, the grounding of the Exxon Valdez, the Bhopal chemical plant gas leak, the mis-grinding of the Hubble Telescope mirror, and the explosion of the space shuttle Challenger. These failures were evaluated in the context of five hypotheses that define risk mitigating and non-risk mitigating organizations. The failures provided support for the following five hypotheses. Evaluation of non-failure HRO also provided support for the following hypotheses proposed by Libuser and Roberts.[11,12]

1. Process Auditing

HRO have established systems for ongoing checks designed to spot expected as well as unexpected safety problems. Safety drills are included in this category as well as equipment testing. Follow ups on problems revealed in prior audits are a critical part of this function.

2. Reward System

The HRO reward system is the payoff an individual or an organization gets for behaving in one way or another. HRO are concerned with reducing risky behavior that can lead to malfunctions and degradation in safety. An organization's reward system has a powerful influence on the behavior of individuals in it. Similarly, inter-organizational reward systems influence the behavior of organizations.

3. Degradation of Quality and/or Inferior Quality

This refers to the essential quality monitoring by the HRO system involved as compared to a system that is generally regarded as a desirable and acceptable standard for safety. This allows difficulties to be identified and corrected at early stages of development.

4. Perception of Risk -

Two elements of risk perception are involved: (1) Whether or not there is any knowledge that risk exists at all, and (2) If there is knowledge that risk exists, the extent to which it is acknowledged appropriately and minimized.

5. Command and Control -

This hypothesis is comprised of five elements.

a. Command by negation - this includes migration of decision making (the person with the most expertise makes the decision). It also refers to management activity in which authority is pushed to the lower levels of the organization by managers who constantly monitor the behavior of their team members. Decision making responsibility is allowed to migrate to people with the most expertise to make the decision when unfamiliar situations arise.

b. Backup - provision of backup systems for people and hardware. Robustness (redundancy, ductility, excess capacity) involves people, procedures, and hardware.

c. Formal rules and procedures - a definite hierarchy but not bureaucracy in the negative sense. Procedures that are correct, accurate, complete, well organized, well documented, and are not excessively complex are an important part of HRO. Adherence to the rules is emphasized as a way to prevent malfunctions and achieve safety, unless the rules themselves contribute to degradation in safety.

d. Training, imparting both skills in task performance and knowledge of why the tasks are performed - HRO develop constant and high quality training programs. Training in the conduct of normal and abnormal activities is mandatory to avoid malfunctions. Establishment of appropriate rewards and punishments consistent with the organizational goals is critical.

e. Senior managers who can see the "big picture." - managers who don't micro-manage or use traditional power strategies. They empower the members of the team, rewarding production and promoting development of capabilities. They perceive the important early warning signs of important degradation in safety, properly integrate them, and then develop high reliability responses.

CONCLUSIONS

The offshore industry has developed a wide variety of guidelines and procedures to help assure adequate and desirable safety is achieved during the life-cycle of offshore platforms. Experience indicates that these procedures are effective in the vast majority of cases. But, low probability and high consequence situations associated with HOF are slipping through the safety nets. The structures and hardware are not the primary source of safety problems. People are.

GLOSSARY

Accident - an occurrence that leaves a system damaged or defective.

Cognition - the capacity or mechanisms that lead to knowledge; those aspects of mental behavior involved in the diagnosis of events

Commission error - an error that results from an unintended action, excluding inaction; incorrect performance of a task or action

Communication - the capacity or mechanisms of information transfer between or among people

Consequence - the result of an event or action

Conditional probability - the probability of an event occurring given that some other event has occurred

Decision making - the activity of choosing one course of action among alternatives

Dependency - a relationship between the occurrence of one event (factor) and another event (factor)

Diagnosis - the attribution of the most likely causes of an abnormal event to the level required to identify these systems or components whose status can be changed to reduce or eliminate the problem; interpretation

Error - deviation for an intended or desired human or organization performance or any deviation from an intended result

Ergonomics - the discipline concerned with designing hardware, operations, procedures, and work environments so that they hatch human capacities and limitations

Event tree - a graphical representation of the logic of the interactions of intermediate events between an initiator and its identified consequences

Failure - any deviation from an intended or desired hardware, software, human, or organization performance

Fault tree - a graphical representation of the logic of the causes of failure of a specified event

Hazard - a feature of the environment that could be harmful or damaging to a system

Hardware - mechanical, structural, equipment, and other similar artifices

Human errors - actions or inactions by individuals that can lead an activity to realize a lower quality than intended; mis-administrations; departure from acceptable or desirable practice on the part of an individual that can result in unacceptable or undesirable results

Human factors - any attribute of a situation or object that is due to the actions or attributes of one or more persons

Human performance - result of human behavior as measured against some goal or standard

Human reliability - the probability that the performance of a person or group of people will be successful or acceptable against the standard or goal of the performance

Human factors - a discipline concerned with designing hardware, operations, procedures, and work environments so that they match human capacities and limitations; any technical work related to the human factor in manned systems

Incident - an occurrence that interrupts the performance of a system rather that leaving a system damaged or defective

Influence - a causal factor for a specific event

Initiator - the occurrence that starts an incident or accident

Interaction - the relationship between the behavior of two systems or components to produce a combined consequences that would not occur if only the behavior of the individual system or component occurred

Knowledge-based behavior - behavior that requires one to plan actions based on an analysis of the functional and physical properties of a system

Lapse - an error in recall

Man-machine interface - the abstract boundary between people and the hardware or software they interact with

Mistake - an error in establishing a course of action

Model - a characterization or description of a system that is an abstraction that represents symbolically the way in which the system functions

Omission error - an error that amounts to an unintentional or unnoticed inaction; failure to perform a task or action

Organization errors - actions or inactions by groups of individuals that can lead an activity to realize a lower quality than intended; group mis-administrations; departure from acceptable or desirable practice on the part of a group of people that can result in unacceptable or undesirable results

Perception - the capacity or mechanisms that lead to recognizing sensory input

Performance shaping factor - an influence on performance

Probability - a number between 0 and 1 that quantitatively ranks the likelihood or chance of the occurrence of a postulated event

Procedure - the formal realization of a task; verbal instructions or written actions

Probabilistic Risk Assessment (PRA) or Quantified Risk Assessment (QRA) - a rigorous and systematic identification of the levels of compromises in quality that could result from system operations and a quantitative assessment of the likelihood of such occurrences

Quality - fitness for purpose; freedom from unanticipated defects; meeting requirements of serviceability, safety, compatibility, and durability

Random - variability that cannot be predicted or its causes are unknown or its results have no discernible pattern

Reliability - the probability that the performance of some hardware, software, individual, organization, or their combination will be successful

Risk - the chance of a loss or damage; the frequency of an undesired consequence; the uncertainty of a hazard; the product of the likelihood of an event and the consequences of that event

Sequence - a chain of events that trace an initiating event to a specific consequence

Rule based behavior - behavior in which a person follows remembered or written rules

Skill - an ingrained ability or capacity toward specific action; the performance of more or less subconscious routines governed by stored patterns of behavior

Slip - an error in implementing a plan, decision, or intention

Software - information stored on paper, film, electromagnetic media, etc.

Stress - the physiological or psychological reaction to loads, burden, or other stressful influences on people; feeling of treat to one's well being; human response to a stressor (causes bodily or mental tension)

System - a group of entities consisting of hardware, software, people, organizations, or their combination that interact to produce joint behavior that can be measured against some goal or standard

Task - a series of human activities designed to accomplish a specific goal

Taxonomy - a classification or way to characterize and describe

Uncertainty - a lack in knowledge or a failure in being able to predict a postulated event

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"Safety Management Systems within Offshore Oil and Gas Companies – Experience from Assessment and Auditing of UK North Sea Operations"

G.A. Blackmore - Health and Safety Executive. U.K.

I: i *Introduction*

a: The Health and Safety Executive (HSE) is the UK government's regulatory body responsible for health and safety legislation and its enforcement onshore in industries such as construction, chemical processing, nuclear and railways, and offshore, through its Offshore Safety Division (OSD)

b: OSD has assessed over 200 safety management systems, carried out over 28 major corporate audits of Operators & contractor organisations and conducted hundreds of inspections of installations. This paper draws together some experience from this work under two parts. Part I deals with experience gained from assessment of operations and Part II deals with one aspect of safety management for installation design.

Part I Experience from assessing operational safety management systems

I. An agenda for cultural change

A. In June 1996 the HSE and the United Kingdom Offshore Operators Association held a joint seminar entitled 'A living safety culture' to discuss the development of safety management systems. The seminar was attended by senior safety and operations personnel in the UK oil and gas industry. Papers were given by operational managers, safety professionals and safety representatives.

B. The seminar noted that the Offshore Installations (Safety Case) Regulations 1992 had brought about advances in health and safety by requiring companies to produce a Safety Case to demonstrate that they have systems to manage risk. However, it concluded that further improvements in safety will only be obtained through a greater personal commitment by all to making the systems work.

C. Discussions during the seminar showed that companies believe that they have policies, standards and procedures but that they needed to address the human element more fully. The message was clear - we need a cultural change to move to a regime in which improvement is self sustaining. The discussion was summarised under headings that promote or undermine cultural change (figure 1), thus providing an agenda for the industry. The headings arranged vertically are directly within the control of management. Civil litigation and media pressure are not as easily influenced but they have a significant impact on the business. The headings are not prioritised - nor could they be, the relevance and ranking will be specific to each company.

D. This paper describes some of the strengths and weaknesses found during the Health and Safety Executive's assessment of safety management systems using four headings from the framework.

Transparency of Risk.
Management, peer and self-induced pressures
Commitment Gap
Ownership of risk controls

I. *Transparency of Risk.*

A. **<u>The need to understand risk</u>** The delegates at the seminar considered this to be one of the fundamental weaknesses in safety culture on offshore installations, i.e. if people do not understand the magnitude of risks how can they hope to control those risks? Safety cases have helped in identifying key risks offshore and Quantified Risk Assessment (QRA) has helped in ranking those risks. Whilst QRA has been useful for the specialists and regulator, it has been of little value to the workforce in understanding prioritisation of risks. Moreover accidents usually occur because of a failure in several control measures. The workforce needs to understand how their actions contribute to the multiple controls for key risks.

B. During a number of inspections and audits the HSE's Offshore Safety Division (OSD) has compared the workforce's knowledge of key risks against information in the safety case and the results have been disappointing.

C. Many safety cases have focused on key risks controlled by the offshore workforce with less attention being given to the risk drivers that originate onshore. For example, there is little in the safety cases on managing organisational change and the increased risk caused by unfamiliarity with systems. Additionally safety cases have not recognised the contribution to risk caused by poor or inadequate planning both in the long-term and short-term. In fact an audit of one of the largest companies revealed planning standards that did not refer to health and safety implications but only to operational demands.

D. An inspection on an offshore platform gave rise to the following finding with its root cause in local planning arrangements.

The work appears to be organised in a way that gives rise to unnecessary risk. In particular there is insufficient attention given to the Permit To Work system and this has resulted in clashes of activities, technicians not having sufficient knowledge of the task and people perceiving pressure to do work without a permit.

1. **There is a need for greater understanding by the workforce of how their actions contribute to the control of risk.**

B. **The ability to understand** This lack of understanding by the workforce may bring into question their competence. Competence was a key element in OSD's assessment of safety cases. Many safety cases identified key roles and, to some degree, competencies. One international company identified seven safety critical positions for offshore personnel, and listed their key responsibilities. The competence framework within the company was developed to ensure that these responsibilities could be discharged.

C. Many UK companies use a nationally derived competence assurance framework. Their approach is more advanced than simply specifying training because they require individuals to demonstrate their ability to discharge certain prescriptive tasks and require a degree of underpinning knowledge. OSD definition is slightly broader in that competence is deemed to have three parts, an ability to do the task, experience of similar tasks and a degree of underpinning knowledge.

D. Generally there is little formal testing of knowledge carried out although a number of companies will conduct simple tests after conducting training.

1. **In competence assurance, the industry may be focusing too greatly on the ability of individuals to do simple tasks and not enough on testing underpinning knowledge.**

E. **Knowledge and understanding** The Safety Case Regulations required companies to have an independent internal audit system. All companies now have such systems in place, some based on quality assurance systems, others on proprietary safety audit systems and more advanced companies have developed their own. Auditing tends to look for compliance with systems and more could be done to test that the workforce understands the key risks to the installation. Induction programmes also focus on systems such as permit to work or emergency response and less on key risks. On one installation OSD detected that the management team offshore did not understand the concept of risk. They believed activities were either safe or unsafe. They were not aware that risk arises from the product of likelihood and consequence.

F. In conclusion, safety management systems have been successful to some degree in identifying key risks and key responsibilities. However they have not been successful in improving the understanding by the workforce of key risk drivers. The next stage in development of safety cases requires clearer identification of the customers for the safety case.

II. **Safety cases should be developed so that the specialist and the regulator receive full safety case documentation. The workforce should receive a version that gives them an overview of risk on their platform highlighting their contribution to controlling it.**

Management, peer and self-induced pressures

A. In general, when moderate demands for stimulating work are placed on people their motivation increases. Excessive and sustained demand decreases motivation. This relationship will vary from employee to employee. It is this cause and effect process that makes assessment so difficult. There are numerous examples of management, peer and self induced pressures that result in accidents or lead to poor performance.

B. As an example, management in one company set planning criteria to be met before a modification workpack could be sent offshore. Criteria included such things as: all drawings must be at final revision, all personnel, resources and materials must be available. In an OSD audit, a middle manager was found to start stages of projects before these criteria had been met. The decision may have been made with the best intent, i.e. to retain a workforce that could have been laid off. A more cynical view is that the project commenced early to achieve a promised start time. For the workforce this decision to start the project early meant rushed deadlines, more rework and a constraint on their ability to plan the job effectively and safely; all factors that would de-motivate them. The audit used this finding, supported by others, to question the effectiveness and accountability of middle management decision making processes.

C. During an audit of a leading company, OSD commented on contrasting styles of management on different installations and linked them to differences in enthusiasm for continuous improvement. Whilst the company considered people to be an important part of management controls, it is interesting that they did not consider such observations valuable.

D. An accident on a semi-submersible took place whilst a small team was recovering flow lines from the sea bed using tugger winches. The flow line slipped as the chain clamp came loose and knocked the deck supervisor into the water. There is no doubt that this was a motivated and enthusiastic team. The installation manager was operating one of the winches and the deck supervisor was engaged on recovery work. Observation of the installation manager in other circumstances showed that he was the type to get involved in the detail of activities. Peer and self induced pressures were very evident in this activity.

1. There is little discussion in safety cases and little reporting in company's internal audit on workforce pressures and yet they are a significant underlying cause of accidents and incidents.

III. Commitment Gap

A. The delegates at the seminar did not question that Chief Executives were committed to safety but thought that their messages were diluted by the time they reached supervisory level. OSD's assessment of safety management systems within safety cases addressed this issue of commitment by looking for the traditional indicators such as safety policy and safety objectives. Objectives may require senior managers to show an active interest in health and safety by making site visits, enquiring about performance issues and attending safety meetings and functions.

B. During a recent OSD audit, an international oil company was found to have set numerical objectives for senior management to visit platforms but no quality objectives. The audit showed that the frequency was not being achieved and the visits were not meeting workforce expectations.

C. With regard to resources the following finding was produced after a visit to an installation shortly after commissioning was completed.

There appears to be a high workload on some groups, if not all groups of technicians, which shows no sign of abating. Besides any stressful consequences there is a belief that planned maintenance work is not being done and hazard fault cards not being completed. This is exacerbated by people working outside normal shift patterns and the uncertainties in continuity of work for people because of contractual matters.

I. Empowerment, whether it is seen as a cost cutting exercise, a means for company survival or a way of raising job satisfaction is ever present in current North Sea operations. There are very significant H&S implications in empowerment that affect managers, supervisors and the workforce. The empowerment process aims to persuade people to take greater responsibility for their decision-making and usually involves reductions in staff or reducing the amount of supervisory time. Leadership and commitment are vital elements in selling empowerment.

II. OSD audited one company who had pushed empowerment further than most. It was clear from interviewing managers and supervisors that they all agree that empowerment was a good idea but there was disagreement on how the vision would be realised. This disagreement caused confusion amongst the workforce and in a short space of time it caused significant divergence in control of technical integrity on different platforms. The following paragraph is extracted from a recent OSD audit report showing how inconsistent decision-making lead to poor technical standards. 'We found that the company often achieved an incorrect balance between empowerment and management control. Two examples are: poor understanding of the boundaries of empowerment leading in one case to the failure of glycol monitoring; and poor management control of the 'simplification' of the platform.

III. The following list of pre-requisites for effective empowerment is distilled from interviews with this particular company's managers.

Leadership which sets and shows commitment to a corporate policy or value;
Communication which is open and two way;
Authority delegated with clear boundaries, and accountabilities assigned within a structure;
Resources which enable discharge of authority;
Plans which have been developed after a structured and co-ordinated identification of hazards and priorities, with measurable success criteria, and management overview of critical areas;
Monitoring commensurate with the level of confidence that delegated authority is being used effectively;
Accountability arising from review of individual and team performance with appropriate rewards and sanctions.

I. ***Ownership of risk controls***

II. Some delegates at the seminar thought that lack of ownership of risk controls arose from apathy or lack of interest. A safety case facilitator in a large Operator dismissed workforce involvement with the phrase 'you can take a horse to water but you can't make it drink'.

III. **Apathy, Ownership, Concentration?** Consider the following accident that took place during commissioning of a 13 Kv generator on an offshore installation in 1996. The generator in question was supplying a small amount of power to the busbars on a fixed installation. The generator was showing an earth fault. While the commissioning team were considering the causes of this earth fault, an electrical engineer and a manufacturer's representative went to the control panel and operated a lever that switched the three phase supply directly to earth. The result was a blinding flash, a loud noise, plenty of smoke and destruction of the earth switch. Fortunately there were no injuries.

IV. Why should two people have such a significant mental aberration and connect high voltage power to earth? I am sure that human factors specialists will provide a number of generic causes. This was not an act of sabotage so it must have been a lapse or a slip or some other generic category for human error. The electrical engineer could not offer an explanation for his action. Was the risk transparent? To an electrical engineer the risk of connecting 13.8 Kv to earth is very transparent and apathy is unlikely to be a root cause. The designers clearly recognised that switching to earth would have major consequences and therefore they had installed engineering controls to prevent this happening. Unfortunately these controls were not sufficiently robust. A higher degree of engineering control was practicable but not specified by the designer.

V. The company examined its electrical procedures and found them wanting in this area. Having identified high voltage switching as a key risk the company has decided to use two competent electrical engineers to simultaneously carry out any switching process. The author questioned whether this was an appropriate long term solution.

VI. Another incident occurred earlier this year whilst two people were testing a lifeboat release mechanism. The Safety Management System required two safety lines to be attached to the boat before testing began. A simple task but one wire was fitted correctly and one was not. The boat plunged to the sea below, fatally injuring one person, when the release mechanism was tested. Despite the Safety Case, despite all the effort on the SMS the system failed. Simple engineering controls specified by the designer could have made it impossible to attach the safety lines incorrectly.

1 **Management controls are a poor substitute for engineering controls.**

VII. **Procedures and supervision** The delegates at the living safety culture seminar debated the importance of procedures in risk control. They considered the real issue for management and the workforce is to understand which procedures contribute most to the risk reduction, particularly in times of change, e.g. down-manning or re-organisation.

VIII. Clear procedures rigorously implemented are barriers against risk caused by human error. However, there is a balance to be maintained between the slavish following of procedures which may have become out of date or which were not good to begin with, and doing it "off the top of your head" until one day a way is invented that proves dangerous.

IX. The document 'Improving compliance with safety procedures' ISBN 0-7176-0970-7 describes the role of safety procedures in preventing accidents. Quoting from the document under the heading 'The management role' ...

> *"Violations are highly susceptible to management influence as most underlying causes of violations are either created by management, accepted by management or condoned as normal working practices by management neglect. Very often, a workforce believes that management would "pressure" them to perform jobs more quickly - this belief being based, in part, on the evidence of management apparently turning a blind eye to any improvised methods. This could have been because managers did not notice such improvisation, or management pressures may be real, rather than perceived. As a result, in many workplaces, violations have become the normal methods of working, rather than the laid down procedures. Not surprisingly these breaches in rules eventually lead to incidents. In a study of Dutch railways, it was found that 80% of the workforce considered that the rules were mainly concerned with pinning blame, and 95% thought that work could not be finished on time if all the rules were followed. None of the 50 respondents could remember ever having referred to the rules in a practical situation".*

I. This line of thought on rule violation states that people will always transgress boundaries as there is little incentive to abide by them and that management must supervise activities to demonstrate clearly that it is committed to a policy of working safely by following rules. Consider the example in the previous section where the company chose to have two electrical engineers carry out switching operations. This action is unusual in an era of empowerment. However the management did not see this as one engineer supervising another but peer reviewing this key activity - this is more in tune with empowerment. The question remains - Will this rule be violated when the two electrical engineers know and respect each other's competence?

1 **Creating management controls where they will inevitably fail is worse than doing nothing.**

II. **<u>Workforce commitment</u>** The guidance to the Safety Case regulations states *'High standards of safety and health performance on an installation cannot be achieved without the positive and informed commitment of the workforce. The safety management system should describe the broad arrangements for securing this commitment through the provision of information and <u>advance</u> consultation.....'* The main thrust of the regulations is one of consultation in the belief that this leads to commitment.

III. OSD assessed the safety management systems in safety cases for evidence of workforce consultation and certainly where none was found this issue was raised with the company. Other research into workforce involvement in the UK Offshore Industry has claimed that workers were not involved in the safety case process. The management claim that the workers were involved but did not relate consultation to the safety case process.

IV. A recent OSD audit report praised a company for involving the workforce in problem solving at both local and company level. The report also commented on areas where improvements could be achieved. The following text is taken from the report. *"The process of communication and involvement appears, at times, to take precedent over the quality of the outcome. The emphasis on employee involvement in business management did not meet the needs of employees. This emphasis sometimes drove supervisors and managers to look upwards in the organisation and serve the needs of the process rather than looking downwards to serve the needs of the people who deliver the product, and are at risk".*

V. The safety case regulations have started the process to achieving workforce commitment by requiring advanced consultation by management but they cannot require workforce involvement, just as management cannot, since it is not within their gift.

1 **Management must make a conscious decision on the status of ownership of risk controls and adjust the degree of consultation & supervision accordingly.**

VI. ***Is the model valuable?***

The model was produced from comments made by mainstream and health and safety management as well as employees and consequently should be a good generalised agenda for the UKCS. OSD Safety Case and audit experience supports the agenda. The industry has made significant progress in establishing Safety Management Systems since the introduction of the Safety Case Regulations but all the conditions that encourage people to own the risk controls are not yet in place.

Part II
Aspects of safety management systems in installation design

I. Health and safety performance in design

II. One of the fundamental principles of good design is to eliminate hazards or minimise their consequences before resorting to control measures. This is often called inherent safety in design. Numerous examples of inherent safe design are available. Here are two well publicised examples. Firstly design the pressure envelope to withstand the maximum possible pressure - no need for safety valves. Secondly minimise the inventories of hydrocarbons held on the platform at any time - this minimises the consequences of events.

III. A recent independent research project carried out for OSD stated that inherent safety is not a widespread practice. In addition two examples of poor inherent safety were found during a recent review of an installation design. A control valve was installed in a hydrocarbon vent line to restrict the initial flow of gas and the excessive use of high integrity pressure protection (HIPP) systems.

IV. A recent management audit of a major international design house revealed that project managers took little interest in inherent safety and senior line managers had few means to measure health and safety in design. Draughtsman understood and promoted inherent safe design but earlier decisions based on capital cost, timescales or custom and practice prevented them making substantial improvements in health and safety.

V. During assessment of design safety cases, OSD inspectors and design teams have on occasions held markedly different views on the degree of inherent safety employed in the design. This part of the paper attempts to raise awareness of health and safety in design by contrasting some of the health and safety performance indicators available for design and operational managers.

VI. Indicators for operational performance.

VII. In the past, managers accepted lost time accidents as the only measure of operational health and safety performance. More enlightened managers realised that this process was only reactive and other indicators were needed. As a result companies now measure health and safety performance against a variety of indicators both proactive and reactive. These include:

Near miss reporting rate;
Total incidents rate;
High potential incident rate;
Lost time accident rate;
Availability of Safety Systems;
Planned maintenance backlog in safety systems.

I. The high potential incident rate, derived from a risk potential matrix, is a vaulable indicator of those incidents that could easily have resulted in a major accident.

II. Management indicators in design

III. Setting measurable objectives is a key part of good management. The following are specific reasons why design managers should include health and safety objectives:

Regulators have set risk targets for installations that require risk to be as low as is reasonably practicable;

Objective setting would be useful in meeting requirements in the U.K.'s recently introduced Design and Construction regulations;

There is marketing advantage in demonstrating year on year reduction in residual risk;

I. Finding realistic health and safety indicators is a challenge for design management. Some indicators are used to compare designs. For example, Quantified Risk Assessment provides an absolute risk figure but it is an inaccurate tool. Other absolute measures of risk are difficult to find. So far as hydrocarbon inventory is concerned, installations are complex and very few are the same, consequently an absolute indicator probably would not work. One possibility is to normalise inventory against platform throughput so that current design can be compared against earlier designs.

II. Alternately, indicators could be used to measure the performance of design teams. Current indicators are usually based on finance, quality and timescales. One possibility is to use a design potential matrix, analogous to an incident potential matrix. The suggested matrix shown in Figure 2 could be used by design review teams at formal review stages throughout the design. Any weaknesses found would be 'quantified' as the product of likelihood to cause harm in a given period x consequences.

III. In the short term this indicator could help in showing the effectiveness of the design review process but in the long term it could help in showing the effectiveness of the design process. This indicator has additional significance since it can contribute to the demonstrate the effectiveness of the design verification process .

IV. ***The value of performance indicators***

V. The above examples of indicators for design management are not perfect, few indicators are. However the scarcity of indicators available for design management provides a great opportunity for improving health and safety in this area

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Figure 2 - Design Potential Matrix

*The numbers have been set arbitarily for illustration purposes only.

I.	1 Risk or Consequences of Potential Accident or Incident arising from poor design			
1 Numbers of people 2 Affected	2 Non LTA injury / 3 First Aid Case	1 Minor Injury / LTA / Temporary Incapacitation	1 Serious Injury 2 / Permanent Incapacitation	1 Death
3 1 4	4 1.00	2 6.00	3 24.00	2 48.00
5 3 6	5 6.00	3 24.00	4 48.00	3 64.00
7 10 8	6 24.00	4 48.00	5 64.00	4 80.00
9 100 10	7 48.00	5 64.00	6 80.00	5 96*

SIX YEARS OF EXPERIENCE INCORPORATING HUMAN FACTORS ENGINEERING INTO OFFSHORE FACILITIES DESIGN

Prepared For Presentation at The "1996 International Workshop on Human Factors in Offshore Operations", New Orleans, LA., Dec. 1996

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In the late 1980's Shell Offshore Inc.(SOI) ventured into a new area for us, deepwater. Our geologists told us there was oil and gas there. But drilling, retrieving, and processing those promising reserves in 3,000 foot of water was new, and challenging. It obviously meant that our working platform had to float, but be restrained in both a vertical and horizontal direction. It also meant that the economics of the venture would require that we conduct drilling and producing operations simultaneously, at least for a portion of the platform's initial life. As we all know, this adds a degree of hazard that does not exist if one does just one or the other.

Because of the added risk associated with simultaneous operations SOI decided to seek out every way we could to increase the safety of our operations, first to protect our employees, and second, to protect the structure and the environment. The design effort on our first deepwater platform, called Auger, was initiated shortly after the Piper Alpha disaster in the North Sea so we learned from that episode. We concentrated on eliminating or controlling all of the mechanical, structural, and organizational failures we could identify which might cause or contributed to a fire, explosion, major pollution event, damage to our equipment, or injury to our personnel. But we knew there was another major factor involved in our operations that might cause an accident which we had not properly addressed, and that was human error.

In early 1990 the head of SOI's deepwater Health, Safety, and Environment (HSE) department suggested that we look at an engineering discipline which we at SOI had not used before. Human Factors Engineering (HFE) specializes in preventing or reducing human errors by combining known knowledge about human behavior in a work environment with the traditional engineering requirements to produce as safe a working environment as reasonably possible for both man and machine.

At that time few of us at SOI had any first hand knowledge about HFE but we were to learn quickly. We did know that we did not possess that expertise in-house. We therefore sought outside assistance, and in May of that year, SOI initiated its first ever formal HFE program. in the design of an offshore platform.

Our approach was simple. We ask that our HFE program:

1. Concentrate first on areas where we knew there were problems, or where we thought there was a potential for problems,

2. Strive for both reduction of human error, and reduction of the consequences of errors,

3. Be based wherever possible on design standards backed by data derived from research on human performance

4. Be economically practical, and

5. Be based on the following hierarchy of approach for reducing human errors:

    - Design out the chance for human error
    - Guard against human error
    - Warn against human error
    - Train to reduce human error
    - Write procedures to reduce human error

At the time HFE was first brought on board, the design for our first platform, AUGER, was two years old. It was quickly evident that much of what we could have, or should have done to include HFE in Auger's design was not possible due to economical or schedule restrictions. That was a lesson we learned and corrected on our second platform.

Nevertheless, HFE was able to make enough of what we considered to be positive contributions to our design effort. We became convinced that HFE was giving us an edge on safety that we had not had before.

As an example, we completely rearranged the control room to improve coordination and communication between the control room operators.

We established a platform wide labeling program, which not only improved operator efficiency on Auger, but served as the basis for an even larger labeling effort on Mars, and the other two platforms as well.

We initiated HFE training classes for our engineers, designers and draftsmen, and we included not only SOI personnel but our contractors as well. These were successful to the point that we now provide these same classes for each of the design teams assembled for each new platform we build.

We began, where we still had design flexibility, to base our design effort on known human behavior traits that we could expect our employees to exhibit at their work site. As an example, consoles and control/display panels were arranged, located and oriented to take advantage of the worker's need for spatial relationships between the controls and displays he uses, and the actual equipment he is controlling o monitoring.

We included HFE in some of our hazard analysis efforts, not so much to identify where our operators might make an error, but to suggest the best way to prevent that error once the analysis identified that a human error was a possibility. We did this because we learned that our traditional engineering approach to controlling human error, i.e. more training or more procedures, was not the most effective way of eliminating, or even curtailing, these errors.

We initiated periodic walkthroughs of the modules once construction started so our HFE specialists could detect potential HFE problems we had not caught during the design effort.

We included HFE in our safe practice audits that we at SOI conduct on all of our new platforms before they are sent offshore.

We also learned on Auger that HFE need not always be an added expense, but that it can on occasion, save us money. The riser tensioner system on Auger was something new to us. We had never needed one before. We turned to a contractor for assistance, and HFE was asked to review their design. It was a good, functional, engineering design, but it had a couple of HFE problems. As an example, removal of the tensioner support cylinders required our people to work over their heads, holding heavy impact wrenches, working off of scaffolding which was in turn, supported by a temporary support structure attached to the platform over the open well bay. That design was altered so now the cylinder work is done from the top of the riser arm. No more temporary structure, scaffold, or overhead work. This, and other changes suggested by the HFE contractor, resulted in cost savings estimated by our engineers in excess of $200,000. And, it was safer, and that's the bottom line.

I was not involved in the first HFE efforts, but I have observed HFE at work on the Mars platform, for which I have served as the Program Manager for the past three plus years. I would like therefore, to share with you today some of my observations about the role and value of HFE on our second platform.

Because of our concern for safety on Mars we appointed a person to serve full time as The Risk Manager for our platform. That person had overall responsibility for safety in all aspects of our design. In contrast to Auger, where HFE was physically and organizationally placed in the HS&E group, we assigned the function to the Risk Manager. This turned out to be an excellent choice for it gave HFE access to all of our design decisions covering not only the platform, but ancillary areas as well such as supply boat operations and drilling. It also physically and organizationally placed HFE as an integral part of our total design and operations team.

We started with HFE concentrating on enhancing the design of our structure but we soon found that HFE could also contribute to other areas, such as our manual and operating procedures preparation, platform labeling, and assessing some of our training programs. We even got our HFE involved in helping to make our platform's day-to-day operational decisions easier and more efficient. As an indication of the breath of HFE involvement in the Mars program note the list of some of the HFE activities that were completed over the last three years. (Show V-Graph here). A couple of these activities deserve special mention.

1. Based on our own accident data, as well as that of the industry in general, we knew that falls on platforms are the leading cause of personal injuries and fatalities on offshore platforms. In our case stairs were a major source of those falls. So, we set out to see if we could reduce that problem. The result of that effort was a new stair and ladder design standard based on HFE research data that identified the optimum design standard for this non-non-discrept but important piece of hardware. Not only have we incorporated the new stair design on Mars, but we now are using the new standard on all of our deepwater platforms.

2. Another area of known concern on offshore platforms are crane operations. Crane accidents were a concern, not only for us in the offshore world, but also for all of Shell Oil Corporation's operations, on shore as well as off. In 1994 a company wide team was formed to study this problem, and we provided our HFE specialist to serve on that team. From that study came numerous recommendations to improve our crane safety, including a new emphasis on how our cranes should be designed to enhance both operations and maintenance. Working with our crane vendor we incorporated most of those recommendations into our specifications for the Mars cranes. Our operators tell us that they believe we now have the best and safest cranes ever used by SOI. These same cranes are also being installed on our two follow-on platforms as well.

3. We were doing our best to incorporate HFE into the design of the platform, for we had control of that effort. However, we also knew that we purchased major vendor supplied hardware to install on the platform, for which we had previously taken pretty much what the vendor offered, at least from a HFE perspective. We felt that maybe now was the time to see if we could change that. We sent our HFE specialist to visit several vendors of particular interest to us, such as the suppliers of our lifeboats and gas turbines. HFE audits were made of these items, and where appropriate, design changes were suggested. Cooperation from the vendors allowed us to be able to acquire hardware which had, for the first time, incorporated HFE into its design. As just one benefit of this effort, we are now able to remove a gas turbine from our compressor package enclosure in about one-third the time it use to take us, and in a much safer manner as well. I understand our operators are really happy now with our new turbine enclosure.

There are many more examples of what we feel are benefits to us from the HFE effort but let me shown you a 10-minute video tape which will highlight just a few of the things we have done on our platforms to make them safer, and more efficient from the operator's perspective.

VIDEO TAPE SHOWN HERE

Mars is now on-site in the gulf of Mexico. Our next platform, Ram-Powell, will take its place there in late 1997. Since Ram-Powell is pretty much a copy of Mars, the HFE efforts that we expended on Mars have been transferred to Ram-Powell. There are however, some unique feature to Ram-Powell and HFE was involved in those unique designs as they were completed.

Our fourth project, called Ursa, is under design. It will be larger in size, and production capability, and will work in water deeper than any of the three earlier platforms. I suppose you will not be surprised to learn that HFE is being utilized in its design as well. An interesting note about Ursa is that many of the design team members, having been exposed to HFE on previous design projects, are now sensitive to the requirements of HFE, and are taking a proactive approach to including it in their designs. As a result, our HFE contractor tells me that he is becoming more of a technical resource for specific HFE data, and fine tuner of design, than a educator and pusher of the HFE concept.

It is now almost seven years and fourth deepwater platforms later since we first brought HFE into our design effort, and HFE is still an integral part of our design team.

I don't know for sure, but I understand that in the beginning there were questions concerning whether or not HFE could offer something new and effective toward reducing human error on our platforms. I also understand that there was concern that HFE might delay our schedules, or be too expensive. I can definitely state here today that we feel HFE does contribute to improved platform safety. I also know that there was not a single incident of a delay in schedule on Mars due to HFE involvement in our program.

As for cost, you be the judge. Our estimate is that the total HFE costs on Mars was approximately .08% of the design and construction cost, and about .03% of the total program costs. A single serious accident on Mars, which we could have avoided but did not because of our omitting HFE in the design effort, could easily cost us more that the total HFE program.

There is a secret to a successful HFE program however, which I will share with you today.

1. Get HFE involved early, from the very beginning.

2. Locate the HFE capability in your engineering department, not in a support group

3. Assign the function to someone in your organization who is interested in HFE, and in a position, to champion the HFE effort within your company or project

4. Do not limit HFE's contribution for you will be surprised at all of the places it can contribute to a safer and more efficient platform

Mars is not a perfectly human engineered platform, but it need not, nor could not, ever be such. Nevertheless, we believe we have realized benefits from our HFE program. A few years ago there was a study done by the University of California at Berkeley on the cause of offshore accidents. The results of that study indicated that about 80% of these accidents were due to human error, and 80% of those occurred during operations. What that means to us is that even though we have good employees who are motivated and well trained, human induced errors are still occurring. This is not an indictment of the employee, but rather a statement about normal human beings in a work environment. HFE research over the past five plus decades has given us a lot of knowledge about why and how people behave in a work setting. What HFE has done to date at SOI is allowed us to take advantage of that knowledge to improve what has always been a top priority of ours, i.e. to build in safety in our deepwater platforms for the protection of our employees, our facilities, and our environment.

Evolving Human Factors in Offshore Operations

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Abstract

The major part of this paper outlines the main Human Factors issues in offshore operations, and approaches which may be used to address such issues. The issues are defined both generically, and in terms of contextual examples relevant to offshore operations. The tools available, many of which have proven successful in other industries, are described and some examples of their application are given. Guidelines, principles, and other qualitative data are cited which are typically used to address Human Factors problems. As well as these qualitative data, the availability of quantitative data such as Human Error Probabilities, and the role of Human Reliability Assessment, for use in risk assessments, are also outlined. The paper also discusses practical strategies for integrating Human Factors into the system design life cycle.

The final part of the paper explores the potential use of 'advanced' Human Factors to enhance operability and reduce risk more strategically. Such a venture would require a more fundamental and proactive role for Human Factors in designing, for example, advanced displays, joint cognitive systems, and stronger and more effective teams. Such an approach would aim less at avoiding the weaknesses of human operation, and more at seeking design solutions which capitalise on human strengths, and which therefore would maximise the human contribution to the system's overall health and efficiency. This represents a shift in design philosophy. It is one of 'empowering' Human Factors, and the humans at the sharp end of the system interface, to maximise human-system performance.

1. INTRODUCTION: HUMAN FACTORS

The human being is both the limiting and the enabling factor in offshore operations, depending on ones' perspective, and depending on the availability of tools to support and maximise performance. This paper concerns the discipline of Human Factors and its sub-discipline of Human Reliability Assessment, and some of the popular (i.e. useful) tools available for the determination of the human's limitations, and the improvement of system performance. The paper will steer clear of theory, though some references for such theory will be given. Instead, the focus is on practical assistance in analysing and enhancing offshore operations' safety and efficiency. To some, Human Factors is simply the application of common sense. But getting the human role in a complex and hazardous system right, is no simple matter. Like any other component in the system design process, it is complex and interacts with other system components and the environment, and requires both data and analytical tools. This paper therefore attempts to outline the data types and sources, and the available tools, to support such a critical design activity. This review is based on the author's experience in the offshore arena, and in other contemporary areas (nuclear power, chemical, transport), with techniques which have demonstrated their practical utility.

Human Factors, or Ergonomics (the former term is used, and no distinction between the two terms is made in this paper), is concerned with the maximixation of system performance (safety, efficiency, and quality) via optimisation of the human's limitations and capabilities. It therefore tries to build on the human operator's strengths, whilst recognising human limits. Its origins are mainly from physiology, engineering, and psychology, though it borrows from many other fields ranging from medicine and physics to chemical engineering and reliability mathematics and statistics. Although it is linked to early work study approaches in the '20s, it really became a discipline during and after the second world war, when human limitations, and the crucial need to overcome them, became highly evident in military systems (e.g. radar observation; bombing crew performance; etc.). Since then it has spread to almost all other industrial systems, and flourished particularly in the nuclear power field following the Three Mile Island accident in 1979, and in the chemical world following Bhopal in 1984. Offshore Human Factors similarly received a boost following the Piper Alpha disaster.

It is interesting to note that accidents often spur on research into Human Factors and safety - it appears that in such industries we have to learn the hard way. In contrast, the past decade's boom in Human Factors in the computer industry has been driven by economics - the human computer interface (HCI) industry mushroomed after the meteoric success of the Graphic User Interface (GUI), an early recognition by one company that computers could perform better if they were adapted to the way people think. The GUI is based on Human Factors principles, and made an important and powerful technology usable. The GUI's impact on society and business is hard to conceptualise, but it has empowered many people-computer 'joint' systems to achieve tasks which were inconceivable only a decade and a half ago. This concept of empowerment, which is arguably missing from most other modern industries such as nuclear power and offshore, will be returned to at the end of the paper.

It can be argued, in contrast, that the nuclear power industry learned the importance of Human Factors too late. In the aftermath of the Three Mile Island (TMI) and Chernobyl accidents, hardly any nuclear power plants have been built in the West (none in the USA since TMI, and one in the UK, with further plants now cancelled). The offshore industry, very highly human dependent in its operations, has an opportunity to take account of the human's limitations, and also to try to harness man's potential. This road is that of Human Factors. There are no miracle or one-shot cures - humans in work systems represent complex systems, and Human Factors itself is still a relatively young 50 years of age as a discipline, and there is still much research and development to be done. However, there are some straightforward approaches that give good return on investment, by clarifying the human operator's role, and how better to support it. Furthermore, there are some clear ways forward for maximising human and system performance, but this depends on the perceived role of the human in the system, and the perceived role of Human Factors itself, within the system design life cycle or business process. This paper is therefore firstly gives an outline of some of the well-tested approaches, data and tools, and attempts to place them in a useful framework for offshore systems, relating them to the system design life cycle. Secondly, towards the end of the paper, th epotential usage of advanced Human Factors is explored. This is an area which require research effort to reach fruition, but may have significant benefits for offshore operations' safety and productivity. The two parts of the paper, in total, attempt to answer the following questions:

- *What are the main Human Factors issues and application areas in offshore operations ?*
- *What data and tools exist to address these issues ?*
- *When should these issues be addressed ?*
- *What positive future role should Human Factors play in maximising operability and safety ?*

These questions will be addressed throughout the development of this paper.

2. HUMAN FACTORS ISSUES

Human Factors can be considered to cover six broad areas, related to offshore operations. These areas are as follows:

- **Allocation of Function**
- **Person Specification**
- **Staffing & Organisation**
- **Task & Interface Design**
- **Training & Procedures Support**
- **Human Reliability Assessment**

These areas are best illustrated by questions, as follows:

1. *Should a system be manual, semi-manual (manually supervised) or automated ?*
2. *Who should operate a particular system or sub-system ?*
3. *How many people are required, and how should they be organised ?*
4. *What task interface and equipment (displays and controls) should be provided ?*
5. *How should we train personnel, and what procedures and job aids do they need, to achieve good on-line performance ?*
6. *Is the specified system safe enough from human error, and does it take advantage of human error recovery ?*

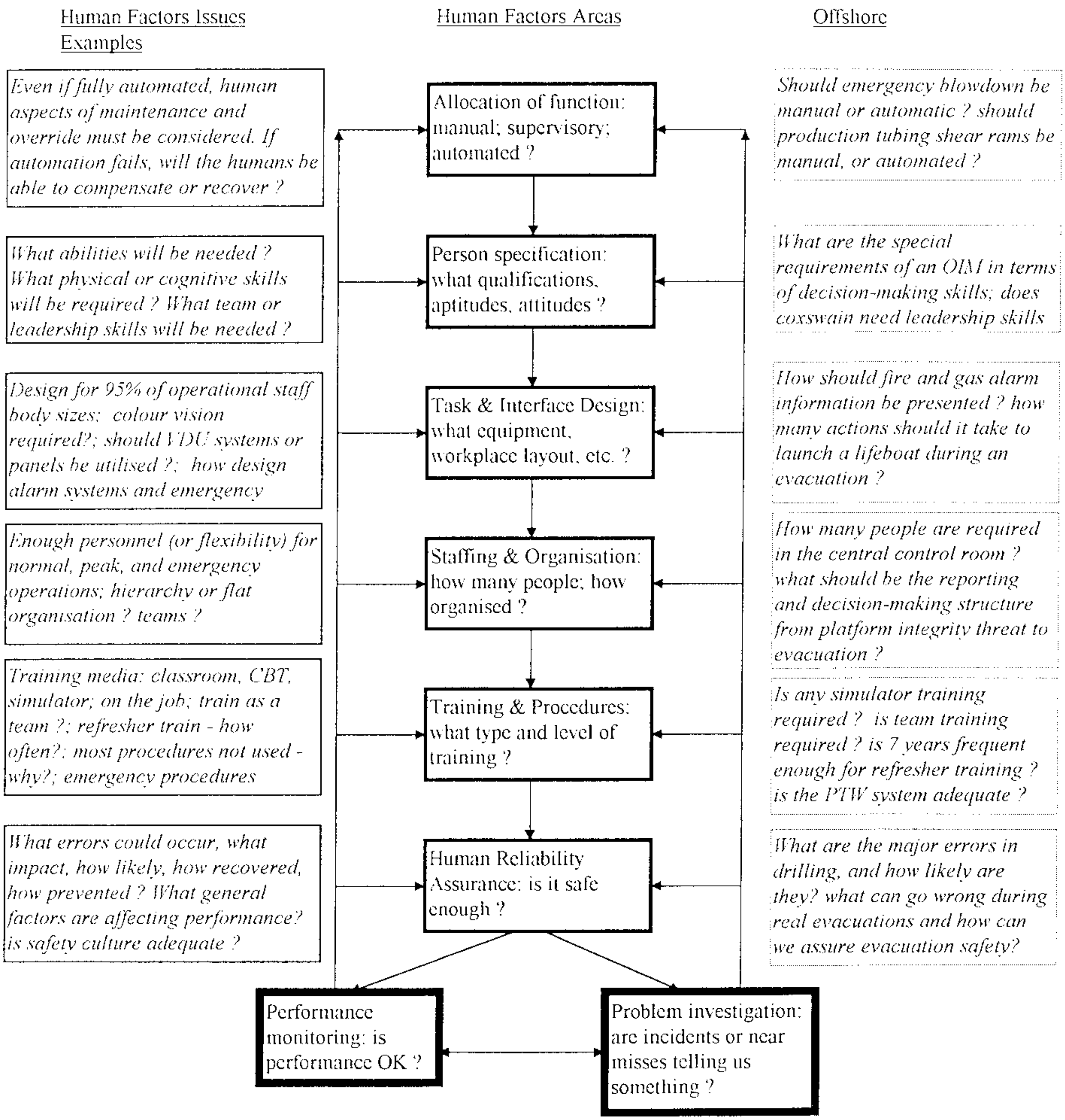
These six issues can also be represented in a flowchart, as shown in Figure 1. Each of these issues is briefly developed in the following paragraphs.

2.1 Allocation of function

Allocation of function can be briefly summarised as 'human or machine ?'. When designing or changing a system, there is always an option to change the 'level of automation'. There are three basic categories, ranging from fully manual, to semi-automatic, and to fully automatic. Some systems may need to be controlled so quickly, or with such precision, or in such a complex way, that they are beyond the basic capabilities and skills of the human operator, and these are usually automated. Other system functions may require such adaptability and flexibility, or problem-solving skills, that there is no possible automation route, and in such a case manual control is similarly inevitable. Many other tasks, however, and these probably represent 90% of system functions, fall into the middle ground, where automation or manual control is possible.

Cost will play a large part in deciding whether such system functions are automated or manually controlled, in that some system functions may be very expensive to automate. Other factors relevant to the allocation of function issue are legal factors (some tasks are too hazardous or unhealthy for human operation), reliability and quality factors (some repetitive tasks may require 100% performance all the time, implying automation, whereas others may require high quality inspection, implying human inspection), and safety (some tasks may have disastrous consequences if carried out incorrectly - suggesting automatic execution and human supervision and over-ride capability). Added to these considerations must be the job satisfaction of the employees who must carry out a task - no-one wants to repeat the same trivial task 600 times a day, and no-one wants to sit in a room watching a perfectly-controlled screen for a 12 hour shift without having to do anything. Similarly, few people really want to know that if they make the wrong decision or press the wrong button, then all platform personnel will die. In the need to focus on technical problems and solutions, and system functions and tasks, these very human

Figure 1 Human Factors Application Areas



dimensions of job satisfaction and role meaningfulness are sometimes underplayed. We cannot afford to do so, however, as such factors as motivation, and reaction to stress, can be determining factors in system performance and safety. These types of issues can again be summarised by a series of questions:

- *can the function be automated ?*
- *can it be manually controlled ?*
- *is manual/automatic control cost-feasible ?*
- *what reliability of performance is required ?*
- *what quality of output is required ?*
- *are there legal precedents for automating a system function ?*
- *how motivating will the task be ?*
- *how stressful will the task be ?*

When deciding allocation of function, reference is often made to a list of human and machine attributes, called Fitts' List, after the eminent ergonomist Paul Fitts who produced the original version. Although it is only meant to be guideline in nature, it is useful to consult the listing. An abbreviated version of it is shown in Table 1.

Table 1: Abbreviated Fitts List: Some Examples of Relative Strengths of Human and Machine

Human Strengths	Machine Strengths
Flexible	Wide range of operating speeds available
Adaptive	Power
Problem-solving	Repetition with high precision and consistent accuracy
Pattern recognition	Wide range of inputs available
Dextrous	Can be designed to tolerate hostile environmental conditions
Excellent long term memory storage	Short-term memory and access excellent
Decision-maker	Does not get bored or suffer fatigue, or need frequent rest breaks
Creative	Powerful productive media available via computers
Able to discriminate signals from 'noise'	Very fast information processing

Allocation of function is never truly straightforward, and cannot be solved simply as a Human Factors issue, since it involves consideration of many other engineering and cost factors, but it should definitely be a key player in the equation. Although allocation of function used to be (and still often is) thought of as 'human or machine', or even 'human *versus* machine', it is more useful to consider the optimum human role in the system. This means that the system is conceived of as a joint system. Allocation of function then becomes '*human-system role optimisation*'.

Allocation of function, however, is a relatively under-developed component of Human Factors. This is due to a lack of industry focus on this issue, itself due to the implicit assumption that Human Factors enters the design process later on, after allocation of function and the preliminary design have been completed. This is a mistake for two reasons. Firstly, basic Human Factors principles may be omitted from the early design, leading to later costly design retro-fit, or acceptance of a sub-optimal design concept. Secondly, it does not optimise the system by capitalising on human strengths and capabilities, instead at best simply avoiding the major human weaknesses. Allocation of function is therefore a key area for development in Human Factors, and a key potential means of system improvement.

The tools for allocation of function are essentially those of task analysis, particularly hierarchical task analysis, tabular task analysis, and timeline analysis. These tools are defined later.

2.2 Person specification

The determination of who is needed to carry out various tasks is partly a Human Factors issue, and partly (mainly) in the domain of Personnel (Occupational) Psychology. A Central Control Room (CCR) operator, for example, will need certain minimal educational qualifications, and specified length of practical experience, plus other training course requirements. However, it may be decided that certain personnel, e.g. the Offshore Installation Manager (OIM), or a lifeboat coxswain, need leadership abilities, or that the CCR operators need an aptitude for computers and computing. Such requirements can be derived based on an analysis of the tasks that personnel have to carry out, and based on considerations of factors affecting performance. Human Factors task analysis techniques, especially Hierarchical Task Analysis (HTA - discussed later), can determine in detail what personnel have to do, and (via tabular task analysis) what information they will have available to them at the time. Based on such detailed knowledge, it will be apparent as to what educational skills they will need, and which information-handling media skills they must be capable of. The analysis of stressful tasks, such as emergency evacuation, may suggest that stress will be very high. If in such a situation the staff are organised hierarchically, then leadership skills will be required to achieve effective response. If the organisation is very flat, then team skills may dominate performance effectiveness.

2.3 Task & Interface Design

The detailed design of controls and displays, including the details of large Distributed Control Systems (DCS) and Supervisory Control and Data Acquisition (SCADA) VDU systems, and of the surrounding workplace is very much the domain of Human Factors. Human Factors has a large database of statistically-defined body dimensions, with allowances for both general clothing and protective clothing, which can be used to lay out workplaces to fit 90% of male and female populations. Typically for a mixed operating environment, the workplace layout is designed to accommodate the range of personnel from the 5th percentile female to the 95th percentile male. It is very hard to accommodate 100% of people, since at the extreme ends of the full range of body sizes are very short/small and very big/tall people - inevitably some personnel will not fit a standard design, and special provisions will have to be made on an individual basis, but the 90% approach will minimise problems of both efficiency and physical health/comfort. The usage of body size data is known as *anthropometrics*, and some useful references are given at the end of this paper. It is important to account for cultural differences in body sizes (i.e. design for the local population), and there are different data sets, e.g., for people from the UK and from the USA, and from other countries.

There are similarly data and techniques associated with physical strength, and the ability to carry out both dynamic and static work of varying types. Such data and predictive techniques form the sub-discipline of *biomechanics*, and such an approach is relevant to, for example, maintenance tasks and other physical tasks.

Control and display design are assisted by the application of principles, such as those shown in Table 2 for panels, VDUs, and controls. There are textbooks written solely on these individual aspects (see references at the end of the paper), and so this area will not be dwelt upon here. The most relevant task analysis techniques for task and interface design are, however, tabular task analysis and link analysis, described later.

Additionally, the environment in terms of lighting, thermal, noise, and air conditioning aspects, must all be considered, and once again there are many guidelines and practical techniques and measuring equipment for achieving an efficient and motivating environment. Certain offshore operational considerations will require special attention, e.g. emergency lighting for shutdown operations and emergency evacuation to either escape liferafts or lifeboats, or to Temporary Safe Refuge (TSR) areas, and the impact of noise on communications in the drilling and certain production areas.

Table 2: Examples of Human Factors Principles Used in Design

Principle Area	Principle
Control Room Layout	Has general layout been according to the placing of the most important and frequent displays and controls in primary areas, and with specific layout according to use of functionally-related grouping of instruments, and sequence of use ?
	Will the range of body dimensions accommodated by the design accommodate 90% of operator sizes (from the 5th percentile female to the 95th percentile male)?
	Are all displays on vertical consoles placed in a band between 41 and 70 inches from the floor, with those requiring frequent or precise readings placed between 50 and 65 inches from the floor ?
Displays	Has character height on VDU displays been sized for optimum legibility according to viewing distance (e.g. 4mm high for a 900mm viewing distance) ?
	Colour should not be the sole coding mechanism used ?
	Does each colour only have one coded meaning ?
	Do successive related VDU screen displays maintain spatial continuity, and representativeness of the real plant, not reversing actual orientation or topography ?
	Are process flows on displays represented by arrows ?
Alarms	Are all messages concise, informative and unambiguous ?
	Is the alarm system prioritised, with no more than four levels, and with far fewer alarms in the top priority alarm band ?
	Is alarm chronology recorded in the control room, on a VDU and/or printer ?
	Is there a high level alarm or overview display, showing the overall safety integrity of the system in terms of its major safety parameters ?

2.4 Staffing and Organisation

Staff cost money, and so in many industries there is a drive to reduce manning levels. However, there must be enough personnel to achieve safe and effective operation under both normal *and* abnormal operations, including emergency response, and including provision for the fact that some personnel may have become incapacitated by an incident (e.g. an explosion). The determination of how many personnel are required is something that Human Factors can help with, particularly via the method of Timeline Analysis, described later. This technique can also give an insight into the appropriateness of the organisational structure for a set of tasks (e.g. emergency response), in terms of how quickly it can be achieved by the team structure, and whether any individuals will act as a bottleneck on the task execution.

The organisation of the staff will often be a product of the culture of the company and its origins (e.g. some companies may operate along tight 'commando lines' with strict vertical organisation, whereas others may have flatter and less rigid organisational structures. As well as company cultural and evolutionary organisational structures, some offshore contractor-based functions, such as drilling, or even scaffolding, may also have their own evolved way of operating, which may fit in well with the company's ethos, or may conflict with it but be tolerated because they 'get the job done'.

The more 'socio-technical' considerations of organisational structure effects upon morale and (thereby) performance, are considerations of job design within Human Factors and, as with person specification, overlap considerably with personnel psychology and occupational psychology. These are therefore fairly broad issues, and as such, cannot be treated properly within the confines of this paper.

2.5 Training & Procedures Support

Training and procedures both have the same aim - to ensure that the person can do the job effectively when required to do so. The difference is that training acts upon the memory, so that the operator remembers what to do and/or what factors to bear in mind when doing the task, whereas procedures aim to prompt the operator on-line, based also upon what the operator is likely to see in the task, and know and remember through training. Training and procedures are therefore inextricably linked. Usually, the less training, the more procedures will be required, and vice versa. However, since in all heavy industry sectors there are problems with procedures (i.e. non-use or non-adherence, because procedures are not usually written ergonomically), it is not wise to minimise training and maximise procedures.

Some tasks may require no training, because the task required is already within the operative's required (person-specified) skill-base, e.g. an electrical fitter may already be a trained electrician onshore, and a number of tasks will be the same offshore as onshore. Other tasks will require theory [understanding the task or skill], demonstration [seeing how it should be done, and building a mental template for the skill], and practice [learning the skill], via the use of part-task (e.g. mock-up) trainers, full-scope simulators, or on-the-job practice. Training should occur until the skill can be performed with adequate quality and speed, with flexibility to adapt to new situations, and with sound knowledge and readiness to apply it in the right situation, and not to apply it in inappropriate situations. Much of training in reality will occur on the job, partly because this is cheap, and in many cases it will be sufficient. However, certain tasks will require simulator training, particularly where rapid and effective response will be required in stressful situations, or where mistakes in performance cannot be tolerated during on-the-job training periods. Some examples are drilling, and various emergency scenarios (e.g. emergency shutdown, blowdown, etc.). The simulations, especially where trying to prepare people for stressful events such as evacuation, must be realistic, or else the training will not transfer to the real situation, and people may simply go to pieces when a real event occurs.

Skills such as handling abnormal events will need to be refreshed, since actual events will be rare, and so practice opportunities will not occur naturally. In such a situation performance will decay, and the skill and the understanding of the task will diminish. Typically, refresher training tends to be scheduled every two years. However, evidence is accruing which strongly suggests that performance decays much faster, namely 50% within 6 - 12 months. Important rare-event training (e.g. for blowdown and evacuation) should therefore occur more frequently than every two years, and should preferably be at least on a yearly basis.

Procedures can be lengthy, complex, out of date, and time consuming, and physically difficult to use in an offshore environment. These and other factors contribute to their non-use by personnel, not just in the offshore industry, but elsewhere. They are also often written by people who are distant from the job itself. Human Factors offers many guidelines on how to write more effective procedures and get them used, and also when not to write any at all. Task analysis (particularly hierarchical task analysis) is often used to help develop more effective procedures, in terms of their accuracy and relevance for the task being proceduralised.

2.6 Human Reliability Assessment

The determination of what errors can occur, what impact they will have, how likely they are, and how they can be recovered or prevented, is the subject of human error assessment (if qualitative) or Human Reliability Assessment (if quantitative as well as qualitative). Human Reliability Assessment (HRA) feeds into Quantitative Risk Assessment (QRA; or Probabilistic Safety Assessment, PSA), bringing the human factor into the risk equation. The human contribution to risk may not always be a negative one - human recovery potential is one of our strengths, and should be represented in risk assessment fault and event trees. The advantage of HRA is that it can prioritise human error problem areas, and can be used to choose between two candidate designs (e.g. between a manual and an automatic system).

A long-standing problem with HRA has been the lack of robust data on Human Error Probabilities (HEPs) to utilise in HRAs (e.g. for tasks such as 'driller fails to activate shear ram in blowout scenario). This may change in the very near future, however, due to a UK Health & Safety Executive (HSE) Offshore Safety

Directorate (OSD) sponsored study into offshore human reliability. This work has so far led to data collection in the areas of offshore evacuation and drilling, and work is currently proceeding on Permit to Work (PTW) errors. Some examples of the type of data to be generated are given in Table 3 below.

Table 3: Offshore Human Error Probability Data1

Error descriptor	Human Error Probability	Data Source
Fail to Check Blowout Preventer Panel	0.07	Observation
Drillstring pulled out of hole too fast	0.001	Expert judgement (2 convergent techniques)
Fail to close BOP and shut in well completely	0.003	Expert judgement (2 convergent techniques)
Fail to set alarms effectively	0.01 - 0.2	Expert judgement and observation
Choke opened too much	0.02	Expert judgement (2 convergent techniques)
Fail to check lifeboat air support system prior to emergency launch	0.04	Observation
Incorrect lifeboat brake cable operation	0.04	Observation
Fail to check wind speed and sea state prior to launch	0.13	Observation
Fail to position steering wheel to ensure lifeboat will clear installation legs	0.008	Expert judgement (2 convergent techniques)

The above six areas of Human Factors are summarised in Figure 2. This figure shows the areas in an iterative cyclic fashion, which is in practice the way Human Factors works. It also shows Human Factors as a toolkit with which to solve problems of design and operation. The task analysis tools which are in the toolkit, as shown in the figure, are the main subject of this paper, and are outlined in the next sub-section.

1 This data collection work is still in progress, and is sponsored by the Offshore Safety Division of the Health & Safety Executive, UK, as part of a longer term project to develop a human error database for industrial risk assessment support. The database has been developed at the University of Birmingham (Taylor-Adams and Kirwan, 1995; Taylor, 1995; Basra and Kirwan, 1996; 1997).

3. HUMAN FACTORS DATA AND TOOLS

Some Human Factors data can be applied directly, such as data on desk heights and reach distances for controls, etc., and many principles can be incorporated into the design philosophy directly (e.g. co-location of functionally-related controls and displays. However, since many interfaces are new and sophisticated, in most cases analytical tools will be required to ensure that such data and principles are implemented effectively. This section therefore discusses first the types of data available, and then secondly focuses most effort on describing the tools that are used in contemporary industries to achieve good Human Factors design and operational solutions.

3.1 Human Factors Data and Checklists

A great deal of Human Factors data has accrued on the physical characteristics and mental capacities and aptitudes of humans, and of human physical skills, strengths and limitations, and variations in human performance between different individual workers. This has led to a large database of Human Factors information. This Human Factors database contains information on the capacities and limitations of human operators in a range of working conditions, as well as, for example, design information on body sizes and muscular strengths, and how people process information, and thus how information is best presented, etc. Such information can be used, for example, in the design of the physical layout of machinery on the drill-floor, as well as determining which operations can be done manually (based on knowledge of strengths and biomechanics), and for which tasks there should be mechanical assistance (e.g. use of tongs on the drill-floor, or other aids during maintenance). There are a variety of Human Factors principles which can be used to aid the design process. Some examples have already been cited in Table 2 earlier, and some references (e.g. Ball, 1991) summarise key design principles for high-technology and process control-related industries. Some typical guiding principles are shown in Table 4.

Table 4: Example Human Factors Guiding Principles (adapted from Ball, 1991, and Mitchell, 1996)

Principle	Source
All relevant information must be supplied	Ball, 1991
Displayed information should be derived directly from the function it represents	"
There should be sufficient displays (e.g. VDUs) to show simultaneously all the information required to make a decision	"
All sound signals to the operator should be clear and distinguishable to the operator, such that the operator can identify each one, whether on its own, and when co-occurring with others	"
Operators should be trained to recover from their and others' errors	"
Teams should be trained in the transfer of information and the transfer/allocation of responsibility	"
Periods of continuous mental inactivity or social isolation should be less than half an hour	"
Periods of sustained concentration should be shorter than an hour, including during emergencies	"
Decision aids should retain the operator in the decision process	Mitchell, 1996
Operator displays should be intelligent, matching the operators needs given the current system state	"
The operator should remain 'in the loop'	" ; various
An operator should be able to see and understand what an automated system is doing, why it is doing it, and what it will do next	"
Human-centred automation requires a model of operator intent	"

As well as principles which embody the philosophy of Human Factors, there are checklists which check the degree to which the actual designed system fulfils those principles in practice. There is a variety of checklists available (e.g. Kincade and Anderson, 1984; Health & Safety Executive, 1989; Ball, 1991; Blackman et al, 1983; Dul and Weerdmeester, 1993; and NUREG 0700, 1996), which is currently increasing, for a range of ergonomics audit functions or application areas: *VDU design; format design; workplace layout; environmental adequacy; equipment design; general Human Factors reviews; job design; maintenance task design*; etc. These enable the audit of most if not all current human work systems in the Oil and Gas industries. However, a number of the checklist sources offer guidance not merely on auditing a design, but on *design* itself (Ball, 1991; Kincade and Anderson, 1984; Woodson, 1981; Pheasant, 1986). This enables the designers to 'get it right' the first time (i.e. prior to audit), by explaining the theory, data, principles, and techniques available to develop human work systems. In this respect the checklist sources are referring more to the Human Factors Database of data and techniques which under-pin the checklists themselves (see also Wilson and Corlett, 1995; Grandjean, 1988).

Checklists offer a quick, and to a large degree robust and valid, assessment medium (where published checklists are approved by ergonomists), to show whether a system is generally adequate, and to identify ways to improve the system's adequacy. The disadvantages of the checklist approach are that most checklists cannot offer advice on relative importances of checklist items, and usually take no account of the context in which the system is being used. Also, in large systems, checklist evaluation can take up a large amount of resources. Currently many evaluations using checklists, rather than attempting to be exhaustive, select randomly from a comprehensive set of questions, and ask only a proportion of the questions, thus gaining an insight into the adequacy of the system, without consuming excessive resources.

Interface Surveys are a basic and quick, but often illuminating way to audit a workspace or the working environment. There are a number of interface survey types, e.g.:

- **Labelling surveys** - reviewing meaningfulness and ambiguity in labelling schemes;
- **Operator modification surveys** - reviewing how operators have carried out their own additions to the interfaces (e.g. via 'post-its and 'dymo' labels) to make them more usable/safe;
- **Sightline surveys** - determining what information can be read/seen from operating positions
- **Environmental surveys** - measuring lighting, noise, and thermal factors;
- **Coding consistency surveys** - detailing each coding mechanism and all its variants, determining whether the coding system is unambiguous or not;
- **Coding/display analysis** - determining the display medium used for each control function available, and then determining (via ergonomics) the suitability of the medium for that function .

Survey methods are relatively easy to administer, and identify inconsistencies and ambiguities in the interface which can lead to errors, and the methods can be employed with little or no interruption to the system or its users. Some of the methods can only be used when the system exists, and with large systems, carrying out the surveys can become an onerous task. Such interface surveys and audits give a quick snapshot review of the Human Factors adequacy of the system. For a deeper look, and for resolution of identified inadequacies and conflicts, more analytical techniques need to be applied. Therefore, with most system designs, it is necessary to select and apply specific tools to analyse tasks and subsequently synthesise task design formats. Such tools are predominantly those of Task Analysis, defined below.

3.2 Human Factors Tools - Task Analysis

Although a large database is already available on designing human systems, many workplaces will be designed in different and novel ways. A number of techniques are available for analysing these designs to make them more 'user-friendly', and therefore more likely to avoid or recover from human errors that could lead to system downtime or contribute to incidents. The most important and useful set of techniques within the Human Factors Assessment (HFA) approach is that of ***Task Analysis***:

> *Task analysis2 is the study of what an operator (or team of operators) is required to do, in terms of physical actions and/or cognitive (mental) processes, to achieve a system goal, and it can also document the information and control facilities used to carry out a task. It is the formal analysis and description of operator behaviour, based on the discipline of ergonomics or Human Factors, which is concerned with the study of humans in work systems.*

When a new plant or platform is being designed, formal descriptions of the hardware design are produced in the form of engineering flow diagrams, piping and layout diagrams and other system schematics, etc. These representations of the formal hardware and software design allow constructive analysis and checking to take place in systematic ways. Task analysis, in a fundamental sense, aims to provide similar representations for the human element in such systems. Task analysis techniques give the designers and future operations departments of these systems a more formalised and robust definition of the human's role and support requirements in the systems being developed. Task analysis techniques are also useful for safety assessors, since these techniques generate definitive descriptions of how the tasks should be carried out, and these descriptions then serve as the basis to begin to consider what could go wrong (human error analysis). They are also of great utility for trainers and procedure/instruction developers, since certain task analysis techniques generate most of the content needed for training and procedures. There is a range of task analysis tools available, as outlined below in Table 5 (see also Kirwan and Ainsworth, 1992).

Table 5: Human Factors Analysis Techniques

1. Data Collection Techniques	
Observation	Gathering of raw data by observational methods such as direct observation, video-recording, etc.
Interviews	Use of structured or exploratory interviews to gather data. May be supplemented by questionnaires.
Activity sampling	Observation-based recording of frequency and sequence of task activities of interest in a pre-specified format
Critical Incident Technique	Interview-based search for near-miss information on errors that may not have been reported or are not reportable
Verbal Protocols	Concurrent reporting of what an operator is thinking while carrying out a task. Useful for analysis of problem-solving scenarios/diagnosis.
Table-Top Analysis	A group of experts meeting to identify problems or to resolve them is a table-top exercise; this can be relatively unstructured or can be highly formalised. Typical uses are to identify hazards in a process, to derive data via expert judgement methods for Human Reliability Analysis methods, or to identify control/recovery methods for identified hazards or human errors.
Walk and Talk-Through	Talk-through is a form of table-top discussion, in which an operator talks through how a scenario would progress and how it would be handled, and

2 Adapted from Kirwan and Ainsworth, 1992.

what could go wrong, and is usually used to explore error potential in scenarios, or as a training/competency technique. Walk-through is the

Table 5 continued

same approach but the operator carries out the exercise in the workplace, pointing to displays and controls that would be used at each stage, and stating what would be expected values and system responses at each stage. The walk-through can be used to gain time estimates for HRA or timeline analysis purposes, or can be used to evaluate the interface or competency, or for training.

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2. Representation Techniques

Hierarchical Task Analysis (HTA)	Probably the most popular and useful task analysis technique. A top-down (hierarchical) description of a task, from a top-level goal, to the tasks which fulfil the goal, to the individual physical actions and observations (called operations) in which the tasks are effected. Plans are used at each 'level' in the HTA to show when each operation/task should be carried out.
Tabular Task Analysis (TTA)	Usually following on from HTA, TTA focuses on the information which tells the operator when to act, and when the act has been effective (or not). TTA can be highly effective for analysing control-display interfaces, and identifying operational vulnerabilities or error potential.
Timeline Analysis (TLA)	Two methods (vertical and horizontal TLA) which determine how long an operation will take, and how many staff will be required to carry it out. Can also be used to identify where operational 'bottlenecks' can occur, and for examining communication errors in scenarios such as emergency response. Follows on from HTA and TTA. Can be integrated into OSDs (see below).
Link Analysis	A schematic format showing the frequency of links an operator must make between different controls or displays in a workplace, during a scenario. Used for evaluating workplace layout (e.g. a drillfloor or a control room). Can be integrated into OSDs (see below).
Operational Sequence Diagrams (OSDs)	A mixture of flowchart and timeline analysis, this technique maps out each operator's actions in sequence, showing how information is passed from one crew member to another, and how the team must function together to achieve the task. Useful for analysis of critical operations (e.g. an escalating emergency leading to evacuation).

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3. Error Analysis Techniques

Barrier Analysis	Analysis of the physical and administrative barriers that prevent hazards from occurring. Useful for assessing adequacy of control methods.
Work Safety Analysis	Analysis of the operator's work environment, used to determine what injuries could occur with moving equipment. A tabular format is used, and it resembles a HAZOP (Hazard and Operability Study) table.

Table 5 continued

Human Error HAZOP	As for HAZOP[3], but a Human Error HAZOP approach is focused more on the human interactions highlighted by prior task representations (e.g. HTA/TTA).
Human Error Analysis	A number of methods exist, a typical example being the Systematic Human Error Reduction and Prediction Approach (SHERPA: Embrey, 1986) system, which resembles a Failure Modes and Effects Analysis (FMEA) approach, and is based on a set of definable error 'modes', and is also useful in identifying control and recovery methods.
4. HRA Quantification Techniques	
Human Reliability Quantification Tools	These techniques aim to quantify the likelihood of human errors occurring, usually as a function of the adequacy of various contextual factors in the workplace or in the task itself. Several methods exist such as HEART, THERP and SLIM (see section 3.4).
5. Ergonomics Checklist (EC) Techniques	
Ergonomics Checklists	There are a range of ergonomics checklists available for general and specialised evaluations (e.g. general workplace design; VDU format adequacy; etc.) as noted earlier. These can also survey the environment (lighting, noise, thermal comfort, etc.).

Some of the key task analysis representation techniques are described below.

(i) Hierarchical Task Analysis (HTA)

HTA is used to represent the relationships between goals, tasks, sub-tasks and operations. It provides a diagrammatic representation of the task, and is highly adaptable, able to represent most if not all tasks. It defines tasks in a logical and unambiguous way.

The method involves defining an overall goal, such as 'carry out drilling', breaking this down into tasks (such as tripping, drilling, etc.), sub-tasks (e.g. changing the drill-bit), and at the lowest level of description, operations (e.g. close valve). These are represented usually diagrammatically in a hierarchical fashion. The relationship between a set of sub-ordinate tasks (or operations or sub-tasks) and their parent goal (or task or sub-task) is defined by a plan. The 'plan' at each node in the HTA states 'when' each of the tasks or operations below it are to occur. These plans represent the real expertise of any task, since a novice usually knows the basic operations that make up the task, but an expert knows not only the sequence of the operations, but also the different permutations that will be required depending upon what is happening in the situation, and such information or 'deep knowledge' can be captured in the plans. There are a number of plan types available, which can describe most types of relationships. The HTA is usually also numbered for easy and reliable reference to the various tasks/operations and levels in the task analysis representation. Transfer from one page of HTA to another is achieved via transfer boxes as in fault tree analysis.

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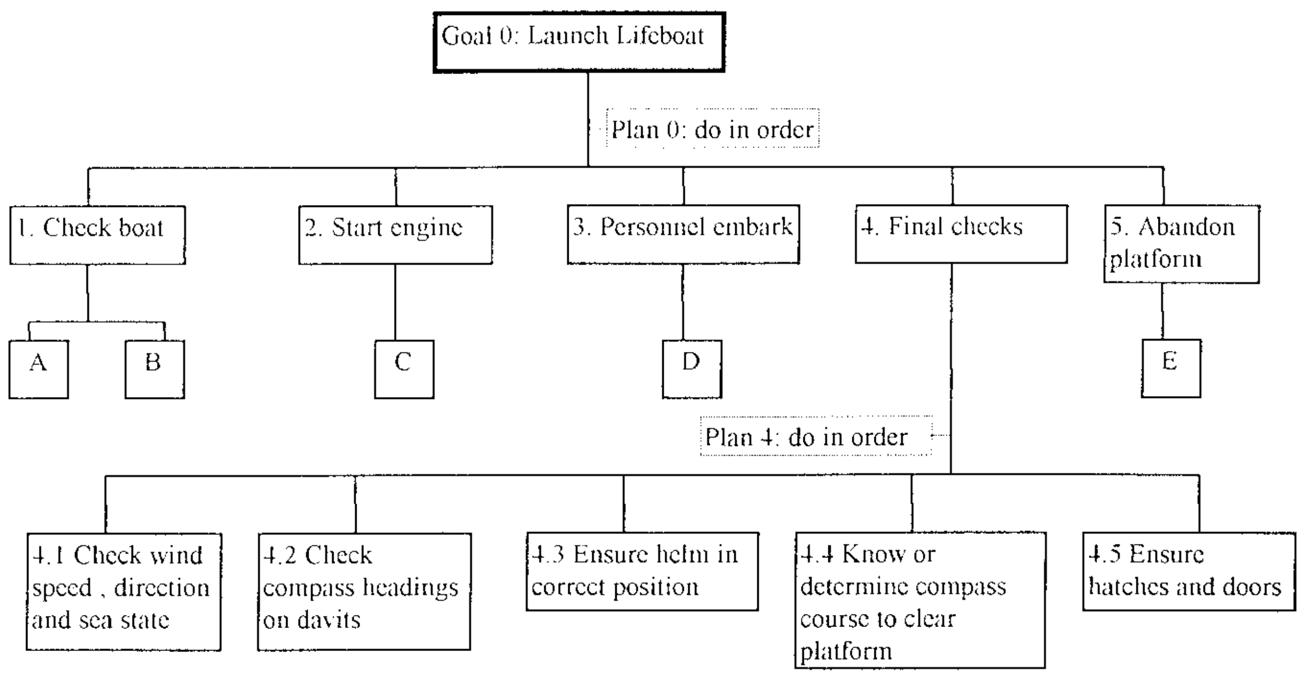
3 HAZOP is a powerful and popular hazard identification method, used in many industries including the offshore industry. It was originally developed at ICI in the UK by Kletz et al (Kletz, 1974).

The diagram overleaf shows a HTA. Stopping rules exist to decide how far to decompose the task.

The technique itself at first sight resembles a flowchart, but the boxes are laid out hierarchically in a top-down fashion, going from a top level goal (e.g. carry out drilling), to the various tasks which together fulfil that goal (e.g. operating mud control; drilling; pulling out of hole; etc.), to the actual physical and mental operations that are required to carry out the task (e.g. operate brake; open kelly cock; monitor mud volume; etc.). Three 'levels' in the HTA is usually the minimum, with seven as a practically-recommended maximum: the required depth of the HTA depends on the depth of analysis and the complexity of the task, e.g. drilling might utilise five levels, evacuation three, etc.

HTA is the most popular and probably the most useful of all the task analysis techniques. It is a representation method, but offers a powerful medium for developing training and procedural systems, and is a pre-requisite for many of the techniques which determine interface requirements and human error potential. It has been used as a basis upon which to make allocation of function decisions, as well as for identifying person specification requirements. It therefore can be used for all six main areas of application of task analysis techniques, and in this respect is fairly unique. An example of part of a HTA for lifeboat evacuation (Basra and Kirwan, 1996) is shown in Figure 3.

Figure 3: Example HTA for launching a lifeboat



(ii) Tabular Task Analysis (TTA)

Tabular Task Analysis is primarily aimed at evaluating interfaces, although it can also be used to investigate error potential with respect to errors caused by poor or misleading interface design or communication. The method starts from an HTA and then examines what prompts the operator to carry out an action, what feedback the operator receives to say the operation has/has not proceeded satisfactorily, and what the action was. Potential deficiencies are noted, as are potential interface improvement measures. This is documented in a sequential columnar table (see figure overleaf). Vulnerabilities in the interface design, and potential remedial measures. Potential errors may also be identified.

TTA usually follows on from HTA and is primarily used for assessing the adequacy of operator interfaces (displays and controls). There are typically a number of columns such as task step, indication, action or decision, feedback to the operator following the action, and potential problems or errors. The two critical focuses of the approach are the indications that tell an operator when to act, and the feedback (or lack of it) that tells the operator that the action was successful (or not). Often when analysing a task, it is found that certain steps are not clearly initiated via unambiguous indications, or else there is indirect or misleading feedback, or no feedback at all telling the operator if the action was successful. This can lead to errors, and the TTA can be continued to look at the errors likely due to interface problems, consequences of those errors, and the necessary changes to resolve the inadequacies and prevent the errors (see Human Error Analysis).

A typical application of TTA would be the analysis of the driller's work interface, during critical operations such as responding to the detection of a 'kick', including the consideration of whether or not to operate shear rams. In such (potentially) rapid response tasks, where consequences of incorrect operation are high, the interface design would warrant the detailed assessment by a tool such as TTA. A TTA could also be carried out to develop a good interface for the entire Central Control Room on a platform.

TTA is a powerful analysis method, and usually develops solutions to the problems it identifies as it progresses, and the TTA itself usually allows designers, operators and Human Factors analysts to represent the task and its interfaces in a commonly-perceived format, so that agreement on required changes can be achieved. TTA can however be highly resource-intensive if carried out in the early detailed stage of design (when it is most useful), since often there are not the experts available to determine how the interface should be used at the required level for analysis. Nevertheless, if highly usable interfaces are required (e.g. for emergency shutdown panels) then the resources will be justified. Once an interface is in use, TTA resources are less, but the cost of changes to the interface are correspondingly higher. An example of a TTA is shown in Figure 4, based on an emergency blowdown analysis (Kirwan, 1987).

Figure 4: TTA example for emergency blowdown analysis (based on Kirwan, 1987)

Task Step	Cue initiating action	Action	Feedback	Comments
2.2 Initiate sector A blowdown (separators)	Fire in the separators area. separator indicator lights red (stopped)	Press buttons SBD 1 and SBD 2 on emergency blowdown panel in CCR.	SBD lights on panel go green (safe)	Panel labelling should discriminate more between SBD and CBD buttons.
2.3 Initiate sector B blowdown (compressors)	Fire on platform. Wait 4 minutes after step 2.2 to avoid flare overload. Compressor lights red (stopped)	Press buttons CBD 1 and CBD 2 on emergency blowdown panel in CCR, after 4 minutes	CBD lights go green (open)	Operator may forget about 4 minute delay, given that red also means danger. Green lights that will then occur will suggest to the operator that the action was in fact safe.

(iii) Timeline Analysis (TLA)

The objectives of TLA are to determine how long a task will take, and to evaluate operator roles, workload, and interactions (e.g. communications) during a task carried out in a set time-dependent sequence. There are two types of TLA, horizontal and vertical: horizontal shows the times for each task with tasks on the y-axis and time on the x-axis; vertical TLA is columnar, with time in one column, task/sub-task in another (from a HTA), and operators represented in other columns. Communication between operators can be represented as links across columns for the respective operator columns.

Timeline analysis follows on from HTA, and represents the temporal aspects of the task. Usually, two basic types of timeline analysis are used: **horizontal TLA** which determines the time it will take to complete a task; and **vertical TLA** which focuses on personnel roles and resources requirements during the execution of the task. The former can therefore be used to determine overall success likelihood for completing a task in a certain time-frame, and for identifying potential bottlenecks or tasks which are on a critical path. The latter (vertical) TLA approach is used for analysing crew functioning aspects.

The timing estimates themselves can be derived from observation, timed trials, expert judgement, or in some cases from standard data on times for certain tasks or task components. Usually however, observation plus judgement is utilised. It is always important to include 'extraneous tasks' which are often omitted from studies, such as answering telephone queries, responding to nuisance alarms, dealing with injuries during evacuations, etc. Also it is important not to make optimistic assumptions about times for grave actions, e.g. whilst it might take two seconds to physically operate shear rams, an operator may deliberate for several minutes before actually carrying out the physical operation, due to the severe consequences of their operation (or non-operation).

In the vertical format, the crew members carrying out the task must all be allocated, and this way the team resources requirements become readily apparent, including the noting of communication requirements between personnel.

The horizontal TLA can also be used to gain a crude indication of workload, in terms of how busy each operator is, e.g. over a shift period. 50-75% utilisation (outside break periods) is recommended, i.e. the operators are fully active for 50-75% of the time: >75% will lead to errors after e.g. an hour of continuous activity, and <50% will lead to boredom. These are gross recommendations, but at least offer some guidance. Timeline analysis is therefore also sometimes used to determine manning levels, e.g. requirements for operators in Central Control Rooms. Figures 5 and 6 show TLA examples.

Figure 5: Horizontal timeline analysis for evacuation scenario

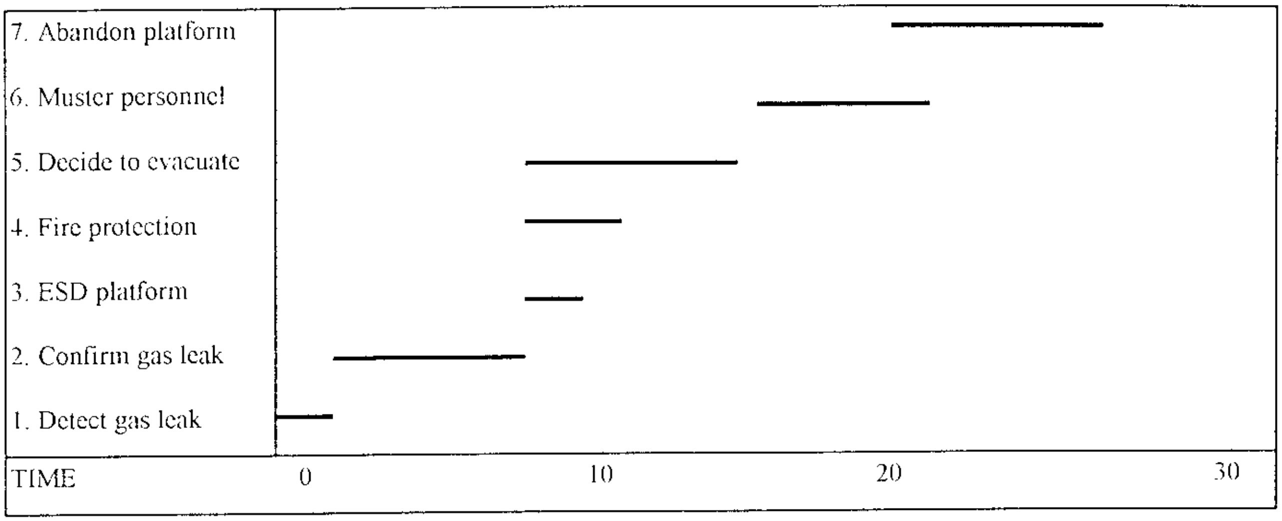


Figure 6: Vertical timeline analysis example extract for evacuation analysis

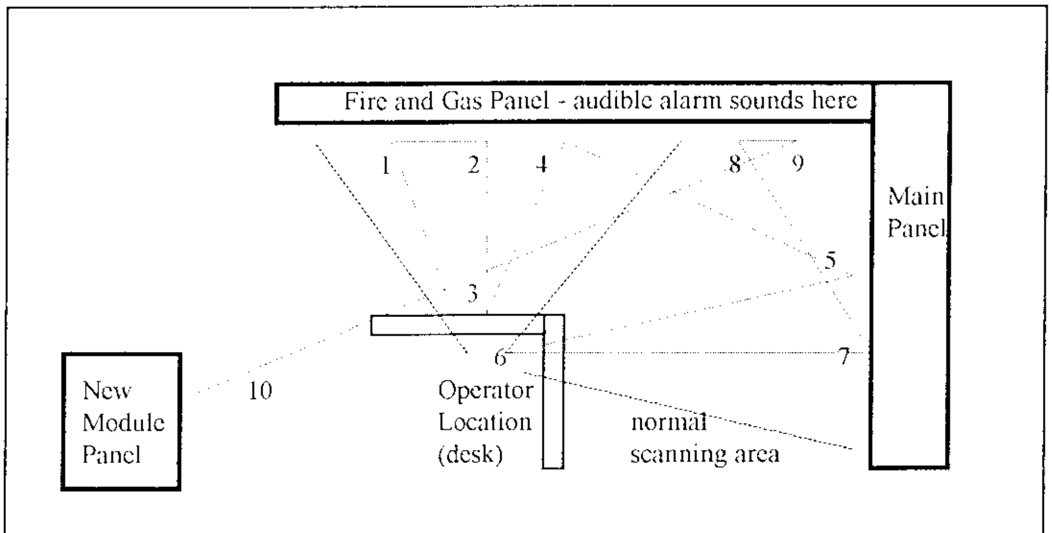
Task step	Time	System state	CRO1	CRO2	Other	Comments
1. Detect gas leak	0.00	Large gas leak	Detects 1st GD alarm			Assumes false alarm
	0.01		Detects 2nd and 3rd GD alarms	Calls OIM		Now knows more serious
	0.02		Locates area		OIM heads for CCR	
	0.04		Calls local operator to investigate		Local operator (LO) receives call	Procedure for confirmation moves local operator into danger area; no formal communication protocols, prone to communication errors
2. Confirm gas leak	0.06				LO picks up portable gas detector and respirator and goes to area	Procedure should involve at least two personnel (buddy system)

(iv) Link Analysis

A diagram is drawn showing visual or physical movement between system components, including frequency of movement and item importance. Items can then be arranged to minimise movement times or distances, or both, or by placing important items in primary locations (according to importance), or by placing items in the usually-used operational sequence, or by grouping them according to operational function.

Link analysis identifies the relationships or links between an individual and parts of the system. The links recorded are usually physical and observable occurrences, i.e. the operator moves to a panel in the control room, or selects a particular VDU 'page', or moves his/her attention visually from one symbol on the VDU mimic page to another. Obviously the links in the last sentence are at different levels of resolution: the first would be appropriate if reviewing control room layout; the second if evaluating the layout of the VDU pages in the software system, or its ease of use ('navigability'); and the latter might be used if evaluating the design of individual VDU pages. The type of links are first established (between the operator and the different parts of the system under investigation), at a level of resolution appropriate to the investigation purposes. Then the system is observed and the number of links are counted. A simplified example of a link analysis is shown in Figure 7.

Figure 7: Link analysis example (showing visual links during an alarm scenario)



In this schematic example of a central control room (CCR), the operators usual visual scanning pathways are bounded by the dashed lines. A new system was installed into the CCR, but there was no space for it within the primary scanning arc, so it was placed behind the operator. However, the audible alarm source was routed through the normal fire and gas system. This meant that when an alarm occurred for the new system, then the operator would scan all around the fire and gas system and related equipment, before realising it was the new system. Alarms occur frequently but are often spurious on the fire and gas system , but those on the new system are rare but highly reliable, with little time to respond before an incident occurs.

3.3 Human Error Analysis Tools

Human Error Analysis is the third component of the Human Factors Assessment (HFA) approach. Having used task analysis approaches to determine what the operator or team of operators need to do in a system, potential human errors and human recoveries from system failures and disturbances can next be considered. For example, task analysis might be used to define drilling operations during offshore exploration, and might include the analysis of 'tripping out' (the task of pulling the drill-string and drill-bit out of the drilled hole) There is a risk of developing a 'kick' or pressure imbalance during this operation, and the risk of a kick (which can develop into a full scale blowout), although in part dependent on the geology of the drilled area and the stage of drilling, is also dependent on the performance of the drilling team (e.g. if the drill is pulled out too quickly, or if the driller, toolpusher or mud processing engineer fail to notice certain warning symptoms of an impending kick). If errors occur, the risk of blowout can therefore be heightened. If a kick does occur, then the team must respond quickly and smoothly to prevent it escalating to a blowout, which will otherwise lead to a full evacuation of the platform, as well as extensive asset damage, and possible injury to personnel.

This drilling example usefully highlights certain aspects of both the task analysis approach and the human error approach. Firstly, task analysis would analyse all the jobs of the drilling crew, and then their interfaces with the hardware systems (e.g. control panels, visual indications and access on the drillfloor, etc.). The analysis might focus on the adequacy of the interfaces for helping the crew to detect indications of a kick. Such analyses could themselves refer to the Human Factors Database on interface design, for example, concerning the best way to group indications for rapid visual scanning, the best way to display analogue trend information, and how to design alarm systems to ensure rapid and unambiguous diagnosis of the situation by the operators, should a kick occur. A human error analysis would focus on potential errors throughout normal and emergency scenarios, e.g. the already-mentioned pulling-out-of-hole too quickly, as well as mis-reading errors by the mud processing engineer or driller, or even decision errors by the driller or toolpusher which could lead to a delay in activating last-ditch prevention measures such as shear rams. Should the kick lead to a blowout, the analysis could continue to consider how quickly the entire platform complement would be likely to evacuate, as a function of the layout of the platform escape routes, but also considering potential decision delays (errors) and errors in launching liferafts and lifeboats, etc..

Four specific techniques related to human error analysis are discussed below. The first two are analytical aimed at identifying errors that will lead to increased system risk. The second two are aimed more at occupational injury type incidents, although barrier analysis can also sometimes identify potentially catastrophic errors or barrier violations which should feature in any system risk analysis.

(i) Human Error Analysis (HEA) & Human Error HAZOP

Two methods are available, HEA and Human Error HAZOP (Hazard and Operability study - see Whalley, 1988). HEA is similar to Failure Modes and Effects Analysis (FMEA), and follows a HTA and/or a TTA. The HEA is tabular in approach, and for each task step considers what errors could occur (e.g. error of omission or commission), and what recovery potentials there are. Error reduction is also usually identified in terms of potential procedures, training and design recommendations. HEA is carried out by a single assessor. Human Error HAZOP uses a HAZOP group and format, but oriented towards addressing human error potential. It usually requires some form of HTA or OSDs as a starting point. Keywords are then used to identify potential errors, via a group of experts considering the task sequence.

Human Error HAZOP is very similar to HAZOP, except that the guidewords are slightly altered to be more focused on human activities, and instead of Piping and Instrument Diagrams (P&IDs), other task analysis representations and/or the procedures themselves may be 'operated upon' by the Human HAZOP (e.g. HTA, OSDs; TTAs, etc.). As with HAZOP, the usefulness is critically dependent on the constituent group members and the team leader. There are keywords specific to Human Error HAZOP, as follows:

Human Error HAZOP guidewords related to traditional HAZOP guidewords (Whalley, 1988)

HAZOP GUIDEWORD	***HE HAZOP G'WORD***	***HAZOP GUIDEWORD***	***HE HAZOP G'WORD***
No	Not done	-	Repeated
Less	Less than	-	Sooner than
More	More than	Reverse	Later than
As well as	As well as	-	Mis-oriented
Other than	Other than	Part of	Part of

Human Error Analysis is more similar to Failure Modes and Effects Analysis, and as with Human Error-HAZOP (HE-HAZOP) uses keywords to help identify failure modes, as follows:

- *Action omitted*
- *Action too early/late*
- *Action too little/much*
- *Action too short/long*
- *Action in wrong direction*
- *Right action on wrong object*
- *Wrong action on right object*
- *Wrong action on wrong object*
- *Check omitted/on wrong object/wrong check/check mistimed*
- *Communication error*

The above keywords would be applied by the analyst to a HTA and resultant errors, consequences, and recovery opportunities identified in a tabular format. The most well-known variant of this approach is the SHERPA system (Systematic Human Error Reduction and Prediction Approach; Embrey, 1986).

The HEA and HE-HAZOP approaches also consider the major factors that could lead to the error, such factors being know as Performance Shaping Factors (PSF). The major ones are as follows:

- *Quality of interface (including workplace layout)*
- *Quality of training*
- *Quality of Procedures/Instructions*
- *Time pressure (or lack of it)*
- *Staffing and Organisation (shiftwork; workload and fatigue; motivation; teamwork)*
- *Task difficulty or complexity (need for diagnosis; number of operations; etc.)*

Both approaches are resource-intensive, but represent powerful and detailed methods for identifying errors and inadequacies in system designs, and as such can feed into operability analyses or safety analyses, whether the latter are qualitative or quantitative. The principal difference between the two techniques is that HEA is a single analyst technique, whereas HE-HAZOP is a group technique. If a conventional HAZOP is already being used on a system which has high human error potential, then Human Error HAZOP might be incorporated into the HAZOP schedule. Human Error HAZOP does require at least one person in the team to have Human Factors or Human Reliability Analysis expertise. With respect to HEA, it is also preferable to have the HEA checked by another analyst, for Quality Assurance (QA) purposes, since variance between assessors using HEA (or HAZOP) is not insignificant in practice. However, these two techniques have shown their worth in a number of assessments across a number of industries, for the human-critical equipment or operations, including the offshore sector (see e.g. Kirwan, 1994). Human Error HAZOP in particular is useful in the early stages of design, whereas HEA can only usually only be applied during or after the detailed design stage. An example of a HEA tabular output is shown in Table 6.

Table 6: Human Error Analysis Table extract example for lifeboat evacuation (Basra and Kirwan, 1996)

Task step and equipment	Error	Consequences	Recovery	Error reduction measures
4.1 Check wind speed, direction and sea state	Information unobtained	If conditions underestimated, will put lifeboat and personnel in danger. Wind conditions may not be used to their full advantage. Boat may collide with platform		At least two personnel should assess the conditions to decide if it is safe to launch at all or from that side of the platform, and the heading to take upon landing on the water
4.2 Check compass heading on davits	Wrong information obtained	Coxswain steers boat into platform	None if smoke or fire on the water	Improve location of compass - difficult to read at present.
	Information not obtained	Coxswain steers boat into platform	None if smoke or fire on the water	At least two personnel should check the compass, and agree the course.

(ii) Barrier Analysis (BA)

This technique aims to identify hazards that could lead to accidents involving injury or fatality, or to determine whether protective barriers could fail due to human error or violation. BA is a tabular approach, in which all physical and administrative barriers are represented. Potential human errors are then identified which could lead to barrier failure.

Barrier analysis defines all the barriers that keep harmful energy sources away from personnel, whether these barrier types are *physical, temporal, spatial*, or *administrative* in nature. Once this has been done, the analyst can consider ways in which the barriers could fail or be breached by the personnel. The approach also has a number of generic barrier types that can be considered to improve the defences against local hazards, and typical reasons that barriers may fail or may be missing. Barrier analysis has been developed in the field of accident analysis, but can be used productively or prospectively to evaluate barrier systems *before* they fail. The basic approach is as follows:

- Define the energy sources present (electrical; chemical; kinetic; thermal; biological; environmental; radiological)
- Define all the barriers that should be present
- Consider barrier failure mechanisms
  - *Necessity of barrier not realised*
  - *Barrier not possible*
  - *Barrier too expensive*
  - *Physical barrier failure (hardware, software, or environmental failure)*
  - *Operator error/violation*

It offers a very practical viewpoint when assessing the safety of work systems, and is particularly useful for identifying administrative barriers, and highlighting reliance on them (compliance with administrative barriers is often over-estimated). However, in complex and well-defended systems, barrier analysis may be inappropriate, and other risk analysis techniques (HAZOP, Fault/Event Tree Analysis; etc..) may be more usefully employed. Nevertheless, Barrier Analysis would be appropriate to a large number of offshore and onshore operations (e.g. crane operations; simultaneous drilling and production; maintenance involving Hot-Work-Permits; etc.). The main barrier solutions to identified problems are shown below.

Major barrier types

Use an alternative energy source
Reduce amount of energy & prevent build-up
Prevent sudden release
Modify rate of release
Separate targets (personnel or structures etc.) from energy in time or space
Use barriers between energy source and target
Use energy attenuation devices
Strengthen target
Damage limitation measures

(iii) Work Safety Analysis

Work Safety Analysis (WSA) focuses on occupational injury risk during man-machine interactions, typically involving moving machinery. Once a task sequence has been determined (e.g. via HTA or simple observation and/or interviews), then potential hazards and their causative factors are considered by considering the following questions:

- *If the equipment can be used improperly at some time it probably will be: what hazards will this cause?*
- *What short-cuts can be taken to overcome awkward procedures ?*
- *If maintenance is difficult, it will suffer from errors/omissions. What hazards will this cause ?*

Hazards thus identified by this approach are then classified according to their likelihood and their potential consequences, according to a rough classification system as follows (see Kirwan and Ainsworth, 1992):

Likelihood	Consequences
0 - Hazard eliminated	
1 - Very improbable (e.g. less than once in ten years)	1- Insignificant (only first aid required)
2 - Improbable (once in ten years)	2 - Little (1-2 days off required)
3 - Slightly probable (several times in ten years)	3 - Considerable (3-21 days off)
4 - Rather probable (once a year)	4 - Serious (22-300 days off)
5 - Very probable (more than once a year)	5 - Very serious (over 300 days off)

The above are multiplied for each hazard to give a quantitative **relative risk** categorisation (note that if the likelihood is classified as '0', then the risk categorisation will be '0' and the hazard will not be considered further). Corrective measures are usually determined when carrying out the hazard identification stage, and their importance will then be determined by the relative risk categorisation for the identified hazard (see example below).

WSA is aimed at immediate hazards in the workplace (e.g. working with moving equipment, such as on the drillfloor), and is primarily concerned with the safety of the operator at the workplace. It is not so effective for looking at more subtle impacts of the operator's actions or errors on the system, and HE-HAZOP and HEA should be used for this latter purpose. WSA, however, is a very practical approach and can be used to identify and eliminate many of the injurious hazards that will otherwise lead to lost-time accidents.

If these various Human Error Analyses are taken to their logical conclusions, their qualitative estimates of potential errors would be quantified in terms of how likely the errors (and recovery actions) were, and this information could be incorporated into a quantified risk assessment. This quantification of identified human errors is called ***Human Reliability Assessment*** (HRA). Such analysis is common in other industrial sectors, such as nuclear power, and occurs to a certain extent in the offshore/petrochemical and chemical processing sectors. The extent to which HRA occurs within QRA depends on the perceived risk associated with the system operations under consideration, and the importance of the human role in contributing to, or preventing, onshore and offshore accidents. Blowout risk, for example, would often include the quantification of certain identified human errors, using the approach of Human Reliability Assessment, which involves the quantification of assessed human errors and their recovery potential.

3.4 Human Reliability Assessment

Human Reliability Assessment entails the quantification of Human Error Probabilities (HEPs), according to the following simple formula:

$$\textbf{HEP} = \frac{\textbf{Number of errors occurred}}{\textbf{Number of opportunities for error to occur}}$$

Thus, for example, if during normal operations a certain push-button must be pushed 300 times per year, and 3 times the wrong button is pushed, then the HEP is 3/300, or 0.01. Typically HEPs are in the range from 1.0 (i.e. failure every time) for very complex tasks under severe and stressful conditions and time pressure, to 0.0001 for a well-trained crew with excellent interface, training and procedure, etc.

Two techniques, Absolute Probability Judgement (APJ: Seaver and Stillwell, 1983) and the Success Likelihood Index Method (SLIM: Embrey et al, 1984), use task domain experts to estimate HEPs. "expert' here refers to someone who has done the job for at least ten years, or longer, and may also include trainers. The basic assumption, which should be considered on a case-by-case basis, is that these experts will have an experienced-based 'feel' for how often the errors are likely to occur. APJ is a group approach which is fairly unstructured, and usually the experts discuss each error in turn and then either agree on an estimate, or else make their own estimates which are then mathematically aggregated. SLIM asks the experts to identify the significant PSF for the scenarios under investigation and the influence of each PSF on success likelihood is estimated. These estimates are then calibrated using two or more real human error data points (from the limited human error database that exists) to derive new HEPs for the errors being considered. Both techniques therefore use experts but APJ may be considered more direct, but less structured, than the other (SLIM). Both methods are resource-intensive, but are particularly useful for 'non-standard' error types, e.g. APJ for rule violations, and SLIM for cognitive errors (misdiagnosis).

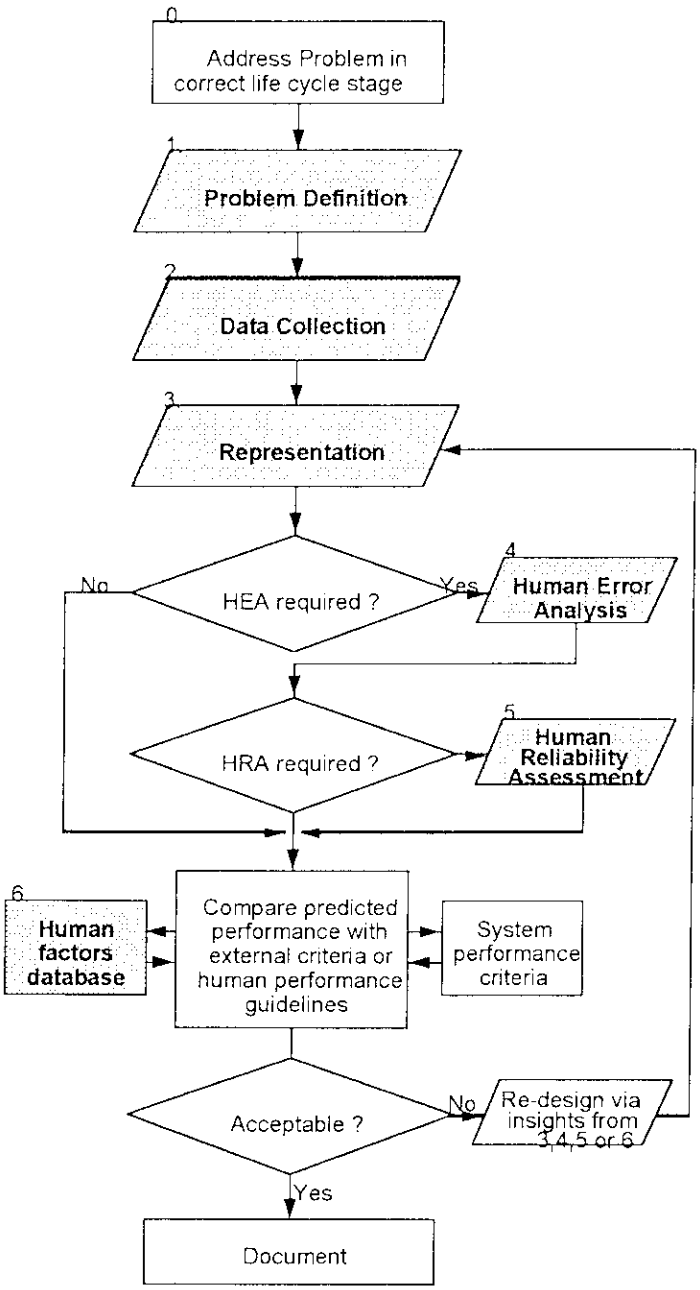
The Human Error Assessment and Reduction Technique (HEART: Williams, 1986; 1992) has a limited database of 'generic' HEPs, which can then be modified by PSF considerations (each of which has its defined own maximum effect on the HEP - equivalent to the weighting used in SLIM), to generate HEPs. The Technique for Human Error Rate Prediction (THERP: Swain and Guttmann, 1983) is probably the most well-known HRA technique, and in practice makes less use of PSF, but has a far more extensive database. THERP's database was developed based on Nuclear Power Plant operators, who are given far more training, procedural, and interface support than is found in most offshore situations. Hence THERP's applicability to the offshore situation is most often justified by using the higher (more pessimistic) values for individual HEPs in the THERP database when being used in offshore/petrochemical assessments. HEART and THERP generally require less resources than SLIM and

APJ, and so are used more routinely in assessments. In the UK HEART is soon to undergo development for application in the offshore industry4. This will entail incorporating human error data into the HEART database. Table 7 summarises some of the key attributes of these HRA techniques, and Figure 8 shows the overall HRA process with a simplified example.

Table 7 Attributes of key HRA tools (see also Kirwan 1994, 1996)

Technique	Types of Error	Accuracy	Usefulness in identifying error reduction measures	Potential drawbacks
APJ	All types	High if good expertise available	Moderate if this is a specific goal of the group approach used in APJ	Garbage in, garbage out; requires expert group and group facilitator
HEART	Not rule violations	Moderate	Moderate, but should be predicated also on task analysis.	Consistency of technique still an issue; dependent on analyst
SLIM	All types	Moderate	High	Resource intensive; requires expert group, facilitator and calibration data.
THERP	Not rule violations or diagnosis	Moderate to high	Low	Not originally designed for offshore application.

4 Ned Hickling, Electrowatt UK, Human Factors Group, personal communication, 1996.



EXAMPLE :

Platform in preliminary/detailed engineering phase

Will all personnel be able to evacuate within 30 minutes ?

Interviews; observation of drills on similar platform; critical incident technique; talk-through of decision-making sequence and command chain

Timeline analysis; operational sequence; diagrams; evacuation in 15 minutes

Error analysis of decision errors: e.g. poor choice of evacuation route by personnel leads to extra 10 minutes

SLIM and APJ

Comparison with system criteria: 0.01 probability of complete evacuation failure, 0.3 probability of major failure of 30% personnel failing get off platform

Insight from '3' and '4' suggests too many personnel in the decision chain, and lack of guidance over identifying safe / unsafe escape routes. Re-design these elements. Iterate analysis from '3'

Figure 8 : The HRA Process

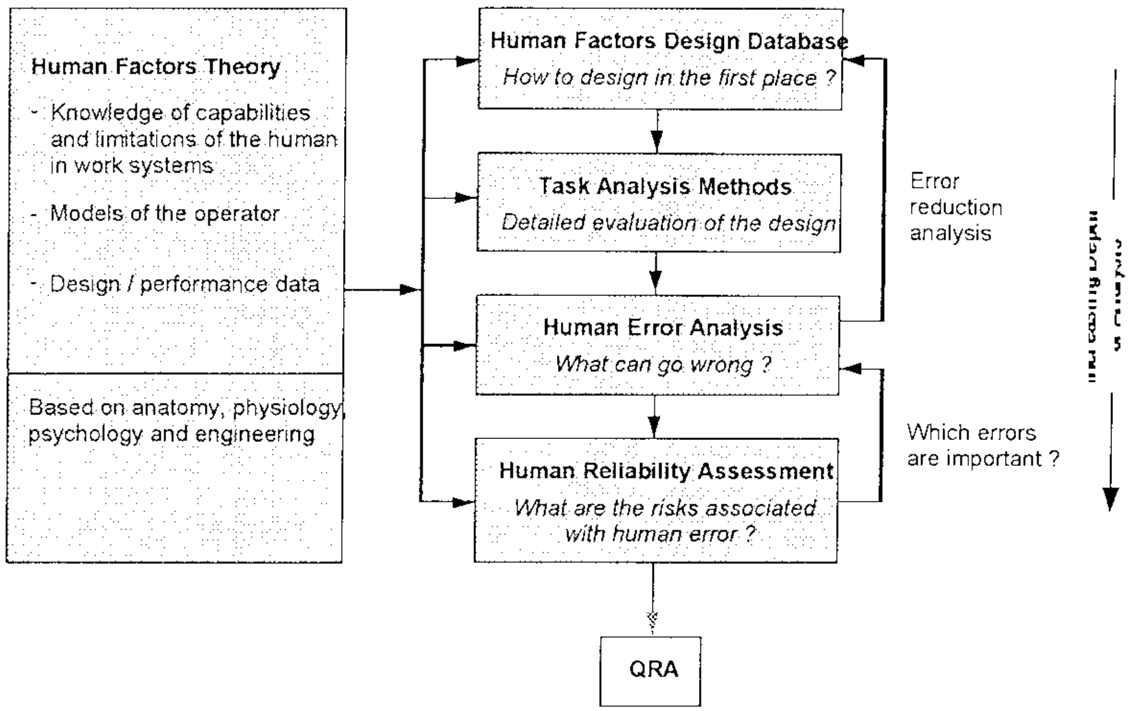


Figure 9 : Relationship between the four Human Factors Analysis approaches

Figure 9 shows the four parts of Human Factors discussed in section 3, namely data and principles, task analysis tools, human error analysis tools, and HRA tools. The figure shows that human factors theory feeds into all four areas, and that there is a logical progression from data through to HRA in terms of becoming more quantitatively-oriented, and at the same time moving from reliance on application of hard data to more analytical approaches. In this sense, Human Factors can be seen to be partly science and partly a practitioner's art. Table 8 also summarises the four components according to their forms, functional outputs, and main general uses.

HFA Approach	Basis of Approach	Form of Approach	Major Functional Outputs	When utilise ?
Human Factors Database	- Knowledge of human capabilities and limitations in work systems - Human performance data	- Design Principles - Design Database - Checklist & Survey Methods - Models of the Operator	- Guidance on design of the system - Evaluation criteria	When designing a human work system
Task Analysis Techniques	- Tools for understanding and 'modelling' the demands on the operator and resources available in a work situation	Techniques - Data Collection Techniques - Representation Techniques - Analysis Methods	- Detailed evaluation of the system from the human perspective - Operability information	When designing a novel system when operability is important
Human Error Analysis Techniques	- Tools for identifying potential errors, their consequences, and ways of avoiding them	Techniques - Safety of Operator - Safety of System and Environment	- Safety assessment (qual.) - Operability assessment	When safety is important
Human Reliability Analysis Techniques	- Approaches for integrating the human error analysis into QRA (risk assessment)	Techniques - 'Routine' Errors - 'Non-Routine' Errors	- Quantification of human contribution to risk-input to QRA	When risk analysis of the system is required

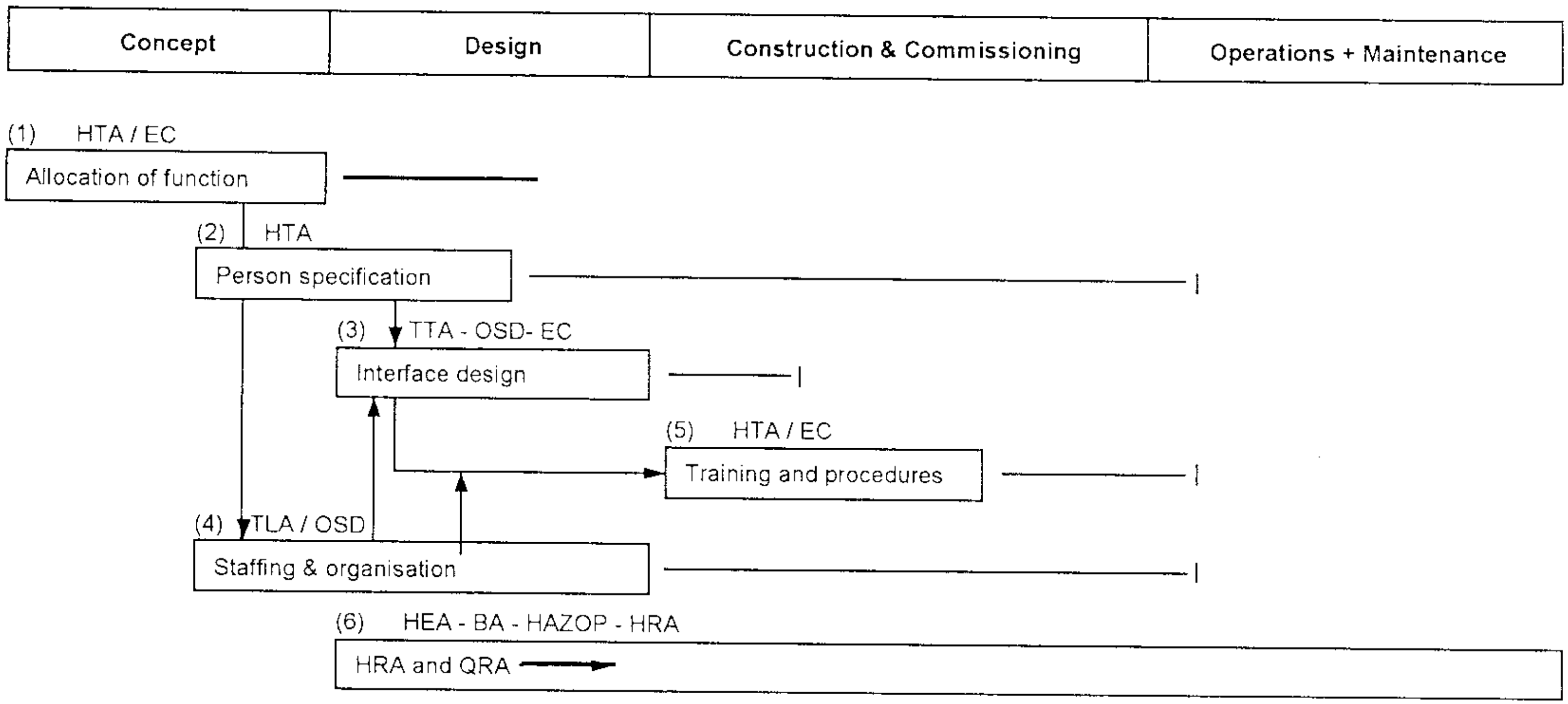
Table 8 : Nature of the four approaches comprising Human Factor Analysis

4. HUMAN FACTORS FRAMEWORKS

4.1 Integrating Human Factors into the System Design Life Cycle

Each application area or Human Factors issue is optimally addressed at a certain stage in the System Life Cycle. Thus, for example, it is not usually cost-effective to address detailed interface issues at the Concept stage of the design of a new system, due to lack of required detail on interface characteristics. Conversely, however, if the interface is not assessed until the commissioning/construction phase, or the operational phase, then identified improvement needs will be very costly to implement. Figure 10 therefore shows the optimal times to address each of the six Human Factors application areas. For existing installations, HFA can still be highly useful, since ultimately human performance is a function of three main factors: the workplace interface; training; and procedures. Thus it is not always necessary to change hardware. Furthermore, even with identified interface inadequacies (e.g. in control rooms), often significant improvements can be made with minimal expense (e.g. via re-labelling, demarcation lines around control and display groupings, etc..). Inevitably, however, the need for hardware alterations will sometimes be identified. It will then be a matter of deciding, often on a risk or economic basis, whether the improvement is beneficial in either improving system performance or avoiding significant losses (financial and/or personnel).

Table 9 shows the ideal application time and applicability of each technique for each of the six Human Factors functions defined earlier in Section 2. This table also highlights which of the six areas are best addressed by each individual technique. Table 10 shows the relationship between techniques, application areas, and system design life cycle stage, this time focusing on the application area. Each of these three illustrations therefore shows when to use what technique and for what application, but each diagram or table is 'driven' by a different aspect: figure 10 is driven by life cycle stage; Table 9 by technique; and table 10 by application area.



Note: '6' can be used to help determine design options optimality for any of 1 - 5, e.g.
HRA can be used to decide between an automated and a manual system
(an allocation of function issue)
HRA also impacts upon interface design, staffing and organisation, and training and procedures

Figure 10 : HFA and the Sytem Life Cycle

Table 9; Task Analysis Tools (upper case in the first column indicates earliest life cycle stage application)

Human Factors Analysis Process Steps

Task Analysis Tool	*Allocation of Function*	*Person Specificat-ion*	*Interface Design*	*Staffing & Organisat-ion*	*Training & Procedures*	*Human Reliability Assessment*
Hierarchical Task Analysis *CONCEPT*	Y	Y	Y	Y	**YY**	(Y)
Tabular Task Analysis *DETAILED*			**YY**		Y	(Y)
Barrier Analysis *PRELIM.*			Y			Y
Work Safety Analysis *OPERAT'N*			Y		Y	Y
Timeline Analysis *DETAILED*	(Y)		Y	**YY**		Y
Link Analysis *PRELIM.*			**YY**	Y		
Human HAZOP *PRELIM*	Y		Y		Y	**YY**
Human Error Analysis *PRELIM*			Y	Y	Y	**YY**
Walk-through *DETAILED*			Y	Y	Y	Y
Ergonomics Checklists *CONCEPT*	YY	Y	**YY**	Y	Y	
HRA Quantitative Techniques *PRELIM.*	Y		Y	Y	Y	**YY**

The Double 'Y's in the above table signify that the technique is especially adapted to that particular function. The bracketed 'Y's indicate that results of the technique can be used indirectly for that particular function, possibly by serving as an input into another technique. The letters in the first left hand box indicate the earliest time the techniques can be realistically applied, according to the following abbreviations:

Key

CONCEPT = CONCEPT PHASE
PRELIM. = PRELIMINARY DESIGN PHASE
DETAILED = DETAILED DESIGN PHASE
COMMISS. = COMMISSIONING (& CONSTRUCTION) PHASE
OPERAT'N = OPERATIONAL PHASE

Table 10: Human Factors Assessment Areas and Techniques

Human Factors and Error Analysis Area	*Task Analysis Techniques*	*Recommended System Life Cycle Stage for beginning analysis*
Allocation of Function	HTA; Ergonomics checklist	CONCEPT
Person Specification	Ergonomics checklists; HTA	PRELIMINARY
Interface Design	HTA; TTA; Link Analysis; Barrier Analysis; WSA; Ergonomics checklists & surveys; Walk-throughs	PRELIM./DETAILED
Staffing & Organisation	HTA; Timeline analysis; OSDs	(PRELIMINARY) DETAILED
Training & Procedures	HTA; WSA; Walk-through; Talk-through	COMMISSIONING
Human error investigation (qualitative)	Human Error HAZOP; Barrier Analysis; Human Error Analysis; WSA	COMMISSIONING / OPERATIONS

<u>Notes on tool inter-dependencies</u>

1. Tabular Task Analysis and Timeline Analysis usually follow a Hierarchical Task Analysis, and in fact a typical sequence is HTA-TTA-TLA.

2. Operational Sequence Diagrams do not require a prior Hierarchical Task Analysis.

3 Link Analysis can occur on its own, or can follow Hierarchical Task Analysis, or Operational Sequence Diagrams, or Tabular Task Analysis.

4. Barrier Analysis, Work Safety Analysis and Human-Error-HAZOP are best following either Operational Sequence Diagrams or Hierarchical Task Analysis.

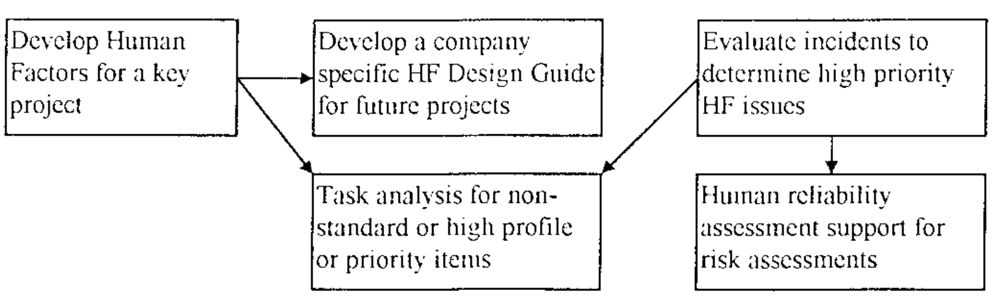
5. Human Error Analysis follows Hierarchical Task Analysis.

6. HRA must follow either HE-HAZOP or Human Error Analysis, or possibly Barrier Analysis or Work Safety Analysis.

7. Ergonomics Checklists/Human Factors Database can be applied at any time.

<u>4.2 Integrating Human Factors into the Project Infrastructure</u>

Ideally an offshore company or project wishing to incorporate human factors should recruit in expertise and integrate such experience into the safety or design team. Such an individual or small team of individuals can then more properly develop human factors support for the company and its projects. Probably the easiest way for a company to start this is to pick a key project where it is known that there will be some significant human factors issues (e.g. novel interfaces; high risk and dependence on human reliability; etc.). It is probably then most useful to develop a company standard on Human Factors design aspects for the company, which will incorporate the human factors data that the company can then use in all future designs. The task analysis and other tools will then only be applied for the more difficult or risky tasks, or tasks where high performance is desirable. Such an individual should also be in a position to review incident experience from within and outside the company, to help prioritise the Human Factors issues, and to feed information into the risk assessment programmes. These ideas are encapsulated schematically in Figure 11.



Progression of activities

PHASE I - INITIAL INTEGRATION

- HF input to a platform design
- Human Reliability Assessment support
- Incident analysis system
- Prioritise HF issues
- Develop HF Guide for future designs
- Task analysis for future designs

PHASE II - PROACTIVE PROBLEM-SOLVING

- Determine key residual vulnerabilities & problem areas
- Determine key improvement potentials
- R&D into new methods/applications
- Implementation of solutions
- Evaluation of solutions

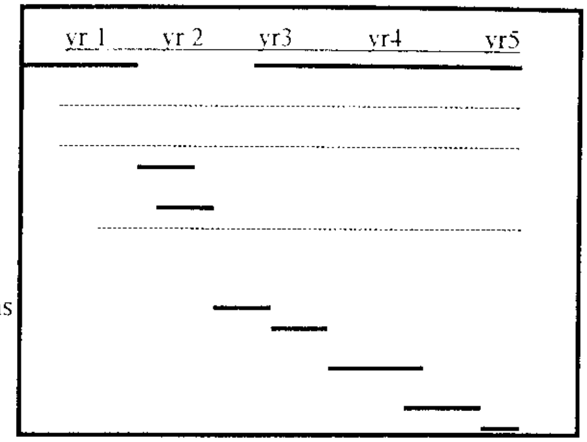


Figure 11: Integrating HF into the Project/Company Infrastructure.

Figure 11 is a very simplified view of some of the activities and timescales involved in evolving HF within a company or project infrastructure. The diagram is a very rough guide, since the success of such integration will depend on a number of key factors, not least of which is support for Human Factors at a high level within the organisation, without which, true integration will simply never occur. The diagram also suggests that the initial phase will be one of dealing with the basic (but not trivial) HF issues. Later on, Human Factors may take a more 'proactive' role, leading to more advanced approaches. These are briefly outlined, conceptually at least, in the next and final section of this paper.

5. ADVANCED HUMAN FACTORS - CAPITALISING ON THE CAPABILITIES OF THE HUMAN OPERATOR IN JOINT SYSTEMS

Automation in most industries is leading to the concept of joint systems, i.e. human and machine. Where such machine systems also have some 'intelligence', these are known as 'joint cognitive systems' (see Hoc et al, 1995). This paper started by considering the Human Factors application area of allocation of function, and it is to this area that the paper now returns. For many years it has been known that humans possess certain unique and powerful attributes - e.g. problem-solving abilities, flexibility and adaptability, pattern recognition, decision-making skills involving judgement, etc. However, automation has not always capitalised on such attributes, and in fact has often designed them out of the equation, resulting in a human role which involves inactive and monotonous supervision of the machine. This means that the system under-performs because inevitably machines do not optimise as the environment changes, whereas humans can. More significantly in terms of risk, if the machine system fails, then the operator, being in a passive role and therefore not effectively 'in the loop', is far less able to detect and successfully rectify failures.

The solution is to design for human-system optimisation from the start, i.e. at the concept stage. This goes beyond simply designing for usability (though that in itself is not simple), since usability implies that the tool or machine and working environment has already been conceptualised. Some general guidelines for more advanced Human Factors design are as follows:

- Design for **error recovery** - *the system should be tolerant of simple errors, and should enable detection of errors and their correction without adverse consequences*
- Design to promote **team-based recovery** - *teams are good at spotting others' errors and their own, but only if trained accordingly (this is a crew-resource-management or CRM issue)*
- Design to support **human situation assessment** - *this is what humans are good at, but so often system designs do not support the tasks of finding and collating the required data to assess the situation. This approach also necessitates a higher degree of consideration of abnormal scenarios during the design process.*

- Design **integrated displays based on user mental models and needs** - *whether these are higher level displays giving overall indications of system safety and integrity, or lower level (i.e. control) displays which are ecologically designed (Vicente and Rasmussen, 1992) or designed to integrate various sensor information,*
- Design to support **predictability** - *use predictor displays, designed around what needs to be predicted and human anticipatory capabilities, and develop anticipatory tasks*
- **Problem and solution driven** rather than technology driven - *design generic displays and team training to identify and solve problems*
- **Transparent automation** - *so that the user knows what the system is doing, why, and what it will do next, and ensure that the system is trustworthy (it does not make mistakes - once trust is broken, it is very difficult to recover - Lee and Moray, 1992)*
- **Error detection of slips/lapses by automation** - *many input errors can be detected easily by automation and then should be pointed out to the user. It is important, however, that the system does not simply auto-correct the user, since may reduce essential user feedback and therefore affect user performance (Wioland and Amalberti, 1996)*

The above are some generalised principles for more human-centred automation, i.e. for emphasising human strengths in joint human-machine systems. However, these are not well-supported by currently-available design techniques. In particular, therefore, there is currently work progressing in the area of cognitive task analysis tool development, i.e. developing task analysis tools which focus on mental and hence unobservable operations, and operators' mental models and intentions in various situations. Similarly, there is research and development in the areas of ecological interface design, and situation awareness support, and trust in automation. These research initiatives are taking place in a number of industries, most notably nuclear power and aviation (including air traffic control). The question is therefore whether the offshore industry wishes to be proactive in not only adopting human factors, but also developing and evolving it for offshore applications, empowering Human Factors and the human operator role in offshore operations. There would certainly be some areas where such investment would seem to be warranted, and which might guarantee return on investment, or at least justify the expense in terms of loss prevention. Such areas would include, for example, emergency management in rapidly-escalating evacuation scenarios; drilling operations (normal, tripping, and abnormal such as kick detection and control); and fire and gas detection and control. Although the emphasis is on abnormal event handling, it is likely that such advanced human factors would have pay-offs in increased performance in production, via decreased downtime for example due to a reduction in error production, and more proactive handling of system or component failures leading to a reduction in downtime/enhanced availability.

These advanced Human Factors approaches would lead to truly human-centred automation and design, empowering the human operator within the system, capitalising on human strengths, albeit whilst still guarding against human failings and limitations. Such empowerment could radically improve offshore system performance.

6. CONCLUSIONS

This paper has attempted to outline practical approaches to incorporating Human Factors into offshore systems. These approaches have ranged from usage of data and principles, to application of task analysis, human error analysis, and human reliability assessment techniques. Some of the more useful of these techniques have been outlined in this paper, together with some guidance on where and when to apply the different techniques. Issues of integration of Human Factors into the project or company infrastructure have also been raised, together with the possibility of empowering the human role within the system via advanced Human Factors design and research.

The management of the human role in offshore systems and operations is a challenging task. Human Factors has data and tools to help design, manage, and optimise this key role. It remains to be seen whether and how the offshore industry responds to this challenge.

Acknowledgements: *The author would like to acknowledge the company Shell (SIPM) for cooperation on a number of projects, one of which was related to this review, and the UK HSE/OSD (via Neville Edmondson) for allowing reporting of ongoing human error data collection work in drilling and permit-to-work systems, being carried out by Gurpreet Basra, Huw Gibson, and the author, at Birmingham University. The author would also like to thank his current employer (National Air Traffic Services) for allowing production/presentation of this paper. The opinions expressed in this paper, however, are those of the author, and do not necessarily reflect those of the above-mentioned organisations.*

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Human Error Reduction through Human and Organizational Factors in Design and Engineering of Offshore Systems

White Paper for the:

1996 International Workshop on
Human Factors in Offshore Operations

December 16-18, 1996
New Orleans, Louisiana

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Human Error Reduction through Human and Organizational Factors in Design and Engineering of Offshore Systems

Abstract

Human error represents a major threat to the safety and affordability of offshore systems. The IMO has reported that up to 80% of accidents at sea are caused by human error. The US Coast Guard, after analyzing 340 marine casualties, also reported that human error contributed to at least 80% of the casualties. The IMO Secretary General concluded that "if we sincerely want to stop accidents from occurring, then I think it is obvious that we should concentrate our efforts on eliminating human error".

A major thrust of the human and organizational factors (HOF) approach to human error is directed at design of human interfaces to reduce the incidence and impact of errors. The lessons learned at Three Mile Island, Piper Alpha and other industrial accident sites is that human errors can result from inadequate equipment design, information handling, emergency procedures, and training, rather than solely from inherent or transitory deficiencies on the part of the operators. The engineering design of a system has a major impact on the incidence of human errors in system operation.

Too often, the response to human error situations in industrial systems is to ignore the design of the human-machine interfaces and place the emphasis on improving training. The implication is that, having failed to consider human operator needs and limitations in the design of system equipment, the system developer integrates the operator into the system strictly by means of training. Basing operator performance on training alone when the design of the human-machine interfaces is often, from an operator point of view, illogical, inconsistent, or complex--especially in times of psychological stress as in an accident situation--is a formula for disaster.

This white paper describes the current state-of-knowledge with respect to the etiology of human error. Design techniques are described for preventing errors, and making systems error-tolerant, such that, if an error does occur, its impact is minimized. Design factors to be addressed include aspects of the system hardware, software, procedures, organizations, facilities, jobs, communications, environments and training which affect human error likelihood.

Human Error Reduction through Human and Organizational Factors in Design and Engineering of Offshore Systems

1. Human and Organizational Factors in Human Error Situations

This paper is concerned with reduction and containment of human errors in offshore systems through design of human and organizational factors (HOF). The International Maritime Organization (IMO) has reported that human error is a causal factor in 80% of marine systems accidents. A problem in identifying the implications of such a statistic is understanding what is meant by human error. Human error refers to any situation in which an operator fails to perceive a stimulus, is incapable of discriminating among several stimuli, misinterprets the meaning of a stimulus, makes an incorrect decision, fails to select the correct response, or performs the response in an incorrect manner.

Human error results from an action or inaction that violates some tolerance limit of a system. Human errors have been classified as: errors of omission (tasks that are skipped); errors of commission (tasks performed incorrectly); sequential errors (tasks performed out of sequence); cognitive errors (incorrect decision, incorrect estimation, memory lapse); and temporal errors (tasks performed too early, too late, or not within the required time).

It is well known that human characteristics can cause or contribute to human errors. These include such factors as fatigue, disorientation, distraction, motivation, forgetting, complacency, confusion, incorrect expectancy or set, 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.

It is also well established that factors associated with the design of systems can influence the potential for human error. Features of system design which influence the incidence of human errors include aspects of the design of hardware, software, procedures, environment and training, as well as task difficulty, time constraints, interfering activities, poor communications, ambiguous lines of authority, information overloads, and excessive workloads. Design features encompass such aspects of the system as: human-machine interface design; information characteristics (availability, access, readability, currency, accuracy and meaningfulness); workspace arrangement; procedures; environments; and training. In a 1980 report to Congress entitled "Effectiveness of US Forces can be increased through improved weapon system design", the GAO reported that poor design of equipment can significantly increase the probability of error- induced failures once a system is deployed. The GAO lists design characteristics which impact error potential to include: indicators and readouts not readily visible, parts not readily accessible, overly complex visual aids, unclear labeling and instructions, and awkward equipment layout and arrangement.

It is therefore clear that when a human error occurs, it is not in all cases the result of a deficiency or lapse on the part of the human operator. That human errors in complex control systems can result from characteristics of the system design is becoming increasingly evident from accident reconstructions. The important implication of this conclusion is that, in seeking to reduce the incidence of human errors in systems, it is not sufficient to focus merely on personnel characteristics; that is to attempt to correct a problem of human error simply by improving personnel selection and training procedures and methods.

To effectively reduce the incidence of human error, it is necessary to consider the extent to which the design of hardware, software, information, environments, organizations, procedures, and training play a role in error causation. Where it can be demonstrated that error situations in existing systems are the result of system design features, such errors can be prevented in emerging systems through application of human and organizational factors. Through effective human engineering design of human-system interfaces, human errors resulting from design factors can be avoided, and the incidence of human errors can be significantly reduced.

It must also be acknowledged that human errors do, at times, result from slips, lapses, and simple mistakes on the part of the human; 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 human and organizational factors for errors due to personnel characteristics is 1) to enhance the likelihood that, having occurred, an error will be detected and corrected in time to avoid serious consequences; and 2) to reduce the impact of an error on system and personnel safety and performance capability by making the system error tolerant. The objective of human and organizational factors with respect to human errors is therefore to prevent error situations by reducing the incidence of errors and to reduce the impact of errors by containing the errors and making the system error-tolerant.

2. A Human Error Case Study - Three Mile Island

One of the clearest examples of an event caused by human errors resulting from poor engineering design was the accident at Three Mile Island (TMI) nuclear power station, unit 2. The accident at TMI was caused by a series of equipment failures and operator errors resulting in the release of radiation of the order of 1200 millirem/hour into the atmosphere and the evacuation of thousands of residents. The accident resulted in no deaths.

The accident began in the early morning hours of 28 March, 1979 when a pilot-operated relief valve (PORV) at the top of the pressurizer vessel failed to close, resulting in the loss of the pressurizer steam bubble and of reactor control system (RCS) pressure and quantity. An indicator on the control panel advised the operators that the open valve was closed. The indicator was not displaying the actual state of the valve but rather the fact that a signal was present commanding the valve to close, causing the operators to believe that the valve was closed. As RCS pressure decreased below the safety injection low level setpoint, safety injection was initiated. In their concern to avoid a solid pressurizer, the operators shut off the safety injection and throttled high pressure injection, resulting in input of only 70 gpm vs. a minimum design injection flow of 250 gpm.

Based on erroneous and contradictory information and recent experience with the secondary system, the operators built up the false expectation that a leak had occurred in one of the steam generators. They then closed two emergency feedwater head isolation valves, which were normally open, causing a steam generator to go dry. It wasn't until 8 minutes into the accident that the operators noticed that the isolation valves were closed, due to the fact that the status lights had been covered with a maintenance tag. At 87 minutes into the accident steam generator B was isolated based on the expectancy that a leak in generator B was causing the high reactor pressure. The operators then confused generator B with A, and began controlling B, allowing A to boil dry. This error was the direct result of panel layout problems. Finally, at 138 minutes into the accident, an operator who had only recently arrived on the scene was able to discern that the PORV was the problem. By the time the valve was isolated, the reactor core was partially uncovered, threatening a meltdown, and radiation had been released into the atmosphere and to the general public.

The errors made by the operators in failing to correctly diagnose the problem, allowing the steam generator to run dry causing the system to go unstable, and failing to restore natural circulation, led many to the conclusion that they were to be blamed for the accident. The Nuclear Regulatory Commission's (NRC) investigation of the human factors aspects of the accident concluded that the human errors which occurred during the incident were not due to operator deficiencies but rather to inadequacies in equipment design, information presentation, emergency procedures, and training. The President's Commission on TMI echoed this conclusion in stating that, while the major factor which turned this incident into a serious accident was inappropriate operator action, such action was caused by training deficiencies, unclear procedures, and deficiencies in the design of the control room.

In attempting to resolve the problem at TMI, Malone (1980) identified the following system deficiencies with which the operators had to contend:

- Over 100 illuminated annunciators indicating a problem and requiring the operator to diagnose from the pattern of alarm activation just what the problem was;
- No annunciator indicating that the reactor had tripped;
- A supposedly direct display of PORV status, which was wrong;
- No training or procedures telling them how to diagnose high PORV exhaust temperatures or how to determine the meaning of the difference in the temperature between the PORV and the code safety valves.
- No training or procedures instructing them what to do in the situation of a high pressurizer level decreasing reactor control system (RCS) temperature.
- No display of emergency feedwater flow, requiring the operator to infer flow by monitoring steam generator levels and RCS temperature.
- No display of flow through the PORV.
- No display that the system has reached saturation.
- A display of RC pump vibration and eccentricity located seven feet above the control room floor.
- No display of coolant at the core, the single most important determiner of plant safety.
- Critical displays on the back control room panels, out of sight of operators at normal operating situations.
- Strip charts of critical parameters, such as pressurizer level, which are almost impossible to read.
- Annunciators (750 total) which are not functionally grouped nor prioritized and which were of no real use to the operator.

- Arrangement of Emergency Safety Features indicators such that only half of the indication could be seen by a 6 foot tall operator.
- Inconsistency between the labeling of controls and displays on the panel, and the designations identified in emergency procedures.
- Emphasis during training on avoiding a solid pressurizer, without regard to the implications on throttling HPI, such as uncovering the core.
- Poorly arranged panels wherein controls and displays are not grouped by function or sequence of operation, are poorly labeled, and are not always consistent in operation.

The NRC's human factors investigation of the incident (Malone et al, 1980) recommended that the NRC establish a clear distinction between human error attributable to operator factors, which is real human error, and error on the part of the human operator which is a direct result of poorly designed control room components and information, inadequate procedures, or ineffective training. A NRC memo stated correctly that if an operator action is incorrect as a result of how information is supplied to him during an emergency, then the operator should not be at fault. To call the incorrect action operator error without determining whether or not the operator was led into the action by poor control room engineering is improper. An operator who is considered poorly trained is not at fault for an action he takes as a result of his training.

The major lesson learned at TMI was that human errors can result from grossly inadequate equipment design, procedures, and training rather than from inherent deficiencies on the part of the operators. It was also apparent that erroneous expectancies played a key role in that the mental models formed by the operators were completely contradictory to what was happening in the plant. These faulty expectations themselves were the result of human-machine interface design problems which denied the operators access to information for diagnosis while at the same time inundating them with irrelevant, confused, and often contradictory information.

The human factors investigation of the accident also revealed that no human factors requirements had been considered in developing the engineering design of the TMI control system. Human-machine interfaces had been designed with no input from human factors standards and human performance data.

3. A Human Error Case Study - Piper Alpha

On July 6, 1988 the offshore platform Piper Alpha was engulfed in a fire that killed 165 persons out of 226 on the platform, and two additional men on a rescue vessel. The accident resulted from a series of human and organizational errors.

As described by Paté-Cornell, (1993) the errors that resulted in the Piper Alpha accident can be attributed to the corporate culture of the British North Sea offshore drilling industry at the time. The pursuit of profit to the detriment of safety led to inadequacies in training (including the advancement of inexperienced personnel); lack of communication among personnel; inadequate or disregarded safety measures (for example, an alarm that repeatedly issued false alerts resulting in real alerts being ignored); platform design (including modifications and additions retrofitted to the platform that compromised safety); platform maintenance; and command and control structure. The decisions that led to and compounded the disaster fall into four categories: design errors, production/expansion errors, personnel management errors, and inspection/maintenance errors.

The safety design of the entire offshore platform system was geared only to the possibility of large-scale accidents caused by "Acts of God" such as large waves. Also, the system was designed for maximum productivity to the detriment of safety. Modules on the platform were not sufficiently isolated to prevent fire spread; the command and control structure was not prepared for the loss of the manager; emergency measures were inadequate due to system placement and lack of redundancy; and retrofitting to the platform in many cases overrode what safety precautions were in place in the original design.

Flaws in personnel management of the platform include the promotion of unqualified or inexperienced individuals to positions of greater responsibility than for which they were prepared. The lack of experienced personnel not only compounded the disaster after the initial explosion, but had prevented the less experienced crew from gaining knowledge and insight they may have gained working with veterans. Also, the corporate culture of Occidental discouraged individuals from reporting small incidents/accidents that may reflect badly. This lack of disclosure led to a system that did not learn from its own mistakes. Shortcuts that increased productivity (but compromised safety) were encouraged.

Another drawback to the corporate culture was the view that maintenance/inspection was often unnecessary and non-productive. In part the government inspectors who were responsible for overseeing safety were responsible since apparently they too felt the pressure to maintain high production levels.

Human errors immediately prior to and during the disaster (in chronological order) included:

- The decision to operate at a higher pressure than normal (650 psi vs. 250) without all personnel being informed (operating at the higher pressure was, however, not extraordinary),
- A pressure safety valve removed from a pump for repair prior to a shift change and the next shift not being informed and operated the pump,
- A blind fitting that had been installed in place of the safety valve which was undergoing maintenance was only "finger-tight" which allowed leakage when the pump was turned on (it is unclear whether "finger-tight" was considered sufficient for this type of fitting if the pump is not operational),
- A warning system alerting personnel of a gas leak from the blind fitting was ignored since it had issued numerous false alarms in the past (the detection of the leak was also displayed in the control room but was also ignored either due to the design of displays or the operator's actions,
- Ignition of the gas by an unknown source that possibly could have been detected prior to the accident,
- Inadequacies in the design of the platform resulted in the failure of electrical power which resulted in failure of deluge system and emergency shutdown system,
- Other primary design inadequacies (insufficient blast control panels, nonresistant fire walls, inadequate separation of modules on platform, poor fire insulation, lack of

adequate separation between modules) and retrofitting (storage of fuel above modules, additions made to the outside of the platform that prevented blast panels from absorbing the brunt of explosions) caused explosions to affect large portions of the platform instead of being relatively contained,

- Design of the fire system had fire pumps placed in the module that were especially susceptible to production accidents,
- An automatic deluge system that was turned off to protect divers in the water,
- Communication/radio system was made inoperational since its design made it especially vulnerable to production accidents,
- The Offshore Installation Manager panicked and did not issue evacuation orders (error here includes improper screening and training of this individual); no redundancy plan for the loss of manager was in place,
- Fire and smoke rapidly spread through the platform due to poor layout and insufficient fireproofing,
- Casualties resulting from lack of adequate evacuation training, poor placement and lack of routine inspection of escape rafts, poor placement of exits malfunctioning and absent protection equipment (survival suits, life jackets); individuals who followed standard escape procedures perished,
- Other nearby platforms continue to pump oil and gas to Piper Alpha despite knowing of the fire since they were expected to continue production.

It is clear in the Piper Alpha incident that organizational as well as design factors played a role in the degradation of human performance which contributed to the course of the accident.

4. Role of Engineering Design in Reducing and Containing Human Error

The Prince William Sound Oil Spill Recovery Institute (OSRI) has stated, "One of the most important preventive measures with respect to the accidental releases of oil and other hazardous materials is the reduction in the occurrence of human errors related to the movement of the substance from one point to another". The OSRI Plan goes on to attribute approximately 80% of accidental substance releases to some form of human error. In the words of the OSRI Plan, this points to the importance of the reduction of human errors as potentially the most effective means by which to reduce the risk of spilling oil.

The OSRI research and technology plan cited a number of approaches to reduce human error. These included education, training, public outreach, and communications programs. Recommendations for reducing human error should also address the influence of design on human error probability, including equipment design, software design, job design, environmental design, facility design, procedures design, and training system design. Coast Guard Regulations, for instance in CFR 33, Subchapter O, Part 154 "Oil Pollution Prevention Regulations for Marine Oil Transfer Facilities" and Part 155 "Oil Pollution Prevention Regulations for Vessels" do address the need for procedures, communications, personnel qualifications, lighting and warning placards, but do not discuss the need to ensure that systems are designed according to capabilities and limitations of the human operators.

In addressing human error in offshore systems, the objectives of human and organizational factors (HOF) are to reduce the incidence of human error occurrence, and to enhance the likelihood that, having occurred, the effects of an error will be mitigated. Error mitigation requires that occurrence of the error will be detected in time to be corrected, that recovery procedures can be implemented in time to return the system to normal operation, and/or that the system will be error tolerant, that is, designed to continue safe operation after a human error has occurred and before it can be corrected.

In both of these strategies (error prevention and error mitigation) engineering design plays a pivotal role. HOF error prevention methods include (1) application of HOF standards in MIL-STD 1472 and ASTM 1166 to ensure that human-machine interfaces are designed in terms of the capabilities and limitations of the human; (2) implementation of a standard HOF design process such as that described in MIL-STD 46855 and ASTM 1337; (3) computer-based modeling and simulation to assess human workloads and performance capabilities, and evaluate and optimize human-machine interfaces; (4) operational test and evaluation methods and data; (5) probabilistic risk assessment; (6) human error likelihood analysis, involving the determination of error potential for specific tasks; and (7) critical incident analysis and collection of lessons learned data to understand the etiology of error situations in existing systems, and to apply the lessons to the design of human-machine interfaces of emerging systems.

HOF error mitigation methods include (1) implementation of a standard HOF design process such as that described in MIL-STD 46855 and ASTM 1337; (2) cognitive task analysis to identify potential error situations; (3) human error likelihood analysis, involving the determination of error potential for specific tasks; and (4) critical incident analysis and collection of lessons learned data to understand the etiology of error situations in existing systems, and apply these data to design of emerging systems to enhance error containment and make systems error tolerant.

5. The Human and Organizational Factors Design Process

One of the more important tools for the HOF analyst to prevent error occurrence, and to make systems error-tolerant is a standardized, formalized, comprehensive HOF design process. This process is comprised of the activities to be conducted by HOF specialists in the determination and analysis of requirements and concepts for (a) reducing error potential, workloads and manning levels, and in an offshore system design effort; and (b) making the system more error-tolerant.

The required characteristics of the HOF design process are that it: (a) represents an application of system engineering to the design of human-machine interfaces; (b) describes the HOF activities, products, and events at each phase of the offshore system design process; (c) is integrated with the system design process, and the milestones, events, activities, and products of the system design process; (d) describes HOF activities across all phases of system design and development at several levels of iteration; (e) is presented as an automated graphic representation of the sequence of process steps; (f) includes guidelines and on-line help for performance of specific process steps; and (g) comprises the context for the HOF error reduction and containment methods, tools and data.

The importance of the HOF design process is that it represents a standard approach to HOF design and evaluation, and that it provides the basis for integrating HOF requirements and considerations into the offshore system design process. McCafferty (1995) described the interactive relationships between the independent processes for implementing human factors and engineering design. In this paper, Ms. McCafferty presents the engineering and human factors processes as spanning four distinct phases: conceptual design; preliminary design; detailed design; and validation/verification. These phases correlate with the phases of ship design described in Malone and Baker (1996) for Sealift ship design. The relationships among these phases are illustrated in Figure 1.

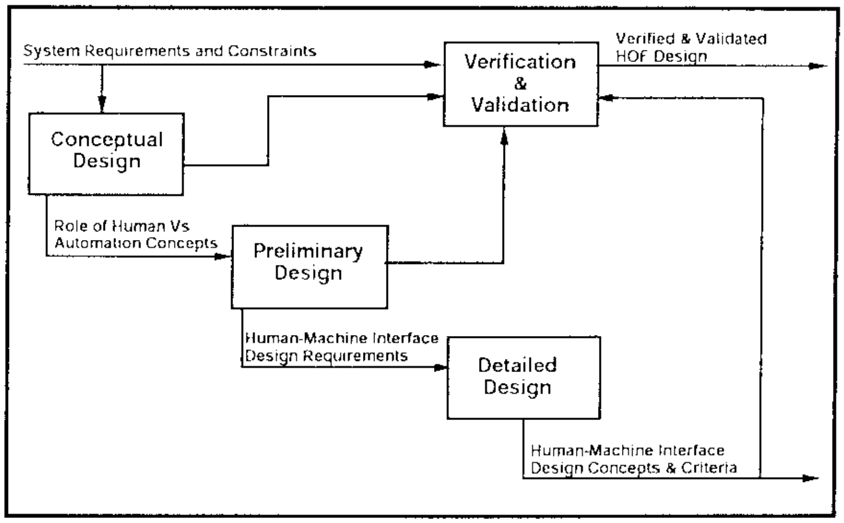

Figure 1. Phases of an Offshore System HOF Design Process

The process depicted in Figure 1 is focused on specific HOF outputs from each phase of the design process. The Conceptual Design Phase produces concepts for the roles of humans in the conduct of system functions, and requirements attendant to the performance of these roles. The Preliminary Design Phase produces a description of human-machine interfaces required to enable completion of assigned human roles, as well as requirements associated with individual human-machine interfaces. The Detailed Design Phase is concerned with the actual design of human-machine interfaces specified in the previous phase, and outputs design concepts and criteria for human-machine interfaces. The Validation and Verification Phase is concerned with evaluating the acceptability, suitability, and effectiveness of human roles, human-machine interface requirements, and human-machine interface design concepts and criteria.

The following sections describe the requirements for HOF application in each of these phases as it contributes to the prevention of human error and to designing the system to be more error-tolerant.

6. Human/Organizational Factors in Conceptual Design

The HOF objectives in the conceptual design phase are to develop alternate concepts for the roles of humans vs. automation in conducting system functions, and to assess these concepts and HOF aspects of system-level concepts.

Based on HOF design activities in this phase, the HOF program will provide specific inputs to the offshore system engineering and design effort. The major HOF inputs to system design in the Conceptual Design Phase include the following:

- definition of the automation level, and the roles of humans vs. automation;
- definition of the manning concept;
- definition of technology development requirements;
- definition of the impact of environmental factors;
- description of the HOF design process tailored for the effort with steps to ensure management buy-in;
- HOF standards;
- HOF lessons learned from existing systems and structures;
- Description of requirements for design team selection and training;
- HOF inputs to the firefighting scheme;
- results of risk analysis studies with emphasis on human error and safety;
- HOF design review strategy (3D models, mockups);
- HOF inputs to procurement and contract documents.

In the conceptual design phase of offshore system design, as described by Bost et al, (1996), the major human and organizational factors activities include (a) the analysis of requirements for missions and system functions; (b) the determination of the roles of humans vs. automation; (c) definition of HOF design concepts identifying manpower requirements and technology developments; (d) conduct of modeling and simulation exercises to acquire human performance, workload, and safety data associated with HOF design concepts; and (e) assessment of alternate system design concepts in terms of HOF considerations. The relationships among these activities is depicted in Figure 2.

The activities shown in Figure 2 are described following the figure.

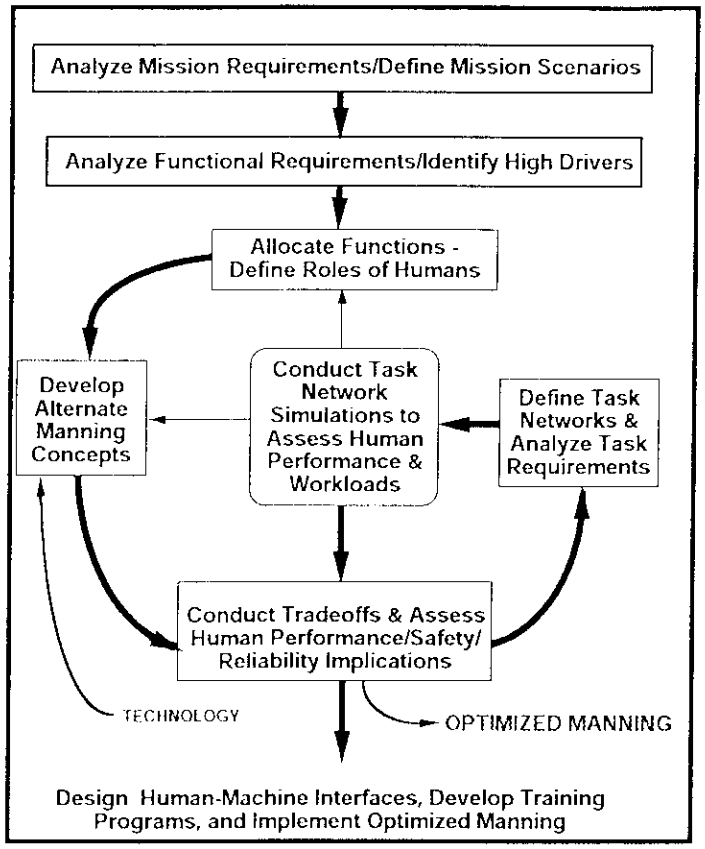

Figure 2. Conceptual Design Phase Activities

Identify and Analyze Missions and Functions The initial step is to identify missions, mission requirements, and mission scenarios. Scenarios will include the offshore system requirements, system top level functions by mission, and conditions under which functions will be performed. Projected conditions under which functions are to be performed include logistics conditions, conditions of readiness (systems not operational, extent of damage, etc.), environmental conditions (lighting and visibility, weather, temperature, sea state, etc.), and operational conditions (sustained operations, tempo of operations, etc.).

System functions constitute the major activities to be performed by the system. This takes place at several layers of iteration, short of the level of specificity which requires designation of the means of accomplishing the function. The offshore system function analysis should, for each system and scenario, identify functions to be performed and provide a functional flow block diagram depicting the sequence of functions for the system completing a mission scenario. The functions will be decomposed to successively greater levels of detail in an iterative manner based on requirements associated with each function.

Conduct Function Allocations and Identify Roles of Humans .

Through a reverse engineering process, functions and tasks in existing systems which impose heavy workloads on humans or which have performance problems associated with them can be identified, and requirements for alternative allocations to humans or automation can be specified. The rationale for allocation decisions in the existing offshore systems can be made explicit and opportunities for alternate allocations can be explored.

Alternative role of the human concepts involve alternate approaches to automation, providing decision aiding to reduce human workload, and improved design of human-machine interfaces to simplify tasks and reduce workloads.

The determination of the required roles of humans begins with an identification of allocation parameters (i.e. should the function/subfunction be automated, performed by humans, shared between human and machines), automated decision making/support requirements, and modes of functional performance (human-machine allocation considerations). An identification will be made as to where the human/machine allocation is apparent. In the conduct of function allocations an identification will be made of preliminary allocations based on allocation parameters.

Identify Manpower Concepts and Technologies.

The HOF approach to offshore system design is focused on
design requirements associated with automation of system functions, consolidation of system functions and workstations, simplification of function and task performance, and elimination of functions.

Function Automation addresses the automation of functions previously performed manually, and
the determination of the roles of the human in automated or semi-automated functions.

Function Consolidation requires a reassignment of functions among available operators to more evenly redistribute required workload.

Function simplification, as described by Anderson et al (1996) requires that, for high driver tasks assigned to a specific operator or maintainer, the demands that these tasks make must be reduced to the greatest extent possible. Task demands include physical, cognitive, and perceptual-motor demands. Specific demands include: a) amount of information to be processed, b) complexity of the information processing, c) number of decisions and options to be handled, d) complexity of actions, e) needs for interactions with other operators, f) extent and complexity of communications, g) task performance accuracies required, h) special skills and knowledge required, i) levels of skills such as reading comprehension, j) level of stress associated with the performance of tasks under representative mission conditions, and k) time constraints. Requirements for task simplification in an HOF analysis must be developed which will determine the potential for simplification of each high driver task and will assist in the identification of alternate approaches to task simplification.

Function Elimination involves: removing a function from the system through tele-operations or tele-maintenance, and reliance on collaboration tools to support dispersed team problem solving, or elimination of a function altogether.

Technology concepts for enabling the HOF design approach will be developed. Technologies will also be applied to result in enhanced human performance capability, human productivity, and human safety in a reduced manning environment.

The attention to technology in the HOF process is to identify feasible potential design approaches to enable the selected roles of the human. In identifying technology approaches to satisfying role of the human requirements, the HOF process specifically addresses technology to support (a) automation of system functions (mainly through software technologies, automated troubleshooting, and robotics); (b) simplification of system functions (through decision aiding, advanced workstation concepts, intelligent tutoring, on-line help, and operator's associate); (c) consolidation of system functions (by use of cross training, data fusion, and Intelligent Associate/expert system for decision aiding and procedural cueing); and (d) function elimination (through tele-maintenance, tele-operations, and collaboration tools to support dispersed team problem solving).

Feasible concepts will be selected based on the results of simulation exercises assessing the workloads and performance problems associated with alternate HOF conceptual strategies. For these concepts, assessments will be made of how to reduce the manning required at functional duty stations, and the impact of manning reductions on readiness, performance effectiveness, and safety.

Simulate to Assess Workload and Human Performance.

The next step is to identify workloads and manning requirements associated with alternate function allocation schemes. The assigned roles of human vs. machine for each function and task will be assessed in terms of impact on workloads through use of the task network simulation. The simulation identifies potential performance problems and quantifies the workload of operators for a simulated mission under the candidate function allocation strategies.

The net result of the application of the simulation is a first approximation of which roles of the human are feasible, what workloads are associated with these roles, what problems are to be expected in specific role of human models, and what human performance characteristics should be further investigated.

Assess Design and Readiness Requirements

Feasible manning reduction concepts will be selected based on the results of simulation exercises assessing the workloads and performance problems associated with alternate manning strategies. For these concepts, assessments will be made of how to reduce the manning required at functional duty stations.

7. Human/Organizational Factors in Offshore System Preliminary Design

As described by McCafferty (1995), in the Preliminary Design Phase the details are defined for individual systems and subsystems necessary to meet system functions identified in the conceptual design phase.

The HOF inputs to Preliminary Design include:

- design team selection and training;
- results of task analyses for operations and maintenance;
- inputs to the escape, evacuation and rescue strategy;
- results of value engineering and life cycle studies;
- results of preliminary risk analysis;
- results of reliability and maintainability analyses;
- HOF inputs to specification development, specifically for long lead items;
- inputs to logistics support requirements;
- human-computer interface (HCI) concepts;
- HOF interface with vendors;
- HOF inputs to management of change;
- HOF inputs to facility design;
- HOF inputs to communications systems;
- HOF inputs to procurement and contract documentation.

The major HOF activities in the Preliminary Design Phase, depicted in Figure 3, include: (a) task analysis; (b) conduct of HOF studies; (c) identification of human-machine interfaces and associated requirements; and (d) integration of requirements associated with human-machine interfaces.

The activities depicted in Figure 3 are described below.

Task Analysis

A task analysis represents a model of human task sequences in the conduct of a series of functions, and identifies requirements associated with performance of each task. The military standard MIL-H-46855B identifies the requirements for task analysis as one of the bases for making design decisions; e.g., determining, to the extent practicable and before hardware fabrication, whether system performance requirements can be met by combinations of anticipated equipment, software, and personnel, and assuring that human performance requirements do not exceed human capabilities. This analysis shall also be used as basic information for developing preliminary manning levels, equipment procedures, skill, training and communication requirements, and as logistic support analysis inputs, as applicable. Those tasks identified during HOF analysis which are related to end items of equipment to be operated or maintained by personnel and which require critical human performance, reflect possible unsafe practices or are subject to compromising improvements in operating efficiency, shall be further analyzed.

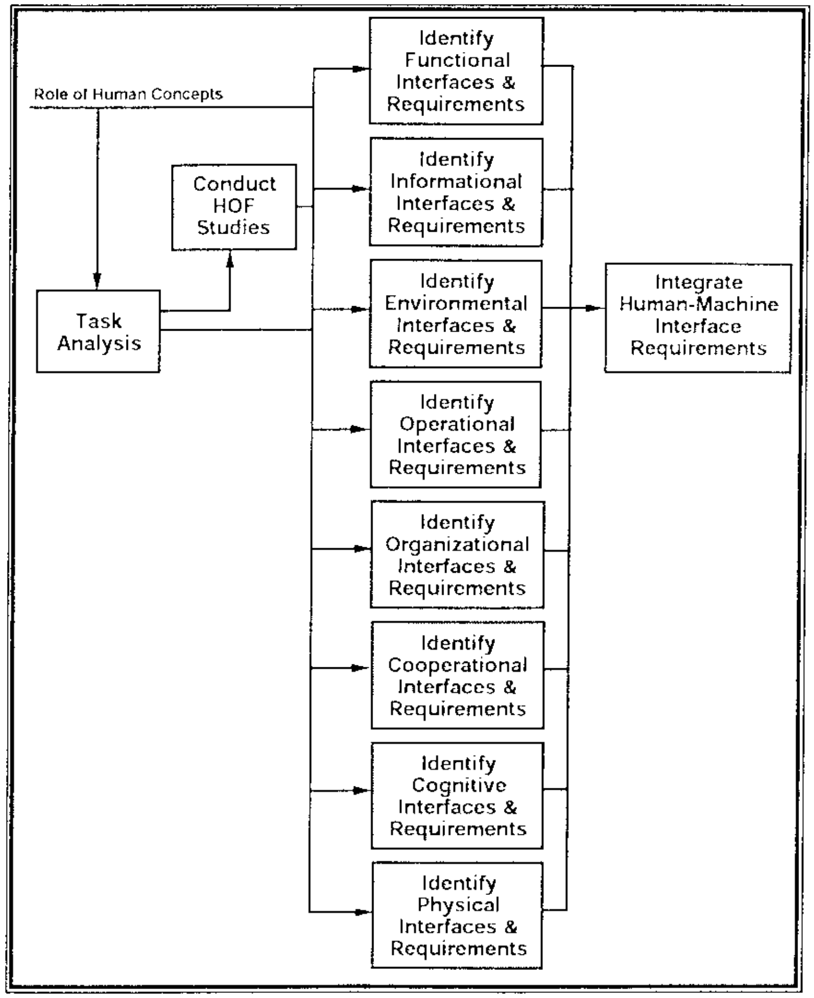

Figure 3. Preliminary Design Phase Activities

Conduct of HOF Studies

HOF studies are conducted in support of the identification of human-machine interfaces and requirements. Studies include additional analyses, (such as cognitive analysis, information handling analysis, timeline analysis, and workload analysis) and empirical (laboratory or simulation) investigations of human performance capabilities and limitations for specific interfaces. In the conduct of HOF studies, consideration is also given to requirements and design concepts for human-machine interfaces in existing systems.

The studies support the definition of interfaces and requirements and serve to further refine requirements developed in the task analysis. The identification of interfaces and requirements will proceed from the task analysis and HOF studies as described below.

Identify Human-Machine Interface Requirements

Functional interfaces.

Components The elements of functional interfaces include (a) the roles of humans versus automation in system operation, control, maintenance and management; (b) human functions and tasks; and (c) roles of system personnel in automated processes (e.g., monitoring, management, supervision, intervention, etc.).

Design Requirements The major issue of this analysis is the role of the human vs. automation. In dealing with human-computer systems the issue is not so much defining the allocation of system functions to human or machine performance as it is defining the role of the human in the system. The emphasis on the role of human in the system acknowledges the fact that the human has some role in every system function. In some cases that role may encompass actual performance of the function or task, or it may involve monitoring automated performance.

It is also important to realize that an assigned role for human performance may alter with changes in operational conditions. Thus a task optimally performed by a human under certain conditions of workload, time constraints, or task priority may be more optimally automated under other conditions.

Informational interfaces

Components These interfaces constitute the information needed by a human to complete a function or task, required characteristics of the information (source, accuracy, currency, quantity), and protocols and dialogues for information access, entry, update, verification, dissemination and storage.

Design Requirements Modern maritime systems depend on information. The need is for design concepts, criteria, tools, and data to support the development of systems which manage the flow of information throughout the system, and maximize the accuracy, timeliness, and usability of information. The management of information has become the major issue for system effectiveness, and the major challenge for system technology. The criteria for adequate information interfaces include the availability of information when needed, in a readily readable and understandable format, and presented at the level of specificity needed for operator decision making and action.

Maritime control systems are typically characterized by information overloads and demands for rapid decision making. Such information overloads have resulted from the fact that sensors and sensor products have proliferated with little attention to the impact on human performance.

In modern day maritime system operation the life's blood of the system is information. The HOF challenge is to provide the characteristics of needed information which make it useful and usable by the human. These characteristics include: the flow of information, the completeness, accuracy, timeliness, and usability of information, the availability of information when needed, and the extent to which information from different sources can be integrated into a meaningful representation of what is happening. The management of information has become the major issue for system effectiveness, the major challenge for system technology, and the major concern for HOF in the maritime industry today.

The HOF need is to identify, develop, and integrate information management technologies that will reduce human error and operator cognitive workload while enhancing the decision-making capabilities of offshore systems personnel. The need is to effectively integrate information and provide information products to users so as to minimize reaction time and the probability of human error. A leading cause of human error is unavailability and/or inadequacy of needed information in an environment of information overload.

Environmental interfaces

Components This class of interface is concerned with the system's physical environment (illumination, noise, temperature, vibration, ship motion, weather effects, etc.), workspace arrangement, facility layout and arrangement, and environmental controls.

Design Requirements This class of human interfaces will be optimized by determining requirements for environments which are within performance, comfort and safety limits, designed in terms of task requirements with consideration for long term as well as short term exposures. Criteria also include determinations that facility designs and arrangements are based on what people must do in them; that arrangements reflect traffic patterns and cargo transfer requirements; that environmental limits comply with standards; that provisions for environmental protection have been included in the design; and that biomedical requirements and risk areas have been resolved.

In terms of human error, environmental factors can serve as stressors, subjecting the human to a level of physical or psychological stress that contributes to the incidence of human errors.

Operational interfaces

Components Operational interfaces include operating, maintenance, and emergency procedures; workloads; personnel skill requirements; personnel manning levels; and system response time constraints.

Design Requirements The major impacts of operational interfaces are on human error probability, and safety. Design criteria for procedures address the extent to which required levels of human performance can be assured given time constraints. HFE improves the accessibility, content, and organization of procedures by ensuring that the procedure is complete, correct, clear, concise, current, consistent, and compatible with the reading/language/skill levels of the users.

Criteria for human workloads include concerns for the impact of workload on human error frequency, and on manpower requirements. Methods to reduce workloads and manning include function automation, consolidation, simplification, and elimination.

Requirements for optimizing personnel skill and manning address the ability of humans to effectively and safely perform assigned tasks under constraints of personnel availability and capability. System response time criteria impact human error probability.

Organizational interfaces

Components Organizational interfaces include the factors impacting the organization of system management functions, policies and practices, personnel jobs, and data.

Design Requirements Criteria for optimization of organizational interfaces include determining that position descriptions are based on functions allocated to the position and include duties, jobs, responsibilities, levels of authority, tasks, and decisions appropriate for each position; that assignment of duties and tasks to each position is realistic; that duties and jobs are consistent with those found in existing systems; and that data required to perform functions and tasks are available, current, and identifiable.

Organizational interfaces can influence human error potential through imposition of management policies which are at variance with human performance requirements.

Cooperational interfaces

Components These interfaces are primarily concerned with communication, collaboration, and team performance.

Design Requirements HOF objectives in optimizing communications are directed at improving both the media and the message. Specific requirements for media design include speech intelligibility and communications device operability. HOF concerns for the message include message standardization, use of constrained language, controlled syntax, and restricted vocabulary, methods of coding message priority, and human error potential in message transmission.

Concerns for collaboration and team performance center around the requirements for crew resources management with emphasis on team interaction, leadership/followership, clarity of communications, workload distribution, cooperative problem solving, and tutoring.

Cognitive interfaces.

Components Components of cognitive human interfaces include decision rules, information integration, problem solving, instructional materials and systems, short term memory aids, cognitive maps, and situational awareness.

Design Requirements Design requirements for cognitive interfaces focus on design for usability, and conceptual fidelity. A major cause for human error is the fact that the human is operating on the basis of erroneous cognitive expectancies concerning what the problem is, what the system is doing, and how it will respond. In attempting to diagnose a problem event, an operator relies on expectancies. These expectancies are developed based on information presented to the operator, his procedures and training, his past experience, design conventions, and, when all else fails, his intuition. Expectancies will support the diagnosis when the cognitive model that the operator has of the system is in close agreement with what is actually happening, i.e. has high conceptual fidelity.

Physical interfaces

Components. 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, hand holds, etc.), and maintenance design features.

Design Requirements. The major requirement for the optimization of physical interfaces is the development of design concepts which are: (1) in compliance with HOF design guidelines and standards; and (2) demonstrated to be operable, usable, maintainable, and safe through use of mockups, models, and simulations.

Integration of Human-Machine Interface Requirements

Human-machine interface requirements are integrated through conduct of HOF studies and through requirements assessment. The assessment of interface requirements will focus on the extent to which interfaces will address human error potential of specific functions and tasks, and the extent to which interfaces will support the design of the system to be error-tolerant.

8. Human/Organizational Factors in Offshore System Detailed Design

According to McCafferty (1995), in the Detailed Design Phase of an offshore system design, HOF issues of workspace design, control and display layouts, and environmental factors are addressed. In this phase the actual design features of human-machine interfaces are defined, specified, and developed. The steps to be achieved in this phase are presented in Figure 4.

The HOF inputs to system design and development in the Detailed Design Phase are as follows:

- Assistance to designers in incorporating HOF concepts and criteria into the design;
- Participation in design reviews;
- Interfaces with vendors;
- Inputs to specifications;
- Detailed (final) risk analysis;
- HOF inputs to Management of Change (MOC);
- Design team selection and training;
- HOF inputs to procurement and contract documents.

The activities to be conducted in this phase are described below.

Conduct of HOF Studies

HOF studies are conducted in support of the development of design concepts and criteria. Studies include: Human-Error Likelihood Analysis; Tradeoff Analysis; and Modeling and Simulation.

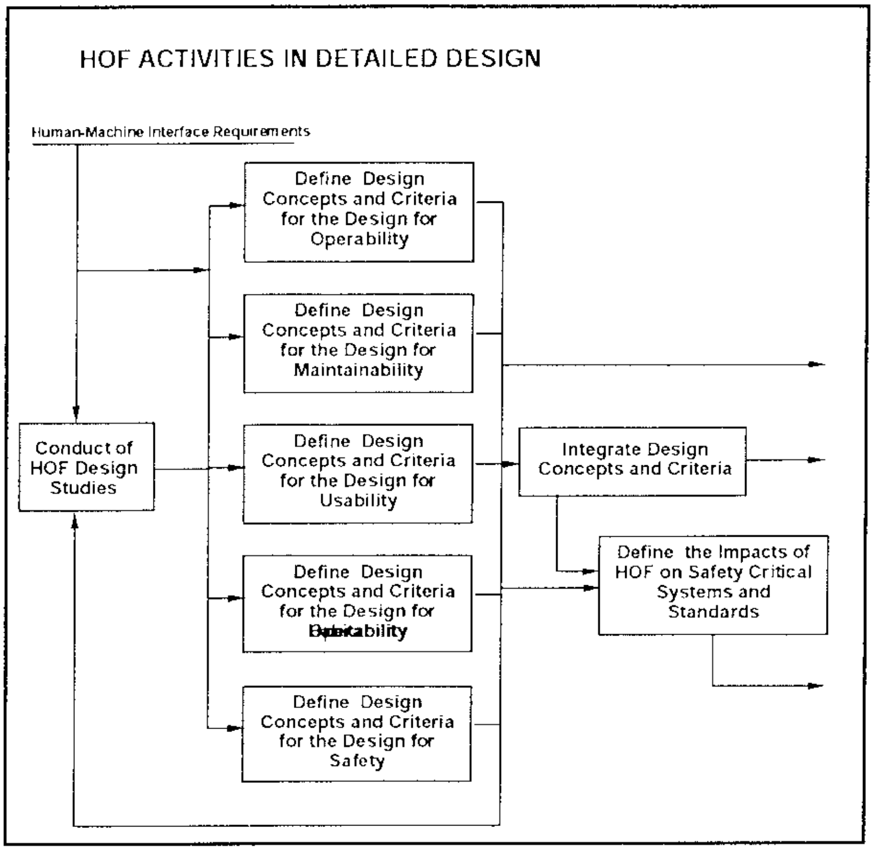

Figure 4. HOF Activities in the Detailed Design Phase

Error Likelihood Analysis The human-error likelihood analysis identifies tasks and task sequences which are critical for a systems effectiveness, pollution prevention, and human and public safety point of view. For each task an identification will be made of the types of errors which have occurred in existing systems, or which could be postulated on the bases of human performance requirements. For each error condition an identification will be made of such factors as: (a) impact of the error on system performance, pollution potential, human performance, and human and public safety; (b) the factors which impact error likelihood; (c) the likelihood that, having occurred, the error can be detected; (d) the likelihood that, having been detected, the error can be corrected; and (e) the design features which will contribute to the system being able to tolerate the error condition.

Tradeoff Analysis Tradeoff studies will address the comparison of alternate design concepts, leading to a selection of an optimal concept.

Modeling and Simulation Modeling and simulation will enable conceptual or actual performance of human operators and maintainers with aspects of alternate design concepts. In this manner, the potential for human error can be assessed through observation of task performance.

Define Design Concepts and Criteria for the Design for Operability

System elements which impact human-machine interface design for operability include workstations, I/O hardware, software, data bases, networks, computation systems, peripheral devices, communications systems, and software engineering environments. Human-machine interfaces include displays, displayed information, display characteristics, display formats, integration of displays, labels, instructions, alarms, symbology and graphics, decision aids, decision support systems, input devices, data designation and manipulation devices, controls and controllers, control systems, control and display arrangements, communications, workspace layout, workspace environment, help features, embedded training, intelligent tutoring systems, and procedures.

A critical need exists for standardization of workstation human-machine interfaces. Before such standardization can occur, workstation human-machine interface (HMI) operability issues must be considered. HMI operability objectives include the following:

- reduce workloads - especially in a system where reduced manning is a system objective.
- reduce training requirements and demands - through task simplification, on-line help/tutorials, and decision aiding.
- reduce operator errors by designing systems to comply with operator capabilities, limitations, expectancies, and requirements, by applying human factors engineering standards such as ASTM F1166-95a.
- reduce impacts of errors and make systems error-tolerant by enhancing the detection that an error has occurred, facilitating the ability to correct the error, and providing design features which enable the system to continue safe operation after error occurrence.
- reduce reaction/response time by reducing cognitive workloads and providing decision support.
- enhance decision accuracy through decision support.
- enhance the understanding of the situation - The importance of situational awareness in offshore operations was cited by Skiver and Flin (1996) who noted that human errors by Offshore Installation Managers in responding to emergencies result more so from faulty situation awareness rather than problems with decision making.
- enhance overall human performance by addressing human roles and requirements early in system development, and designing human-machine interfaces in accordance with ASTM F1166-95a.

Define Design Concepts and Criteria for the Design for Maintainability

Maintainability design requirements include information requirements, design for accessibility, equipment arrangement to facilitate maintenance, procedures, troubleshooting diagnostics and decisions, skill levels and maintenance training, equipment design for maintainability, allocation of maintenance responsibility to man or machine, and requirements for equipment installation, special tools and support equipment, job aids, communications, facility design, and safety design.

The overall goal in applying HOF technology to the design for maintainability is to ensure that maintenance requirements will be effectively and safely met in systems where available manpower has been significantly reduced compared to existing systems. Specific goals of HOF application to design for maintenance include the following:

a) *Reduce the need for maintenance.* The need for maintenance is reduced through employment of high reliability equipment, and attention to human reliability. The GAO has determined that half of the maintenance requirements in military systems result from errors on the part of maintainers and operators. A major goal of HOF is the enhancement of human reliability through reduction of the incidence and impact of human error, and making systems error tolerant.

b) *Reduce the time to repair.* Time to repair, time to reconfigure system components, and time to conduct tests will be reduced through a more usable design, including use of troubleshooting practices which take into account human decision-making capabilities, improved maintenance access, simplified design concepts, improved alarms and annunciators, and improved procedures.

c) *Reduce the incidence and impact of maintainer human error.* As indicated above, human error is the major cause for system failures. HOF methods for reducing human errors include: the imposition of human factors engineering design standards; reliance on test and evaluation procedures, such as interviewing subject matter experts, examination of work samples, observation of task sequences, and use of simulation; and investigation of critical incidents to understand the dynamics and etiology of human error.

d) *Reduce maintainer workload and manning levels required for maintenance* Cognitive workloads are reduced through improved diagnostics, procedures, and decision aids. Maintenance manning requirements are reduced through imposition of human factors engineering design standards, maintenance task simplification, improved design of human-machine interfaces, improved maintenance information handling, improved automated test and diagnosis, and maintenance job design/job aids to reduce the need for multi-person maintenance tasks.

e) *Reduce maintainer skill requirements and training burden* Skill/training reductions result from design simplification, procedures improvement, application of advanced instructional technology, and use of decision aids. Skill requirements will also be reduced by providing maintenance personnel with expert advice and decision aiding to reduce the number and scope of maintenance skills required on board.

f) *Improve the design for maintenance access* Methods for this step include imposition of human factors engineering workspace design standards, and development of models and mockups to assess the accessibility of components and subassemblies for removal/replacement or in-situ maintenance. A major issue in accessibility is the physical anthropometry of the maintenance personnel, which can range from the 5th percentile female to the 95th percentile male.

g) *Improve maintenance procedures* Application of HOF will improve specific features of procedures, including accessibility, content, and organization, by ensuring that the procedure is complete, correct, clear, concise, current, consistent, and compatible with the reading/language/cognitive skill levels of the intended users.

h) *Enhance maintainer safety and health* This can be done through hazard identification, design to eliminate or control safety hazards, and design of jobs to reduce the incidence of health hazards. Since safety is a major concern in achieving a reduced system manning concept, the HOF program will emphasize the techniques for maintaining crew safety throughout all maintenance evolutions.

i) *Increase maintainer productivity* This step can be carried out by ensuring that equipment is usable, that workloads are reasonable, that stress associated with the job is reduced, that the worker is safe, that attention has been focused on the role of personnel versus automation in the conduct of maintenance tasks, and that the design for maintainability will enable workers to work faster with a heightened level of job satisfaction and personnel safety.

j) *Enhance system affordability and reduce life cycle costs* Costs can be reduced by cutting down on costly errors and accidents, reducing system downtime by reducing time to repair, reducing training time through task simplification and use of on-line decision aiding, and reducing the numbers and skills of personnel required.

Define Design Concepts and Criteria for the Design for Usability

The development of detailed HMI design for usability will focus on prototyping HMI concepts to assess and reduce the risks associated with integrating available and emerging HOF technologies into a system design approach to satisfy a validated mission need. Test and evaluation of prototypes will confirm the feasibility of specific design approaches relative to its ability to satisfy the mission need and achieve minimum acceptable operational performance requirements within affordability constraints. Prototyping will be used to assess cost and performance tradeoffs.

The major requirement for a human-computer system is that the interfaces be usable to the human. In this context usability of a system interface refers to extent to which: (a) human-computer interfaces have been designed in accordance with user cognitive, perceptual, and memory capabilities; (b) software command modes are transparent to the user; (c) displays are standardized and are easily read and interpreted; (d) the user is always aware of where he or she is in a program or problem (situational awareness); (e) procedures are logically consistent; (f) user documentation is clear, easily accessed, and readable; (g) on-line help is available and responsive; (h) the user is only provided with that information needed when it is needed; and (i) the user understands how to navigate through a program and retrieve needed information.

The importance of the design for usability in software development is evident in that: (a) the human computer interface comprises from 47% to 60% of the total lines of code; (b) a graphical user interface accounts for at least 29% of the software development budget; and (c) 80% of costs associated with the software life cycle (design, development, implementation, and maintenance and operation) accrue during the post-release maintenance phase of the life cycle, and furthermore, 80% of this maintenance is attributable to unmet or unforeseen user requirements. Therefore, 64% of the life cycle costs associated with a software system is due to changes required to improve the interface between user and computer.

Define Design Concepts and Criteria for the Design for Habitability

Habitability design involves specifying workspace free volume, environmental effects, traffic patterns, workspace layout, facility compartmentalization, and adequacy of the design for habitability. The HOF concepts to be developed will address the major user-machine and user-facility interface issues. HOF concepts will either be developed or will reflect an assessment of architectural/engineering design concepts from a HOF point of view. Specific concepts will include the following:

- Compartmentalization concepts - room occupancy and utilization

- Arrangements concepts - traffic patterns
- Accommodations concepts - compartment equipment and fixtures
- Safety concepts - concepts for hazard avoidance, guarding, or warning
- Facility maintenance concepts - workspace and access space required
- Equipment maintenance concepts - maintenance access
- Environmental control concepts
- Communications concepts
- Supply/support concepts

Define Design Concepts and Criteria for the Design for Safety

The development of human-machine interface design concepts and criteria as they relate to safety will be concerned with identifying, evaluating, and providing safety considerations or tradeoff studies to identify concepts for:

- guarding the hazard
- labeling the hazard
- alarming the hazard
- training/procedures for avoiding the hazard
- designing out the hazard

The effort will entail the review of appropriate engineering documentation (drawings, specifications, etc.) to make sure safety considerations have been incorporated. These activities will extend to reviewing logistic support publications for adequate safety considerations, and ensuring the inclusion of applicable USCG, EPA, and OSHA requirements; verifying the adequacy of safety and warning devices, life support equipment, and personal protective equipment; and identifying the need for safety training.

Integrate HOF Design Concepts and Criteria

Design concepts and criteria will be integrated through modeling and simulation efforts which will produce prototypes of the interfaces for selected scenarios.

Define the Impact of HOF on Safety Critical Systems and Standards

Figure 5 depicts the impact of HOF on safety critical factors. As indicated in this figure, escalation of an incident or accident can be addressed from the point of view in terms of four levels beginning with inherent safety and proceeding through error prevention, and error control, to error mitigation. Error prevention addresses steps to actually reduce the incidence of the error. Error control involves actions to reduce the escalation of the already committed error such as detecting and correcting the error. Error mitigation includes measures to reduce the severity of the consequences of the error. Mitigation also addresses steps taken to ensure that the system is error tolerant, i.e., that the system will continue to operate in a safe manner until the error condition is corrected.

The impacts of HOF on standards are depicted in Figure 6. This figure indicates the areas to be addressed in the formulation of risk based standards, scenario based standards, and performance based standards. Risk based standards involve the elements of the system most likely to be involved in an error situation. These include personnel, the environment, system assets, and system production capabilities. Scenario based standards include areas where malfunctions can result in errors or incidents, including malfunctions or incidents associated with organizations, operators (and maintainers), hardware, software, and the environment. System based standards include the array of actions to be taken to prevent, control, and mitigate an error situation, as defined in Figure 5.

9. Human/Organizational Factors in Offshore System Verification and Validation

McCafferty (1995) observed that Verification and Validation serve as a means to check the design. In this phase, formal assessments and evaluations of human error potential, and human performance and safety issues are conducted. The activities to be conducted in the Verification and Validation Phase are depicted in Figure 7.

The activities associated with each HOF step in Figure 5 are described below.

Conduct of Test and Evaluation

The initial step in V&V is to conduct formal development and operational test and evaluation (T&E). The first activity in this step is to identify marine equipment, systems and operations which are expected to be high risk from a human error point of view. High risk situations are those for which human error likelihood is relatively high and those for which human errors, whatever their likelihood, would produce results catastrophic to human, animal, or environmental safety.

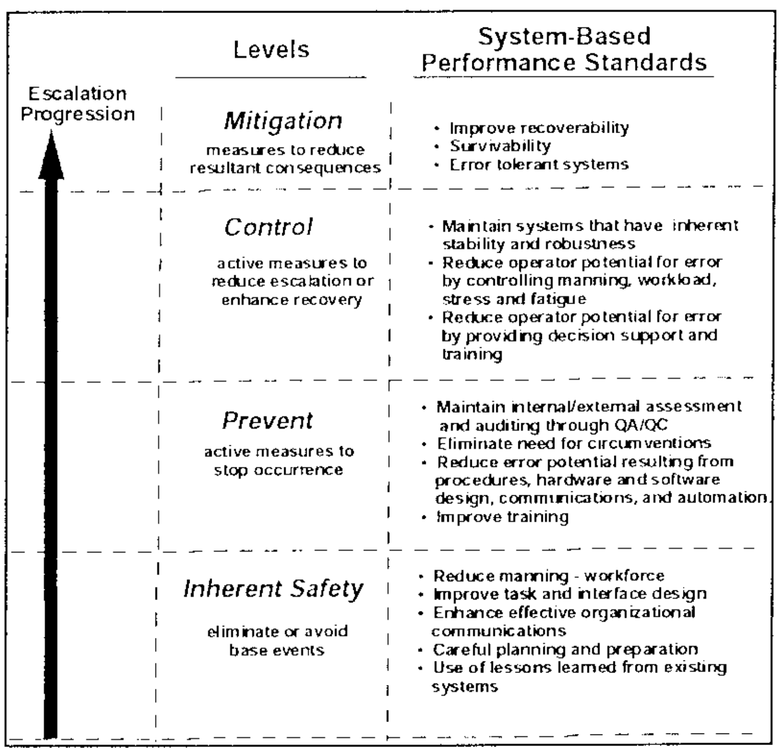

Figure 5. Impact of Human and Organizational Factors on Safety Critical Systems

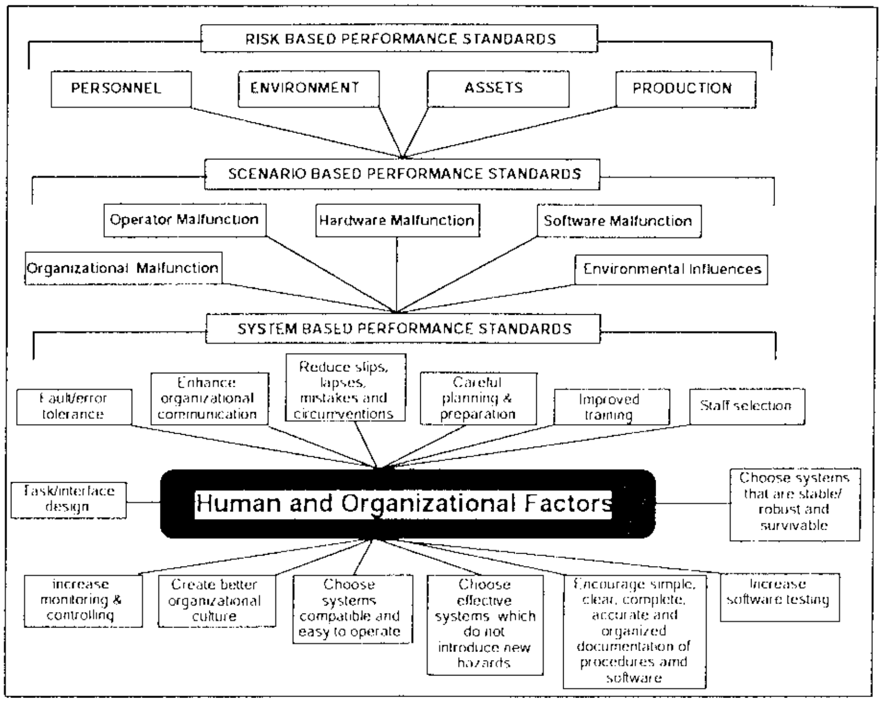

Figure 6. Impacts of HOF on performance standards.

Once high risk situations are identified, requirements and constraints for HOF evaluations will be specified. This will begin with an identification of constraints, including time limitations, legal barriers to evaluations, and availability of data. Requirements for evaluations include functional requirements, information requirements, performance requirements, decision requirements, support requirements, and interface requirements.

The next step will entail identification of HOF evaluation scenarios. When the requirements for evaluation of high risk equipment, systems, and operations have been identified, evaluation scenarios will be described. These scenarios include tasks and test conditions to be included in the evaluation.

The next step will be to identify HOF evaluation measures, criteria, and data requirements including the actual data required from the evaluation, and factors influencing the quality of these data. Data quality factors include data reliability, data validity, and data accuracy requirements.

Methods and data to evaluate human error potential will be developed to assess: (a) human error potential due to equipment design including use of design checklists,

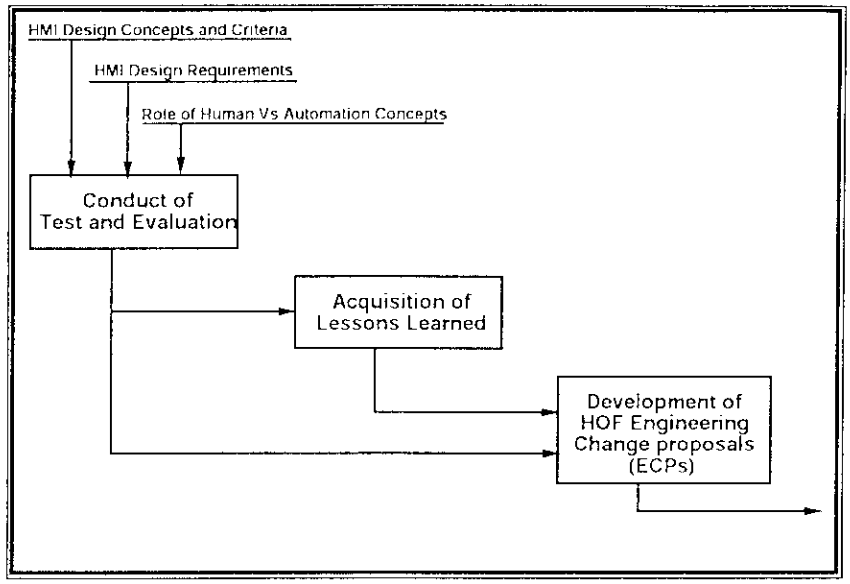

Figure 7. HOF Activities in the Verification and Validation Phase

walkthroughs of operational sequences, interviews with operational personnel, observation of ongoing operations, and HOF analysis. Data include HOF standards against which measurements will be compared; (b) human error potential due to procedures design such as use of procedures/documentation evaluation checklists, walkthroughs, procedures reviews, and interviews to determine procedure completeness, accuracy; clarity, consistency, compatibility with skill levels of users, accessibility, usability, readability, and updateability; (c) human error potential due to training including use of training evaluation checklists, interviews with operational personnel, and human factors analysis of training effectiveness; (d) human error potential due to system manning including use of workload assessment simulation, walkthroughs of operational sequences with proscribed manning levels, interviews with operational personnel, observation of ongoing operations, and HOF analysis of the adequacy of manning levels; and (e) human error potential due to environmental factors including use of design checklists, walkthroughs of operational sequences with suitably clothed test subjects, interviews with operational personnel, observation of ongoing operations in extreme environments, and HOF analysis of the effects of intense cold, wind, reduced illumination, platform motion effects, slippery footing, sea spray, and precipitation.

A major problem faced by the HOF specialist in the evaluation of human error potential in system operation and maintenance is the difficulty in measuring human error and estimating error probability. Human error estimates can be quantitative or qualitative. The quantitative approach to human reliability is predicated on the ability to mathematically predict the probability of error and the impact of design approaches on this probability. A number of researchers have developed tables of error probabilities for discrete activities with specific types of human-machine interfaces. The essence of this approach is that alternate design concepts can be compared based on their calculated overall probability of error. This approach has several inherent difficulties. First there is the difficulty in dealing with the many variables which contribute to the probability of error occurrence at any point in time. These variables include design factors (e.g. panel layout, relationships among adjacent controls and displays, adequacy of labeling, etc.), situational factors (workloads, task complexity, etc.), personnel factors (fatigue, stress, capability level, etc.), and environmental factors (lighting, noise, etc.). Secondly, there is the problem of measuring error rates. Errors are infrequently occurring events, and the number of replications of a task required to enable prediction of error probability with any degree of statistical confidence approaches the astronomical. Any attempt to approximate error probabilities quantitatively without the empirical data cannot be justified from a statistical and a practical point of view. Another problem with error prediction is the difficulty associated with getting system personnel to report errors. Such an approach is viewed by the personnel as spotlighting their own deficiencies or those of co-workers. Finally, an approach to quantifying error rates is an exercise in overkill since the designer is not really interested in the actual error probability but only if it represents a problem for system operation or maintenance.

The approach of qualitatively describing error potential involves determining the likelihood of error given a set of design, job, personnel and environmental factors. The error likelihood approach attempts to determine if the likelihood of error presents a problem to be addressed in the design of the man-machine interfaces. It also addresses the likelihood that, having occurred, an error will be detected, and corrected.

Acquisition of Lessons Learned

Lessons learned apply to lessons from existing systems, and lessons from an emerging system after it has been implemented. Lessons learned data include problems experienced by the system in the operational environment, and positive aspects of the system which should be continued in design of future systems. The importance of lessons learned for human error prevention lies in the ability to obtain data describing near misses. A near miss is a situation wherein an operator either actually commits an error but recovers in time to avoid adverse effects on the system, or is about to commit an error but avoids it. Card (1996) cites evidence to indicate that there are 600 near misses for every accident. For this reason alone, obtaining lessons learned on near misses would be much more productive in serving to identify problems with systems design than would actual mishaps owing to the frequency of near misses. The problem with obtaining data on near misses is, as stated earlier, that it is difficult to get operators to submit self reports in which their performance and competence may be called into question.

Prepare HOF Engineering Change Proposals (ECPs)

When HOF problems have been identified either through test and evaluation or lessons learned, proposals to resolve the problems will be developed. The development of solutions involves identifying design changes to eliminate or attenuate adverse effects of problems. These kinds of HOF solutions include:

- redesign of hardware
- software solutions
- changes to manning
- training, tutoring, aiding solutions
- labeling and marking changes
- instructions or warnings

- modifications to procedures
- addition or modification of safety guards

10. Results of the HOF Design Process applied to Offshore Systems Miller (1996) concluded that to achieve a successful ship safety program requires a commitment to a total HOF program. Only with a total HOF effort, with HOF design "being an important and early participant in the design, construction, and operational sequence, can we expect to reach reduced levels of human error on our ships that will allow all of us to say of our effort, well done." (Miller, 1996).

But what are the specific results of applying a total HOF program to the design and development of offshore systems? What are the benefits to be achieved? The overall result that can be expected is a significant reduction in the incidence of human error, and a decrease in the impact of human errors. Implementation of the HOF design process described in this paper will result in:

- reduced human error potential as a function of manning, workload, and fatigue - through attention to workloads associated with task sequences in representative and worst-case scenarios, and design of systems to (a) define the optimal role of the human Vs automation, (b) reduce cognitive workloads through task simplification, and (c) consolidate functions and tasks to reduce fatigue.
- reduced human error potential as a function of training/skills - by providing on-line help, decision aiding, and intelligent tutoring capabilities.
- reduced human error potential as a function of procedures - by designing procedures and user documentation for ease of access, use, update, and cross-referencing.
- reduced human error potential as a function of software design - through improved design for usability.
- reduced human error potential as a function of hardware, system facilities, and communications design - the results of applying HOF principles and data to the design of human interfaces are:
  (a) displays which are meaningful, readable, integrated, accurate, current, complete, clear, directive, transparent, readily associated with control actions and other related displays, and responsive to information requirements; (b) controls which are reachable, identifiable, operable, consistent, compatible with expectations and conventions, and simple to use; (c) consoles and panels which include the required control and display functions which are arranged in terms of functions, sequence of operations, and priorities; (d) procedures which are logical, consistent, straightforward, and provide feedback. (e) communications which are standardized, consistent, intelligible, clear, concise, identifiable, prioritized, and available; and (f) environments which are within performance, comfort and safety limits, which are designed in terms of task requirements, and consider long term as well as short term exposure. HSI design of offshore systems will be in accordance with ASTM-1166.
- reduced human error potential as a function of automation - resulting from a design approach wherein complacency and excessive trust in automated systems are reduced through improved interaction between automation and the human.

- reduced human error potential as a function of organizational factors - through improved job design, and incorporation of management expectancies into workstation design.

11. Research and Development Requirements

Specific requirements for additional research and development in reduction of errors and error impacts in offshore systems include the following:

- development of a standard HOF design process specifically for offshore systems, and integrated into the offshore system design process;
- development of tools and databases for application of HOF methods and data to offshore systems design;
- research into the role of fatigue and reduced manning in human error potential;
- techniques for making offshore systems more error-tolerant;
- techniques for acquiring data on near misses;
- development of modeling and simulation techniques including models of task sequences for alternative design approaches; simulation to assess alternative roles of the human in the system; task analysis approaches which constitute a model of task performance; and system, subsystem and component design concept development and evaluation through human-in-the-loop simulation.
- techniques to define design requirements and concepts for decision support systems.
- techniques to enable the design of human interfaces to overcome the tendency of operators toward complacency in dealing with automated systems.
- techniques to assess HOF design concepts to reduce human errors in terms of impacts on affordability, risk potential, system reliability and maintainability, manpower and training, human performance capability, and human and environmental safety.
- development of HOF measures of effectiveness.

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HUMAN AND ORGANIZATIONAL FACTOR CONSIDERATIONS IN THE STRUCTURE DESIGN PROCESS FOR OFFSHORE PLATFORMS

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There are six primary interactive and related components that are involved in the human amd organizational factors (HOF) related aspects of achieving acceptable quality during the design phase of an offshore platform (Bea, 1994):

1) individuals (members of the design team),
2) organizations (functional and administrative structures),
3) procedures (ways of doing things),
4) systems / hardware (physical equipment, facilities, structures),
5) environments (complex of climatic and biotic factors; aggregate of social and cultural conditions), and
6) interfaces between the foregoing

Reason (1990a, 1990b) suggested that latent problems with insufficient quality (failures, accidents) in technical systems are similar to diseases in the human body:

> *"Latent failures in technical systems are analogous to resident pathogens in the human body which combine with local triggering factors (i.e., life stresses, toxic chemicals and the like) to overcome the immune system and produce disease. Like cancers and cardiovascular disorders, accidents in defended systems do not arise from single causes. They occur because of the adverse conjunction of several factors, each one necessary but not sufficient to breach the defenses. As in the case of the human body, all technical systems will have some pathogens lying dormant within* them."

Reason (1991) developed eight assertions regarding error tolerance in complex technical systems:

1) The likelihood of an accident is a function of the number of pathogens within the system.
2) The more complex and opaque the system, the more pathogens it will contain.
3) Simpler, less well-defended systems need fewer pathogens to bring about an accident.
4) The higher a person's position within the decision-making structure of the organization, the greater is his or her potential for spawning pathogens.
5) Local pathogens or accident triggers are hard to anticipate.
6) Resident pathogens can be identified proactively, given adequate access and system knowledge.
7) Efforts directed at identifying and neutralizing pathogens are likely to have more safety benefits than those directed at minimizing active failures.
8) Establish diagnostic tests and signs, analogous to white cell counts and blood pressure, that give indications of the health or morbidity of a high hazard technical system.

Research conducted to determine the causes of flaws and errors that occured during the design process (Bea, 1994) identified the key reasons for the failures shown in Table I.

The single dominant cause of structure design related failures has been errors committed, contributed, and / or compounded by the organizations that were involved in and with the designs. At the core of many of these organization based errors was a culture that did not promote quality in the design process. The culture and the organizations did not provide the incentives, values, standards, goals, resources, and controls that were required to achieve adequate quality.

Loss of corporate memory also has been involved in many cases of structure failures. The painful lessons of the past were lost and the lessons were repeated with generally even more painful results.

The second leading cause of structure failures is associated with the individuals that comprise the design team. Errors of omission and commission, violations (circumventions), mistakes, rejection of information, and incorrect transmission of information (communications) have been dominant causes of failures. Lack of adequate training, time, and teamwork or back-up (insufficient redundancy) has been responsible for not catching and correcting many of these errors.

Table I - Key causes of structure design related failures

- new or complex design guidelines and specifications
- new or unusual materials
- new or unusual types of loading
- new or unusual types of structures
- new or complex computer programs
- limited qualifications and experience of engineering personnel
- poor organization and management of engineering personnel
- insufficient research, development and testing background
- major extrapolations of past engineering experience
- poor financial climate, initial cost cutting
- poor quality incentives and quality control procedures
- insufficient time, materials, procedures, and hardware

The third leading cause of structure failures has been errors embedded in procedures. Traditional and established ways of doing things when applied to structures and systems that "push the envelope" have resulted in a multitude of structure failures. There are many cases where such errors have been embedded in design guidelines and codes and in computer software used in design. Newly developed, advanced, and frequently very complex design technology applied in development of design procedures and design of marine structures has not been sufficiently "debugged" and failures (compromises in quality) have resulted.

In general, designer hardware and designer environments have not played major roles in the majority of structure design failure cases. The application of modern building science and ergonomics in the work place have been responsible for this condition.

Another important concept has developed from these failure cases. This concept is that making the structures stronger or utilizing larger factors of safety in its design is not an effective or efficient way to achieve sufficient and desirable quality in the structures. Resources are best focused at the sources of the quality problem which in this case are the humans involved in the structure design activities.

This is not to say that one should not consider the human aspects directly in the structure design procedures and processes. Human errors will occur during design, construction, and operations. One key objective of the design process should be to make the platform structure so that it can better tolerate such errors and the defects and damage that it brings with it. This is design for "robustness." This is design to minimize the effects of inevitable human error (fault tolerance).

Another key objective of the design process should be to make the platform structure not invite or promote human errors. This is the development of design procedures and processes that will promote quality in the work to be performed by designers, constructors, and operators of platform structures (fault avoidance). The design process should promote detection and removal of errors throughout the life-cycle of the platform structure (fault detection and removal).

This insight indicates the priorities of where one should devote attention and resources if one is interested in improving and assuring sufficient quality in the design of platform structures:

1) organizations (administrative and functional structures),
2) individuals (the design team), and
3) procedures (the design processes and guidelines).

QUALITY DESIGN ORGANIZATIONS

Even though it may be the most important, the organization aspects of platform structure design quality are perhaps the most difficult to define, evaluate, and modify. Because of their pervasive importance in determining the quality which is achieved in the design of platform structures, some critical aspects of quality in design organizations will be addressed in this section.

The platform structure design process should be viewed in the context of the multiplicity of organizations that influence the quality of that process. The organizations and their activities form a "mega-system" (Wenk, 1986) that should be recognized and addressed. These mega-systems and their organizational components must be understood as "organisms, living systems that relate to each other."

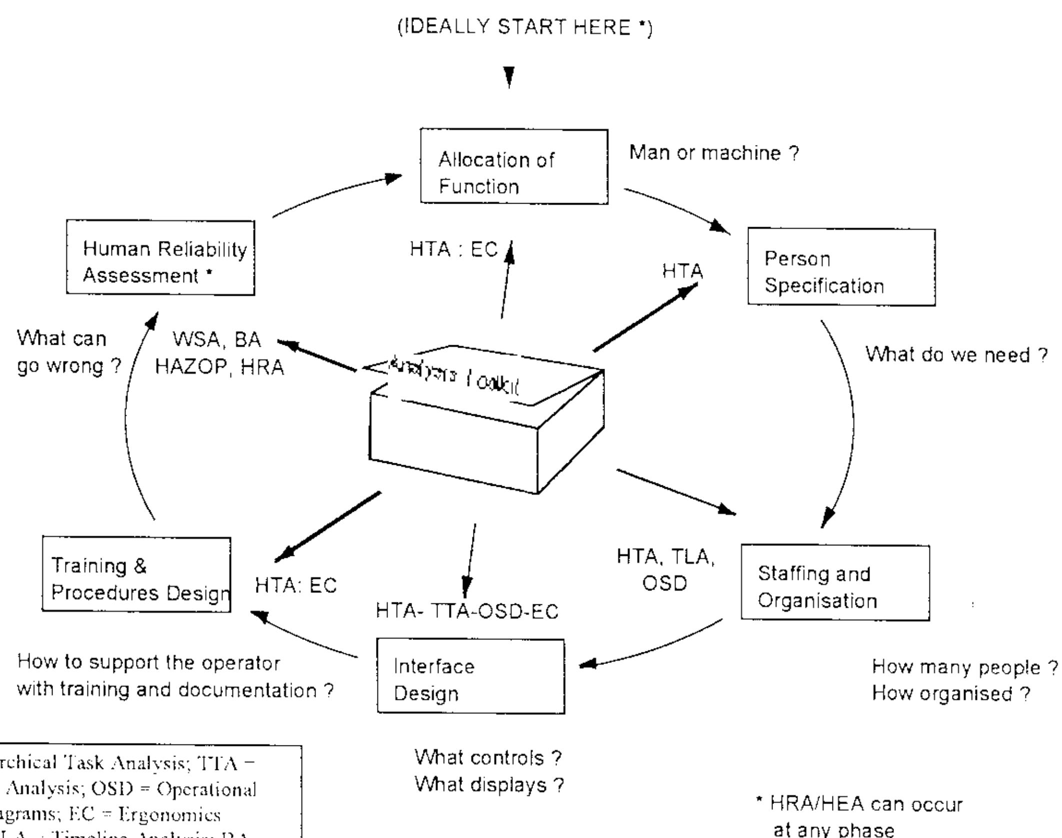
Studies of HRO (High Reliability Organizations) (Roberts, et al., 1989-1994) has shed some light on the factors that contribute to risk mitigation in HRO (Roberts, 1992). HRO are those organizations that have operated nearly "error free" over long periods of time. A variety of HRO ranging from the U. S. Navy nuclear aircraft carriers to the Federal Aviation Administration Air Traffic Control System have been studied.

The HRO research has been directed to define what these organizations do to reduce the probabilities of serious errors (Roberts, 1989). Reduction in error occurrence is accomplished by the following:

1) command by exception or negation,
2) redundancy,
3) procedures and rules,
4) training,
5) appropriate rewards and punishment
6) the ability of management to "see the big picture".

Command by exception (management by exception) refers to management activity in which authority is pushed to the lower levels of the organization by managers who constantly monitor the behavior of their subordinates. Decision making responsibility is allowed to migrate to the persons with the most expertise to make the decision when unfamiliar situations arise (employee empowerment).

Redundancy involves people, procedures, and hardware. It involves numerous individuals who serve as redundant decision makers. There are multiple hardware components that will permit the system to function when one of the components fails.



HTA = Hierarchical Task Analysis; TTA = Tabular Task Analysis; OSD = Operational Sequence Diagrams; EC = Ergonomics Checklists; TLA = Timeline Analysis; BA = Barrier Analysis; WSA = Work Safety Analysis

Figure 2 : Human Factors Application Areas

Procedures that are correct, accurate, complete, well organized, well documented, and are not excessively complex are an important part of HRO. Adherence to the rules is emphasized as a way to prevent errors, unless the rules themselves contribute to error.

HRO develop constant and high quality programs of training. Training in the conduct of normal and abnormal activities is mandatory to avoid errors. Establishment of appropriate rewards and punishment that are consistent with the organizational goals is critical.

Lastly, Roberts (1992) defines HRO organizational structure as one that allows key decision makers to understand the big picture. These decision makers with the big picture perceive the important developing EDA, properly integrate them, and then develop high reliability responses.

In recent organizational research reported by Roberts and Libuser (1994), they analyzed five prominent failures including the Chernobyl nuclear power plant, the grounding of the Exxon Valdez, the Bhopal chemical plant gas leak, the mis-grinding of the Hubble Telescope mirror, and the explosion of the space shuttle Challenger. These failures were evaluated in the context of five hypotheses that defined "risk mitigating and non-risk mitigating" organizations. The failures provided support for the following five hypotheses.

1) *Risk mitigating organizations will have extensive process auditing procedures.* Process auditing is an established system for ongoing checks designed to spot expected as well as unexpected safety problems. Safety drills would be included in this category as would be equipment testing. Follow ups on problems revealed in prior audits are a critical part of this function.
2) *Risk mitigating organizations will have reward systems that encourage risk mitigating behavior on the part of the organization, its members, and constituents.* The reward system is the payoff that an individual or organization gets for behaving one way or another. It is concerned with reducing risky behavior.
3) *Risk mitigating organizations will have quality standards that meet or exceed the referent standard of quality in the industry.*
4) *Risk mitigating organizations will correctly assess the risk associated with the given problem or situation.* Two elements of risk perception are involved. One is whether or not there was any knowledge that risk existed at all. The second is if there was knowledge that risk existed, the extent to which it was acknowledged appropriately or minimized.
5) *Risk mitigating organizations will have a strong command and control system consisting of five elements: a) migrating decision making, b) redundancy, c) rules and procedures, d) training, and e) senior management has the big picture.*

QUALITY DESIGN TEAMS

There are two primary lines of defense to prevent and / or detect and correct individual errors. The first line of defense is centered in the individuals performing the design analyses; the design team. The second line of defense is identified as QA / QC. These are activities of those outside the design team.

First Line of Defense

The first line of defense is associated with prevention and minimization of errors made and not corrected by the individuals that perform the design processes. The quality of the structural design is a direct function of the quality of the design team that performs the design. Table II summarizes the key factors that are need to be addressed to develop a high reliability platform structure design team. Many of these factors relate directly to the attributes of HRO and risk mitigating organizations.

Table II - Key factors in development of a high reliability design team

Communications Personnel selection Training Planning Preparations Discipline Quality resources	Procedures Organization Leaderplatform Monitoring Information seeking, observations Controlling	Information evaluation Distributed decision making Appropriate operation strategies Quality incentives and rewards

Past problems associated with design of platform structures indicates that effective communications, personnel selection, training, provision adequate resources to achieve the desired quality, and provision of quality incentives and rewards are essential elements that determine the frequency and intensity of human factor related problems in structure design.

Communications has been identified as a major human factors problem in many other individual and team situations. The way in which information is presented, information distortion (biasing), and the formatting of the information can have dramatic affects on the effectiveness of the communications within the design team.

The two examples that addressed platform structure design problems clearly identified personnel selection and training as key issues. Personnel performance characteristics need to be matched to the job to be done. Attention to the details of normal and unique structural requirements is an essential performance characteristics needed in structural designers.

Training of design personnel must also match the job to be done. To enhance the performance of a specific task, the more repetition that occurs, then the lower the likelihood of error. To enhance problem solving, experience in a variety of tasks is needed.

Training of design personnel will be particularly important as an platform structure design process is implemented. There will be a loss of "feel" during the early phases of applying such a new design process. If errors are to be prevented or caught and corrected, this intuitive feel must be quickly re-established in those that will apply the new guidelines.

Training of design personnel to understand the effects of biases and heuristics on their decisions is important. Decision makers involved in the design of complex structural systems need to be taught about confirmation bias; the tendency to seek new information that supports one's currently held belief and to ignore or minimize the importance of information that may support an alternative belief. Rigidities in perceptions, ignoring potentially critical flaws in complex situations, rejection of information, and minimizing the potentials for errors or flaws result from confirmation bias.

While not a panacea, the importance of continued and effective training of platform structure designers can not be over-emphasized, particularly as a new platform structure design guideline is implemented into practice.

A very important aspect of minimizing designer error regards team work. Team-work on the front lines of the design process can provide a large measure of internal QA / QC during these operations (Huey, Wickens, 1993). Team-work can be responsible for interrupting potentially serious and compounding sequences of events that have not been anticipated. It is such teamwork that is largely responsible for "near misses." And, it is for this reason that there are many more near misses than there are accidents.

As a result of his work on human errors in the design of non-marine structures, Melchers (1987) identified seven strategies that can be used to manage the occurrence and effects of such errors:

1) Education - on-the-job and continuing professional education.
2) Work Environment - open-minded goal-oriented.
3) Complexity reduction - simplification of complex design tasks.
4) Personnel selection - the skills and abilities of the team members must be appropriate for the type of design to be performed.
5) Self-checking - alertness to spot and correct significant errors made by the individuals performing the design process.
6) External-checking - provision of independent reviews to detect significant errors not detected by the design team.
7) Legal sanctions - deterrence or sanctions to inhibit negligence and deliberate malpractice (violations).

Addressing the last strategy, Melchers observed (1986):

"There is evidence to suggest that sanctions may well be effective for premeditated crime but that in general the effect is likely to be most pronounced on those least likely to be involved. It is reasonable to suggest that few engineers premeditate to perpetrate errors, so that the most likely result of excessive threat of legal sanction is inefficiency, over-caution, and conservatism in the execution of work."

Second Line of Defense

QA / QC measures are focused both on error prevention and error detection and correction. There can be a real danger in excessively formalized QA / QC processes. If not properly managed, they can lead to self-defeating generation of paperwork, waste of scarce resources that can be devoted to QA / QC, and a minimum compliance mentality.

In design, adequate QC (detection, correction) can play a vital role in assuring the desired quality is achieved in a marine structure. Independent, third-party verification, if properly directed and motivated, can be extremely valuable in disclosing embedded errors committed during the design process.

In many problems involving insufficient quality in marine structures, these embedded errors have been centered in fundamental assumptions regarding the design conditions and constraints and in the determination of loadings. These embedded errors can be institutionalized in the form of design codes, guidelines, and specifications.

It takes an experienced outside viewpoint to detect and then urge the correction of such embedded errors. The design organization must be such that identification of potential major problems is encouraged; the incentives and rewards for such detection need to be provided.

It is important to understand that adequate correction does not always follow detection of an important or significant error in design of a structure. Again, QA / QC processes need to adequately provide for correction after detection. Potential significant problems that can degrade the quality of a structure need to be recognized at the outset of the design process and measures provided to solve these problems if they occur.

Knoll's study of structure design errors and the effectiveness of QA / QC activities in detecting and correcting such errors lead to the checking strategies summarized in Table III (1986).

QUALITY DESIGN PROCEDURES

There are three strategies that should be considered to develop quality design procedures (Bea, 1994):

• *Strategy 1* - QA / QC the design procedures and processes (fault avoidance),

• *Strategy 2* - QA / QC is integrated as a requirement directly in the design procedures and processes (fault detection and correction), and

• *Strategy 3* - Measures are introduced into the design procedures and processes that will minimize the effects of HOE on the quality of the platform structure (fault tolerance).

Strategy 1

Current experience indicates that if not properly developed and documented, a design guideline can enhance the likelihood of significant errors being made by even experienced structural designers. These errors can lead to important compromises in the intended quality of the structure. The errors arise primarily because of the dramatically increased complexity of the design guideline, its similarly increased "opaqueness" (frequently caused by associated computer software), and the lack of sufficient training.

Research has shown that the difficulty of a particular task is influenced by five primary factors (Huey, Wickens, 1993):

1) structure of the task,
2) task goals and performance criteria,
3) quality, format and modality of information,
4) cognitive processing required, and
5) characteristics of the input / output devices.

The more difficult a task is made, then the more likely that there will be errors. Those charged with development of platform structure design guidelines should be sensitized to these factors. Design guidelines should be developed that will minimize the difficulty of the tasks to be performed and thereby enhance the likelihood of high quality design results.

In the first strategy, the results of this project suggest that a thorough and independent, third-party QA / QC system should be defined and implemented during the development of an platform structure design procedure. The QA / QC process should parallel the development of the guidelines. Due to the importance of such a procedure, as much effort should be devoted to QA / QC as is devoted to the development itself.

This first strategy has two primary objectives:

1) help assure technical correctness, accuracy, and completeness, and
2) eliminate unnecessary complexity, poor organization, and ineffective documentation in the guidelines.

It should be one of the functions of the first strategy to enhance the quality of the design guideline as much as is reasonable or warranted. The objective is to help minimize design team errors that are caused by errors due to procedures and processes.

Strategy 2

The second strategy is to embody QA / QC directly and explicitly into the design guideline. In this case, requirements for assuring adequate quality in the designers are spelled out. Checking procedures are defined that are appropriate for the particular platform structure. Explicit provisions are made for the correction of errors committed during the design process.

The qualitative and quantitative methods developed and illustrated during this project should be implemented into specific parts of the design guideline to identify the specific parts of the guideline that should subject to QA / QC.

Also of importance is the need to be independent from the circumstances which lead to the generation of the design. This refers directly to the need for independent, third-party verification to disclose embedded errors and flaws in the design. Research and experience both indicate that given that it is done properly, third party verification is the most effective way to detect potential problems in the structure design process.

In the author's experience as a marine structure designer, as a manager of marine engineering design groups, and as a third party verification agent for a wide variety of marine structures (spanning 40 years), it unusual that any serious checking of the structure design is performed. Checking, QA / QC, and verification of the structure design are more what we should do than what we actually do. This is satisfactory when the designs are evolutionary, the design processes well established and proven, the system is highly forgiving, and experienced engineers are at the helm of the design team. This is not satisfactory when the designs are revolutionary, the procedures are not well established and proven, the system is not forgiving, and experienced engineers are not at the helm of the design team.

Recently, the author has been involved in investigation of the failure of a major offshore platform. The failure occurred during installation of the platform. The roots of the failure were imbedded in a design flaw; a failure to address a critical phase of the platform installation.

The design process involved extensive QA / QC. Throughout the design phase, there was a concerted effort to involve the constructor with the design team. Weekly meetings were held to identify, discuss, and resolve design and construction problems. There was extensive QA / QC documentation. A leading Classification Society performed "independent" design and construction reviews. Throughout the project, technical representatives from several major oil companies also performed design reviews.

Given the extensive QA / QC measures, the question was: how and why did the critical flaw slip through? It is noteworthy that one engineer apparently did identify the potential critical flaw. To this engineer, "it didn't look right". But, the groups' consideration of the potential critical flaw did not confirm that it was any problem. As one engineer involved in the checking put it: "no one could prove that there was a problem". The group was concerned with other potentially more serious problems, and in the end, the concern for the potential problem was dismissed. In addition, toward the conclusion of the design phase, there were substantial pressures to complete the work on time and on budget. Worry about "unimportant" details had to be surrendered.

Could the critical flaw have been detected before the accident? Examination of the evidence by a group of experts clearly identified that the flaw could have been detected. Close study of the of the evidence indicates that the flaw was missed for three primary reasons. The first reason was diversion of attention to "more important problems." A high consequence factor was not addressed. The second reason was that the verification and checking that was performed was not "independent" from the circumstances that resulted in the critical flaw. The attention of the checking efforts was diverted just as the attention of the design and construction efforts were diverted. The third reason was the pressure to complete the work on time and on budget. Sufficient resources could not be made available to solve the problem even though the potential problem could be relatively easily and cheaply solved.

This experience points out the importance of truly independent, experienced, and thorough verification of potentially high consequence design "details" (Table III). The cost of such verification and the preventative measures would have been much cheaper than the costs of solving the construction problem. Every dollar invested in prevention could have saved approximately 2,000 dollars in cure. Not many business investments have such an attractive cost - benefit ratio.

Experience has indicated that results from simplified methods that employ first principles can play an important role in identifying problems in results from complex methods. Yet, there is often little "respect" given to such methods by engineers. They feel that complex methods are more reliable and give more realistic results. Simplified methods can not be expected to develop the details developed by complex methods. However, sophistication in analytical design methods does not assure either reliability or realism in results. There is an important need to further develop simplified design methods that can be used to help verify the fundamental results from complex design analyses.

Empirical or experimental verification is needed because of the inherent inadequacies and limitations of most engineering analytical procedures when applied to design of platform structures. This is particularly true when it comes to loading analyses, but it also applies to most structure analyses. The question is the extent of experimental verification that is required. This becomes a problem in trading off the costs involved in providing the verification versus the costs involved when insufficient quality is obtained due to the lack of the verification.

The design guideline should encourage the use of all three verification procedures as warranted. Particular emphasis should be given to the requirements for independent, experienced, and thorough verification of "new designs" of platform structures.

Strategy 3

The third strategy that should be incorporated directly into the design guidelines and their development regards design of the structure to be tolerant or forgiving of human errors. These human errors can and probably will occur in design, construction and operation of a platform structure; even one that has been designed by the most advanced technology available today.

It is rare to find explicit structure design guidelines that address the need for obtaining human error tolerance in the life-cycle of any type of structure. Some have begun to appear, but more work is needed to develop such guidelines. This is one of the most important areas for marine structures research.

The results of the MSIP project (Bea, 1993) indicated that there were four general approaches that should be considered in developing human error tolerant structure design guidelines. These were design for:

1) damage or defect tolerance (robustness),
2) constructabilty,
3) inspectability, and
4) maintainability and repairability.

The first approach is focused on providing fault tolerance in the platform structure system. The last three approaches are focused on providing fault avoidance, detection, and removal in the platform design process.

Structure robustness can be achieved with a combination of redundancy, ductility, and excess capacity in the structure system. Robustness implies much more than redundancy (degree of indeterminacy) (Das, Garside, 1991). Fail-safe design is one aspect of this approach (Bea, 1992).

Robustness needs to be placed in those areas of the platform structure that have high probabilities of damage or defects and high consequences associated with such damage or defects. Such an approach has been used recently in design of several major offshore platforms (Bea, 1994c). The approach had major effects on the configuration of the structures.

Design for constructability is focused on configuration and proportioning the structure to promote / facilitate high quality materials, cutting and forming, and assembly. Design for inspectability is focused on the same structure design activities, but this time the objective is to maximize the inspectability of the platform structure during its operation. Design for maintainabilty and reparability is meant to direct the structure design engineers attention to the long-term life-cycle phase of the platform structure. Corrosion management and buckling and fracture repairs are key issues.

All of these design approaches are intended to minimize the incidence of and effects of human errors that can occur in design, construction, and operation of a platform structure.

Explicit design guidelines should be developed that will adequately address the four major quality attributes of the platform structure including serviceability, safety, durability, and compatibility. In addition, structure design guidelines need to be developed that will address the constraints and issues associated with potential damage and defects in the structure, its construction, its inspection, and its maintenance and repair.

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THE ROLE OF HUMAN AND ORGANISATIONAL FACTORS (HOF) IN THE FABRICATION, INSTALLATION AND MODIFICATION (FIM) PHASES OF OFFSHORE FACILITIES.

Prepared after the discussion in Work Group 2 of "International Workshop on Human Factors in Offshore Operations", New Orleans, Dec. 96.

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Key Words

Organisational learning, Organisational trends, Supervision, Management, Contract, Critical tasks, Weak links, Training, Work Pressure.

Abstract

Most failures in *Offshore Fabrication, Installation and Modification Phases* can ultimately be attributed to Human Factors elements and most failures are not mechanically related as is the general perception of the public. How and to what extent Organisational Factors influence the Human Factors are at present not very well understood, but the safety culture and the qualifications of the organisation are prime factors influencing Human Factors.

This paper will assess the benefit of integrating Human and Organisational Factors (HOF) in the Fabrication, Installation and Modification (FIM phases) of Offshore Facilities.

This will be done by considering the relationship between human factors, human errors and accidents, organisational aspects, the role of the individual worker, training of employees, influence of the design phase, specifics of the FIM phases and the quantification of human errors.

Concluding remarks will be given with respect to the possibility of improved safety with reduced numbers of accidental losses in the Fabrication, Installation and Modification Phases of Offshore Facilities.

Note:
It should, furthermore be noted that the *decommissioning* phase possibly should have been included as well in the discussion of this paper whereby the paper would cover the FIMD phases of an offshore facility.

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INTRODUCTION

The offshore oil industry is a comparatively young industry. It faces unique technical challenges in a hostile environment. It encompasses large international operators and government owned companies for whom safety is prime part of their culture and smaller regional companies. All face the challenge of maintaining and improving safety in an ever changing industrial environment.

This paper discusses the issues that confront the industry and options for managing the achievements of a safe industrial environment.

Many offshore projects are unique in their size and complexity and as the industry moves to deeper waters the complexity previously encountered in the **design** and **fabrication** phases continues into the **installation** phase of an offshore facility. Furthermore, as the industry has matured, several of the offshore facilities are in need of considerable **maintenance** to continue production. However, when the costs of maintenance exceed the income from production, funding for necessary maintenance might be deferred at the expense of reduced safety. On the other hand, an extensive maintenance programme could involve a safety risk, and that a "cost-benefit" safety analysis might document the effectiveness of a lower maintenance level.

It should be noted that the word "safety" in the context of this paper covers safety with respect to personnel, external environment and assets.

> **Question 1.**
>
> What distinguish the FIM phases of an offshore facility from the FIM phases of an onshore facility and to what extent do the differences influence the safety and the accident rates of work related to an offshore facility?

Throughout all activities in the fabrication, installation and maintenance (FIM) phases of an offshore facility, there is a considerable number of personnel involved from company management to the persons carrying out the manual work. The behaviour of the personnel is thus the most important factor with respect to the safety in the FIM phases, and the "human factor element" in these phases will be thoroughly reviewed in this paper. Of considerable importance in this respect is the link between the organisation, its safety culture and the individuals (see also Bea et al, 1996 and Bea and Roberts, 1995).

For fabrication, installation and maintenance of offshore facilities there are certain specific problems which distinguish offshore projects from onshore projects, such as:

- the large amount of work being carried out in confined areas

- the uniqueness of working in the marine environment

- differences in specifications from operator to operator

Furthermore, the trends for

- increased effectiveness and productivity
- cost reduction in all phases
- new management principles rewarding outsourcing and use of contractors rather than company personnel

influence the personnel involved in the FIM phases and further insight into how safety can be maintained under such climate represents valuable knowledge.

The paper contains a number of questions introducing the discussion of key aspects.

It should be noted that the paper contains a long list of important factors. The key point is that all these factors ultimately affect the decision making whether of a front line operator or a manager. See Fig. 1 where the control and monitoring loop for decision making is presented.

DEFINITIONS

Prior to further discussion, there is a need to state some basic definitions for reference and clarity:

The terms *"human factors"* and *"human error"* are often interchanged in the offshore oil industry without clear definition as to what is actually meant by these labels. They are often used interchangeably as general terms referring to the cause of an accident being related to people as opposed to a technical fault. The traditional definition of *"human factors"* is the scientific study of the interaction between man and machine. This definition has been extended in recent years to encompass the effects which individual group and organisational factors have on safety (Wilpert, 1995). Human errors have been defined by Rasmussen (1993) as *"human acts which are judged by somebody to deviate from some kind of reference act ... they are subjective and they vary with time"*. These are specific acts which can cause an accident (see Fig. 2)

Human errors and human factors are usually studied separately and any relationship between them is usually overlooked. The human factors could, however, be regarded as those factors which describe the underlying causes and the human errors are the specific acts which are caused by the human factors and are seen as the immediate cause of the accident.

The diagram (Fig. 2) indicates that the human factors (which includes organisational, group and individual factors) causes the human errors which cause the accident.

1. ORGANISATIONAL ASPECTS

1.1 Organisational Aspects, Safety Culture and Safety Climate

Definition of Safety Culture/Climate

Safety Culture can be defined in terms of underlying belief systems about safety which are partly determined by group norms and regulatory frameworks.

As defined by ACSNI (1992), safety culture is: "the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine commitment to and the style and proficiency of an organisation's health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by the efficacy of preventative measures".

Safety Climate refers to the perceptions of the current environment or prevailing conditions which impact upon safety. The safety climate of an installation is a product of the combined attitudes of the workforce. This is more easily measured than safety culture.

Both safety culture and safety climate can be related to the physical environment in which the system operates, the work environment and features of the work/management system. To some extent the safety culture will underpin and impact upon the safety climate.

It has been postulated that without a good organisational safety climate to which everyone contributes, it is inconceivable that any organisation has a safe working environment (Donald & Canter, 1993). The organisational climate represents the context in which behaviour occurs and the basis of people's expectations. It is not possible to implement a safety culture, as the safety culture is a description of the underlying belief systems about safety. However, it is possible to manipulate the environment by make changes to the prevailing safety climate, for example, by management allocating finance to safety. By focusing on the workers' (from all levels of the organisation) group values, attitudes, perceptions, competencies and patterns of behaviour, it is possible to see where weaknesses in the safety culture lie. This is a particular difficult area, and much research is currently focusing on the concept of safety culture and climate in order to measure it with the view to be able to change and improve safety cultures.

Factors Affecting Organisational Safety Culture

Factors found to be related to safety culture are management's' commitment to safety, safety training, open communication, environmental control and management, stable workforce and positive safety promotion policy (Donald & Canter, 1993). In addition, the following factors have been found to discriminate between companies in terms of safety climate: importance of safety training, effects of workplace, status of safety committee, status of safety officer, effect of safe conduct on promotion, level of risk at the workplace, management attitudes towards safety and effect of safe conduct on social status (Zohar, 1980).

Production versus safety: where the production goals override safety.

> **Question 2**
> To what extent does the offshore industry push production efficiency to a level where safety is reduced in the FIM phases of a facility?

The pressure for production is a drive from the top level of the corporation, through the management levels onto the supervisor and finally directed to the individual at the front line.

Although it is widely recognised that ignoring safety can be more costly than giving it attention, it is often the case that production is the main focus. With this pressure from the top, production management are driven to stay on schedule even if it could be detrimental to safety. For example, maintenance work is delayed or work is continued under severe weather conditions.
Decisions of whether to continue work in bad weather conditions or to have the maintenance work completed must be left up to competent operators at the site. This gives them the responsibility to assess the situation using their knowledge and experience. However, it does leave room for errors of judgement (Paté-Cornell, 1990).

The pressure to reduce production costs leads in the short term to minimum costs for design, fabrication, installation and maintenance while long term effects are increased accidental rates and eventually higher costs.

Resource constraints

Resource constraints are unavoidable parts of industrial life and the engineers and other workers who are subjected to these constraints must try to satisfy them. This may be done by taking short cuts without having clear ideas of the influence on the safety. Budget constraints in the design and verification phases may, e.g. lead to an inaccurate design which may cause a catastrophic collapse in the FIM phases (Paté-Cornell and Rettedal, 1996).

Incentive effects

> **Question 3**
> Should incentives be used to cause increased productivity and safety for personnel and facility in the FIM phases of an offshore facility?

People are influenced by the type of reward structures, thus it is important that the incentives encourage safe working practices. The safety culture of an organisation can in part be shaped through incentives. However, if incentives are given to complete short term production figures, safety could be threatened.

Industry safety professionals are concerned about the fact that safety incentive programmes do not work as incentives to safe behaviour and that they could be harmful to workforce safety performance (Krause, 1995). Incentives are the promise of tantible goods in an attempt to influence workforce safety performance. By "bargaining" with the workforce to get them to the safety meetings (e.g. by giving them a gift if the attend) it will seem that the company is trying to buy the workforce's active participation. The incentives may be unjust, where some workgroups only participating minimally in safety, still get a good safety performance rating, whereas another group may be actively laying down the ground work for long term performance, but get a poor performance rating. The "winning" group gets rewarded for wrong behaviours, and the losers gets punished for doing the right things.

Incentives can cause major distortions of safety performance measures, where injuries are not reported. Workgroup peer pressure is an intense motivator not to report injuries. Pressure from accident - number - conscious managers have been known to bring a great deal of pressure on medics to underreport the severity of injuries (Krause, 1995). The most damaging effects of incentives is the message that is constantly sent: that excellent safety performance is not worthwhile in itself.

Instead of incentives/schemes, ongoing peer-to-peer observations and feedback about safety-related behaviours could be introduced. Personnel need to be reminded that this process is positive, anonymous and solely used for accident prevention, so that they are not anxious about being reprimanded or disciplined for doing badly. Nor are those who are doing the observation anxious of being perceived as "spies" or "traffic cops".

Work during the FIM phases is often short term and the contracting companies need to keep their accident statistics low in order to be re-contracted with the same or new operating companies. They are going to be vulnerable to using "short-sighted" incentive schemes.

Time pressures

Question 4

Are the goals and schedules for the FIM phases of typical modern offshore facilities designed to cause undue time pressure leading to higher accident rates?

Production goals and project budgets set by Corporate Management can be stimulating and motivating, but if the pressure is too much, people tend to cut corners in order to complete the goals in time. In order to cut time, people will carry out more than one task at a time, which can be managed if the tasks are routine and there are few uncertainties. Generally, time pressure increases the probability of errors and decreases the chances that the errors are detected (Paté-Cornell, 1990). To avoid these problems, management must clearly indicate that safety cannot be comprised under any circumstances.

Organisational learning

Question 5
How can organisational learning be fully implemented in the FIM phases of offshore facilities?

Some organisations tend to discourage the reporting of mistakes by creating an image of super performance, making learning difficult for the individual and the corporation.

Personnel are often transferred into different departments or promoted, which makes it difficult for them to observe the effects of their past actions.

Organisations need systems by which they can analyse information about past mistakes and positive experiences in order to gradually reconcile past actions with actual experience. It is necessary to record the human and organisational factors which contribute to the cause of accidents as well as near misses to improve the understanding of how to control potential hazards.

Paté-Cornell (1990) proposed that the following items be considered for organisations to improve their statistics:

- ensuring the effectiveness of learning mechanism
- maintaining corporate memory and updating databases
- using"probability" in management processes to improve communication/decision making
- adjusting scheduling procedures to include uncertainties/delays
- improving feedback to make managers more aware of consequences of their goals
- having project engineers check that the technical changes don't compromise system safety

Kletz (1994) recommended four ways for organisations to learn from past experience: (1) recent and old accidents should be described in safety bulletins and discussed at safety meetings, (2) standards and codes of practice should contain notes on accidents which led to the recommendations, (3) a "black book" containing reports of accidents with technical interest that have occurred should be compulsory reading for all newcomers and for refreshing memories and (4) accident information retrieval and storage systems should be used as they contain a wealth of useful information.

In order to improve organisational learning, feedback from fabrication, operations and maintenance work to designers is particularly important.

New Trends in the Organisation of the FIM Phases of Offshore Facilities

Question 6
How do the new organisational trends influence the safety in the FIM phases of an offshore facility?

Present trends in the organisation of FIM phases of an offshore facility involve everybody in the industry. These trends encompass among others:

- outsourcing, whereby consultants and subcontractors take over work previously carried out by operators and main consultants or larger contractors

- further use of new concepts like production ships and use of maritime regulations and traditional ship industry

- further emphasis on economical constraints and time pressure whereby "fast track" projects are the key to successful project economy with early oil production as the result

- use of functional rather than prescriptive requirements

- new contract strategies, e.g. partnering involving close working relations in integrated teams where the role of Company and Contractor becomes less distinct

- extended emphasis on fast track projects, necessitating early contractor involvement for the benefit of increased interphasing but at the expense of more time pressure

- further use of lump sum contracts where contractors take increased risks for financial success.

- transfer of "old" leases to smaller operators with limited technology base

- further use of smaller contractors (in particular in the modification phase) who cannot demonstrate the same commitment to safety as the larger and more experienced contractors

- reduced independent verification work and spot checks

Human Factor Issues in Alliances between Companies

Alliances are about companies working collaboratively rather than adversarially. The companies in an alliance work together towards a shared common objective. Decisions are taken on what's best for meeting the shared objective rather than on what's best for individual companies. The alliance agreement between the companies is so set up that they all benefit if the shared objective is met or exceeded and they all can lose if the objective is not met (i.e. the aim is to have a "win win" for all the companies in the alliance). Problems within the alliance are worked out jointly rather than by recourse to contracts and law. Benefits from collaborative working can include:

- Reduction in wastage of resources and money incurred in adversarial working

- Provision of an environment were extraordinary performance can be achieved by reducing costs, faster completion of projects, added value, improved quality and improved safety.

The people from the different companies in an alliance work together as a team, preferably located in the same place. The performance of the alliance in achieving its objectives depends crucially on how the people work together. When an alliance is set up, it can involve considerable change in the way people have to work. It can be associated with severe restructuring in at least one of the companies involved. Thus all the HF issues of managing change are applicable. When an alliance is formed several teams need to be set up which include people from all the companies involved. These team can include:

- An alliance steering group made up of very senior managers from each of the companies.

- A management group, made up of managers from each of the companies, which directs the day to day work of the alliance.

- Project teams, with members from each of the companies, which actually do the work of the alliance.

Each of these teams must work effectively to enable extraordinary performance to be achieved. Thus all the HF issues of leadership and building high performing teams are applicable. They are complicated because the team members come from different companies. The people from each of the alliance companies bring with them the "culture" and "baggage" of their own companies together with the "baggage" of their own life experiences. An alliance builds its own "culture" which may or may not include elements of the "cultures" of the alliance companies. Characteristics of alliances which are working well include:

- High degree of openness between the people

- Free flow of information between the people

- High levels of trust between the people

In the course of building the alliance team, managing the change etc., many HF-related things need to be done, including:

- Building shared visions and objectives which are accepted by all the team members
- Building commitment to the shared objectives and to collaborative working.
- Building a feeling of responsibility for achieving the objectives.
- Getting people to challenge their existing beliefs and be open to the possibility of working differently to achieve extraordinary performance.
- Getting people to understand the needs and backgrounds of the people from the other companies with whom they previously had adversarial and arms-length relationships.
- Building a feeling of empowerment among the team members.
- Addressing openly the hopes and fears of the people involved.

These "team-building" interventions can take many forms: "awaydays" or "awayweeks", seminars, workshops, training in collaboration, etc. People who have normally worked adversarially cannot easily adapt to collaborative working - they need to be helped through training and coaching. External facilitators seem to play a crucial role in these interventions, and in some cases external facilitators are employed continually in the workplace where they coach teams in collaboration, in finding innovative ways of doing things and in reminding everyone of the shared objectives.

1.2 Management Aspects

For a general discussion of the effect of management factors on human behaviour and how the effect can be modelled in risk analysis, see Murphy and Paté-Cornell, 1996.

Management's commitment to safety for personnel

Question 7

Do the managers of the oil companies and contractors communicate the message of commitment to safety in the FIM phases of offshore facilities?

In order to have a positive safety culture, management need to be committed to safety. For workers to believe that management are committed to their safety, the following areas of safety need to be addressed:

Safety equipment - Often when there are financial or time restrictions on a job, basic safety equipment (such as gloves) is ignored, although equipment needed for a job is put onto the next shipment. In some situations, safety improvements are only made after an incident occurs. Under this area the role of a tidy working environment to avoid, for example, tripping hazards would be emphasised.

Contradictory safety standards - As the workload increases, standards of safety are often the first to be lowered. It is possible that workers are instructed with regards to safety matters prior to the FIM phases, but are given contradictory instructions when the workload increases, causing safety to be given less priority during the FIM phases. It is important for management to have consistent safety standards in order to show their commitment to safety.

Accident Reporting - The focus is often put on low accident statistics rather than on the welfare of the work force. In some situations, accident statistics are massaged to make them appear lower than they necessarily are. However, those who work on the project are generally aware of the true accident frequency or standard of safety and are likely to perceive this false pretence as a lack of commitment to safety by management. In addition, false reporting is likely to damage worker's safety motivation and their respect for management. Further to accident reporting, near miss reporting should also be urged.

Role of Safety Officer - If the safety officer is given credibility and authority from management to oversee safety, they are more likely to aid in the improvement of the project's safety. However, it can be the case that when jobs are being undertaken which are critical to the flow of the FIM phases, the safety officer is not asked to participate in that particular job, as any hindrance caused by safety enforcement may defer the accomplishment of the task. In this case workers see the job of the safety officer as focusing mainly on minor safety infringements, such as not wearing safety glasses. Such obvious blindness to possible major safety problems would be seen as management being hypocritical and lacking commitment to safety.

Management Style

Humanistic approach to management which focuses on more regard for personal and work problems has been found to be a more effective method. Training in better people-management skills is required.

Openness of management - Senior management are often seen as unapproachable and distant by workers.

Loyalty - The loyalty of management to the workers is determined in numerous ways: job security, wages/salary, pension scheme, shift rotations (e.g. 2 on/2 off), holidays, Christmas/New Year holidays, offshore allowances, helicopter flights, schedules, money allocated to catering and accommodation environment (recreational facilities, etc.).

Regular appearances of management on shop floor - as the workload and workforce increases as in the FIM phases, it is more difficult for management to make regular appearances to all work sites although such appearances increase the morale of the work force (Peters, 1989).

For aspects related to the management's role, see also Paté-Cornell and Bea, 1992.

Communication

Question 8
How can management ensure the necessary communication in the organisation during execution of the FIM phases of an offshore facility?

Errors can occur from problems in communication, where the necessary information has not been gathered, and where communication channels don't exist or don't function. This may be because of unreliable procedures, failure of the communication equipment, lack of informal communications, or deliberate retention of information (Paté Cornell, 1990).

It is important that management open up communication lines, by actively encouraging employees to report near-misses, and to correct improper work habits rather than ignoring them.

Problems of information flow

It is also a common problem that redundant information is provided, that irrelevant information is provided, and that relevant information is mis-represented or ignored (Paté-Cornell, 1990). Organisational boundaries are often communication barriers.

Personnel

High turnover of staff is considered a safety risk, as personnel may not have the necessary level of understanding of the system which is particularly important when the system is pushed to its limits - selection of personnel is in this respect very important.

Group Factors

Question 9
How does positive identification with other project members affect the FIM phases of an offshore facility?

There has been much research into group factors in the aviation industry. This research has been aimed at the flight deck crew where the relationship between crew members in the cockpit are studied (David, 1996). Factors which were found to affect safety performance included how clearly they understood their roles and responsibilities, how assertive they were with other more senior members of the flight crew and whether there was openness and trust within the crew as well as their attitudes to communication (Flin, 1995).

It is possible that similar group factors are as important on an offshore facility project as they have been found to be in the aviation industry. For employees to work safely and efficiently, it is necessary for them to work as part of a team regardless of their position in an organisation.

1.3 Supervisor's Role

Question 10
What is the supervisor's real role in today's offshore industry, in particular in FIM phases of offshore facilities?

The issues: The supervisor has been identified as a key individual in industrial safety. As early as 1931 Henrick stated: *"The supervisor or foreman is the key man in industrial accident prevention. His application of the art of supervision ... is the factor of greatest influence in accident prevention"* The main *Supervisory skills* required to encourage safe working include: instruction, guiding, coaching, developing workers talents & abilities, praise for working safely and setting a good example. The supervisor provides in-house quality control of the worksite and the jobs performed by the group he manages.

Methods of *Communication* - used by supervisors include: e.g. tool box talks, site visits, job assignments & clear directions.

- *Tool box talks* - are an important part of the job which involve discussing the best methods of carrying out the task and problems that could arise and how they should be solved. However, when the workload increases (in the case of FIM phases), the first method of gaining time is to shorten the tool box talks or to discard them altogether. Often supervisors in the FIM phases are supervising large numbers of personnel (up to 20 in some cases) and it can be an impossible task for them to get around to each work group prior to the start of the job. This may result in the tool box talk occurring halfway through the job or in the worst case not at all.

- *Worksite visits* - In addition, if supervisors have a high workload due to the number of workers they have to supervise, they are less likely to visit the worksite. In some cases, crews may only be visited once in a shift. Infrequent worksite visits often means that the supervisor has poor information of the work that has been carried out, leading to handovers which bear little or no resemblance to the actual worksite or amount of work which had been completed. Administrative duties can often prevent them from visiting the worksite more frequently.

- *Relationship with workers* - often there is not enough time for supervisors to build up a relationship with their crew members which can be detrimental to the safe completion of the job. When workers get on better together, they are more likely to be effective/efficient.

Responsibilities - Supervisors need to be given the freedom to make decisions as to whether a job should go ahead as they are the ones who know the details surrounding the job.

Planning - There is a need to give supervisors time to plan their work more carefully in order to reduce time pressure.

Risk communication - Risk communication should be a two-way process, with information moving from one organisational level to answer. Planners, designers and managers need to be the target of risk communication companies - as they are involved in more conscious risk evaluations as opposed to those at the "sharp end", who are carrying out most of their activities at an automatic, pre-attentive level where there is less capacity for the conscious consideration of risk (Wagenaar, 1992). However, other researchers believe that hazards and risks are often identified and controlled most effectively by those involved in the work tasks by a process of constant monitoring or "risk evaluation from below" (Moore, 1991).

Focus on productivity - If senior management are putting pressure (not necessarily explicitly) on supervisors to get a job done, this pressure gets put onto the worker who has less time to complete a task. The focus needs to be put on safety as well as productivity.

Temporary promotion - Workers may be taken from their usual responsibilities during FIM phases and temporarily promoted to a position of supervision (chosen on knowledge of the platform, rather than supervisory potential). These individuals are unlikely to have supervisory experience which may lead to the job being poorly supervised. Since these individuals have taken on new responsibilities, some activities which they did prior to their promotion may no longer be performed. In addition, a lack of confidence in their own decision-making abilities due to being recently promoted without much training may cause supervisors to be more reluctant to stand up to senior management or to make their own decisions, e.g., they would rather request that a safety adviser make the decision to stop a job, relieving themselves of this responsibility.

1.4 Working Environment

Housekeeping - Working in a poorly kept environment is bound to lead to more accidents. This is particularly true in the case of slips, trips and falls, since poor housekeeping increases the workforces exposure to slipping and tripping hazards. As there is an increase of work and left over materials during the FIM stages (particularly during modifications) there is a need for an increase in staffing (such as general assistance) to help clean up the site. Furthermore, it should be noted that good housekeeping is a visible indication of rule enforcement. This is why some safety management auditors look to housekeeping.

Density of workers - During FIM phases there are often too many workers located in the same area. As every job is priority, personnel often are expected to work round each other, in confined spaces with other workers.

Procedures - It is not always possible to follow procedures. In the situation where procedures cannot be followed in order to complete the job, the use of procedures in general can be undermined.

1.5 Accident Reporting

Reporting Routines for Accidents and Near-misses

Question 11
How should accidents be reported in the most useful way in the FIM phases of an offshore facility?

One of the aims of reporting accidents is to learn from past mistakes, thus improving the work environment for the future. It is, furthermore, important that not only incidents resulting in injury and property damage are recorded but also near-misses. It is important when conducting an investigation that those who are involved in the incident are not blamed for it, rather emphasis should be put on the importance of accident reporting for prevention of accidents in the future. In particular in the case of near-misses, anonymous reporting may increase the frequency.

HOF Content of Accident Reporting Forms

Research (Gordon, 1996) into HOF Accident Causation in the UK offshore oil industry has shown that the majority of companies use HOF to categorise accidents, although it is not required by legislation. The majority of UK companies use the ISRS (International Safety Rating Scale) to code accidents.

A study investigating the HOF causes of accidents (Gordon, 1996) found that out of 30 companies, 64% used the 4 basic "Personal Factors" categories (from ISRS) in their accident reporting forms: 1) capability, 2) knowledge + skill, 3) stress and 4) improper motivation. Of the other companies, 16% had additional items under each of these headings and 20% had no Personal Factors (see Appendix I).

Of the 30 companies, only 34% had the basic "Job Factors" codes (organisational, management, supervision and task factors) (Appendix I), 12% had additional Job Factors codes and 54% had no codes to categorise accidents in terms of their job factors. In addition to the underlying causes of the accidents, coding of the immediate causes of accidents are listed under the majority of UK reporting forms. These include items such as: used equipment improperly, working at improper speed, lack of attention and forgetfulness.

It is suggested that human factors content of accident reporting forms should include (Fig. 3) (Gordon, 1996):

- Immediate Causes - Would include human error categories such as, action, checking, retrieval, transmission, diagnostic and decision errors

- Underlying Causes - Would include human factor categories such as, Organisational, Group & Individual Factors.

  - *Organisational Factors:* company policies, standards, systems & procedures.
  - *Group Factors*: management weaknesses, supervision & crew factors
  - *Individual Factors*: knowledge, perceptions, stress & motivation

2. The Role of the Individual Worker

Question 12
How can it be ensured that the individual worker contributes in the most effective way to safety in the FIM phases of an offshore facility?

Human Errors made by individuals at the "sharp-end" (i.e. those who actually carry out the task) are usually observed as the initial cause of the accident. However, these errors usually have underlying causes, such as lack of training, which need to be addressed. When considering possible problems with persons, the following aspects should be looked into:

- ***The capability of the employee:*** in terms of their knowledge and skills, experience, training and qualifications to carry out their job.

- ***Aspects of their job:*** whether they are overworked, bored or frustrated with their job. Whether there is a mismatch between the capability of the individual and the demands of the job, or if there have been any changes in the job description. The job factors may include the following items which can be deviated by supervisors/management:

  Level of responsibility - given a suitable level of responsibility for making decisions of routine operations.

  Clarity of the job - unclear job directions leads to unsafe work

  Timepressure - encourages workers to save time/effort by taking short cuts

  Co-worker support - workers are more likely to work effectively if they get along with each other and are encouraging each other to continue to work safely.

  Motivation in the job - bored, frustrated, conditions of the work (e.g. a very dirty job), lack of incentives, inappropriate peer pressure and aggression can lead to people acting unsafely. Conversely, appropriate peer pressure can lead to people acting/working more safely.

Workload - if the workload is increased, this can lead to workers cutting corners and lead to a reduction in safety monitoring. Safety procedures will often be broken numerous times before negative consequences are realised. Employees are thus seen as more productive at no extra cost and are rewarded for such behaviour. Management needs to highlight the cost of accidents and convince workers that effective performance is important, rather than hasty performance.

Length of job - because workers during the FIM phases know that it is just a short term job and that they are not going to be out there for long, workers pay less attention and care less about their environment.

- ***Job Security & Morale***

Morale - the relationship between morale and accident involvement is complex and it is unclear of how strong the relationship is and whether accident involvement affects morale or whether morale affects accident involvement. However, it seems that there could be a link between low morale and an increase in the number of accidents, furthermore, if you highlight the positive, morale will generally be higher.

Job security - workers who feel insecure about keeping their job may try and obtain some control in their situation to try and secure their job by becoming more productive, which may comprise their own safety (e.g. by cutting corners). This behaviour may pay off in the short term, encouraging them to continue breaking procedures until an accident occurs. Workers who feel insecure about their jobs are less likely to report accidents or safety problems, so as not to look bad. In addition, job insecurity can lead to stress (see below) and low morale.

- ***Stress***

Stress - fatigue, personal problems, frustration, monotony, exposure to hazards & extreme temperature. Research on work-related stress in the offshore oil industry has been carried out in both the Norwegian Sector of the North Sea (Hellesoy, 1985; Ruudmo, 1992) and the British Sector (Sutherland & Cooper, 1986, 1991; Sutherland & Flin, 1991). See Flin & Slaven (1996) for a review of this research. The Norwegian research by Hellesoy found that heat, noise and ventilation were judged as the most unsatisfactory aspects of the work environment and concerns about events at home was the most prevalent personal worry. Depression and loneliness affected 8 - 10% of the crew. Rundmo (1992) found that occupational stress played a critical role with regard to workers well-being, feelings of safety, job performance and accident involvement. The UK work by Sutherland & Cooper

(1986, 1991) showed that offshore workers had higher levels of anxiety than the general population and were less satisfied with their jobs than their onshore counterparts.

The top three stressors were financial (lack of paid holidays, rate of pay, pay differentials between operating and contracting staff). Levels of stress associated with relationships at home and at work were found to predict both job satisfaction and mental health. They also found that those who had been accident victims reported reduced mental well-being and lower job satisfaction. A follow-up study indicated that the principle factors perceived as potentially stressful by offshore workers were underestimation; home-work interface; career prospects and reward; safety and insecurity (Suthterland & Cooper, 1991).

3. TRAINING OF THE EMPLOYEES FOR THE FIM PHASES OF A PROJECT

Approximately 90% of all on-the-job accidents are the result of unsafe behaviours. Because many tasks require full attention, workers may habitually move their hands, feet, or torso in unsafe ways without even realising it. These habits, behaviours engaged in so routinely that the individual becomes unaware of them, are a major factor with regard to accidents. In order to reduce these types of accidents and raise the level of workplace safety, Behaviour Based Safety Methods attempt to modify work activity behaviour. Since behaviour is something which can be observed, it can also be measured and managed. *This behavioural approach considers correct work behaviour awareness to be the most important part of workplace safety.* Over time, the reinforcement of these safe behaviours over unsafe behaviours will result in a decrease in the accident rate.

This approach differs from the efforts which typically focus on reacting to accidents which had already occurred. The behavioural approach is proactive in that it tries to identify safety needs prior to the commencement of work by use of proper training and behavioural awareness. This requires personnel to participate in activities which promote employee involvement, proactive, and behavioural awareness. By designating workers as active agents in the use of preventive measures to avoid accidents, this approach is a means of empowering the workforce.

Behaviour Based Safety Methods, (BBSMs), which are "Training" elements of Human and Organisational Factors (HOF), were successfully used during the fabrication phases of the Mars Tension Leg Platforms (TLP) for Shell Offshore, Inc., (SOI). A management "Safety Performance Monitoring System" was implemented for the entire Mars project. The purpose of this document was to provide an accurate, timely, and fit-for-purpose process to monitor the safety performance of the project and Management involvement was necessary as it is a key to any successful safety program. SOI and three major contractors chose BBSM as the principle safety tool for a major portion of this 100,000 BOPD TLP. BBSMs were subsequently implemented at three major fabrication sites. This effort directly impacted a combined workforce of over 1400 employees.

This paragraph provides a brief summary of the development of the methodology while the details of the implementation and the results are given in Appendix II.

Behaviour based safety methods overview

Question 13 a

What are the benefits of the BBSMs as compared to other methods to reduce number of accidents in FIM phases of an offshore facility? Note that this process focuses on the positive aspects of a job. People will talk about their successes more freely than about accidents or near misses.

Question 13 b

Should a clear recommendation to utilise the BBSMs in the FIM phases of an offshore facility be given? Or should the BBSM process be suggested as an alternative method such that management could see the benefits in order to start the process for their projects.

There are a number of major tasks involved in the development, training, implementation, and analysis of a BBSM system. These include:

Development - The BBSMs are made up of Behavioural Safety Processes, (BSPs), which should be employee designed, implemented and driven. In order to obtain acceptance of this program, the design of the processes should be generated by the same personnel who will subsequently adopt these processes. Safety must be the responsibility of each person in the organisation. The skilled worker has substantial knowledge about related work processes and, therefore is in the best position to provide input on applicable safe behaviours. Thus, rather than applying a long list of behaviours provided by outside "experts", a process development team consisting primarily of employees should be established and tasked with all design and implementation concerns associated with the BSPs. Behavioural Safety Processes which reflect the current work culture within the respective organisation must be developed. These processes will typically include the following:

Development of the workforce safety survey - The purpose of the safety survey is *to evaluate the existing safety culture* within the organisation prior to implementation of the BBSM. When used in conjunction with subsequent surveys, the results can be compared to provide a measure of attitude change in the personnel and to evaluate the effectiveness of the BSPs. The survey should allow the respondents to make note of strengths as well as places where improvements should be made as it addresses the three following subject areas:

Communication - measures the general sentiment of respondents regarding their views on the quality and ease of communication among the workforce (between co-workers and between workers and supervisors).

Commitment to Safety - gauges the general sentiment of respondents regarding whether workplace safety is consistently held as a primary objective by management, co-workers, and the respondent.

Behaviour and Training - reflects the general sentiment of the respondents regarding their views on whether their behaviour impacts the level of workplace safety and the sufficiency of the training they have received.

Correct Behaviour Inventory (CBI) Development - Safety performance standards are necessary to identify behaviours that define safe performance. These standards are also to be used as a means of monitoring the status of safe performance. The Correct Behaviour Inventory is a safety performance standard and *consists of behavioural items necessary to accomplish daily work activities*. The items listed in the CBI should be observable in order to facilitate measurement through the observation process. However, the level of detail of each activity will depend upon how thorough the CBI is to be. A consolidated CBI will require that items be somewhat generic in form in order to apply to a broad range of activities. Personnel interviews are typically used during this period in order to gather information on the behavioural items.

Observation Card Development - Another safety performance standard, this card is to be *used to track the work behaviours* of the related personnel. This card must be designed to reflect the work behaviours listed in the CBI by providing buzz words which represent various behaviours in each safety performance area. The card is also designed to allow personnel the opportunity to make suggestions and to add feedback during observations.

Unsafe Condition Sheet Development - This sheet is used to assign accountability to *identified unsafe conditions*.

Recognition Program - Since BBSM is intended to shift focus from incident rates to that of behaviours which prevent accidents, the typical "Incentive" program is not applicable to this type of process. A recognition program *should be developed based upon the observed performance*.

Training - Once the BSPs have been developed, prior to implementation, both the hourly workforce and management must be trained in their use. Training typically consists of an overview of the BSPs and the observation process. The training should involve:

Formal Observer Training Classes - The observation process is the mechanism which drives the Behavioural Safety Process by providing proactive data of current safety trends. The objective of observers is to *assist co-workers in maintaining the highest level of "safe behaviour"* possibly by observing work behaviours and providing positive reinforcement through feedback. Initially, 10% of the workforce should be trained to be observers. In conjunction with this training, role playing and field observations are performed to assure proper observation procedures and effective feedback delivery.

Management Involvement Training - Management support of the program is critical if the process is to succeed. Also, the use of observer training for superintendents can actively involve middle management in the daily workings of the BBSM process.

Workforce Awareness Training - While the workforce in general does not actively participate as observers, they all have the potential of randomly being observed and therefore, *all personnel should be trained and informed* of the processes involved with BBSM.

Tool Box Meeting Training Sessions - Tool box meetings allow workforce *safety concerns to be addressed on a weekly basis*. It allows the workforce and observers to obtain timely answers to questions concerning safety and the observation process.

Implementation - Initial *success* of the BBSM is directly related to involvement and support of both the *workforce and management* during this implementation. Implementation should consist of:

The required observation process

Soliciting feedback regarding safety and the observation process

Establishing "buy-in" for the process

Reliability checks for the observation process

Reviewing progress and performance data with the workforce

Analysis - In addition to the noted Workforce Safety Surveys, all observation data must also be processed and analysed. Observation cards report safe "S" and unsafe "U" behaviours. One card is used per observation and if any task is marked unsafe, the card is rated as unsafe. The total number of "safe" observation cards are then divided by the total number of cards in order to calculate the "% SAFE behaviour". The resulting quotient is a measurement of the amount of safe behaviour in the workplace.

Software can be used to track the overall % SAFE activity; % SAFE activity in each safety performance area; in need of improvement; feedback participation; and overall observer participation. This data can provide feedback at weekly toolbox meetings and in monthly progress and performance reports which can be used to establish goals and develop action plans for addressing areas in need of improvement. These reports are typically distributed to the workforce and management to assist them in their efforts of continuous improvement, which is a core value for SOI.

4. Influence of the Design Phase on the FIM Phases

Question 14
What factors should the engineers involved in the detailed design of offshore facilities be aware of to minimise the human factor element in the FIM phases of an offshore facility?

It is appropriate to discuss some matters as to how the work in the design phase influences the safety of the FIM phases. In particular, it should be stated that the design phase (including conceptual and detailed design) represents the phase where the decisions about the concept and detailed arrangement are being taken. Thus, an undetected error in the design phase (Ferguson, 1993) might propagate into large errors in the FIM phases of the offshore facility. Risk analysis of the design phase could be carried out (Trbojevic et al, 1995), but in most cases careful independent verification will be sufficient in the design phase (Paté Cornell, 1990). In this respect, review routines as well as systems and technical audits carried out by the operator will be helpful.

Furthermore, it should be recognised that safety for workers throughout all subsequent phases should be designed into the facilities.

Of particular importance for later phases is the incorporation in this design phase of "fabrication friendliness" and "fabrication efficiency" through fabrication studies (as well as ergonometric studies related to the operations of the facilities) and constructability reviews. A "fabrication friendly" concept can be fabricated without delay more so than a facility which is very difficult to fabricate. Some of the large concrete platforms have for example been very difficult to fabricate (e.g. the Hibernia structure) causing costly project delays.

Furthermore, the facilities must be designed such that the installation phase represents minimum risk to personnel involved. In the installation phase, human errors which relate to making decisions, for example exceeding a weather criteria, could represent possibilities for large accidents. The weather criteria for carrying out the different tasks in the installation phase should therefore be decided in the design phase of the project. This will also make it possible to determine a more realistic schedule for the installation phase (Brabazon et al., 1996).

In the design phase, it is furthermore necessary to assess the future modification phase of the facilities in order to make the facilities easy to maintain and modify. If possible, large equipment should be easy to exchange for later modifications of the platform.

Similarly, feedback from fabricators, operators and maintenance is important to improve the goodness of the design.

5. SPECIFICS OF THE FABRICATION, INSTALLATION AND MODIFICATION (FIM) PHASES OF AN OFFSHORE FACILITY

While the other chapters of this paper are more general, the specifics of the FIM phases of an offshore facility will be summarised, possibly with reference to the chapters where further guidance is given.

Contract Format and Contractor Selection

Question 15
How can the human factor element effectively be incorporated in contract format and contractor selection for the FIM phases of an offshore facility?

A contract for the FIM phases of an offshore facility must include HOF requirements by fitting the contract to minimise problems. this can e.g. be done by reducing pressure for productivity and by reducing possibility for schedule crash causing stress and fatigue of workers.

The selection of contractors to carry out the work is very important. Emphasis must be put on contractor's experience, competence and safety record as on price and schedule. The newer contract models used (see Chapter 1.5) emphasise the need to carefully review the human factors element of the contractor's organisation. Furthermore, careful prequalification and selection of contractors and their subcontractors by reviewing their HOF commitment is important.

New Projects vs. Modifications

Question 16
Should "safety benefit analysis" be recommended prior to modifications of offshore facilities?

For new projects there is a possibility to start afresh and incorporate the appropriate human factors elements in the early planning. For modification projects one has to work on what is already installed and the conditions for the workers could only be changed to a limited extent. It is, however, even more important that past experience is incorporated into this phase and therefore company and contractor must involve highly experienced personnel in modification of offshore facilities. This fact should also influence which contractor is chosen for this job.

Furthermore, a "safety benefit analysis" should be carried out prior to upgrading projects to assess whether the upgraded/modified facilities are sufficiently safe to warrant a major modification activity where the risks of accidents would normally be higher than during normal operations with the facility "as is". Of particular concern are un-engineered field modifications where proper design and planning are lacking.

Company In-house Experience

Question 17
Is the trend to reducing own staff and in-house experience in oil companies and contractors coming to a level where negative safety consequences can be encountered in the FIM phases of offshore facilities?

Company's in-house experience in selecting technology, contract format, contractor and implementing safety climate in the FIM phases of an offshore facility will largely influence the project. Many companies are at present reducing their staff of experienced engineers and supervisors with the possible consequence that human errors might be more likely in future FIM projects than in the past. The trend could be alarming and management should watch the trend carefully.

Specific Human Error Sources in the FIM Phases

Question 18
Which are the critical tasks during the FIM phases of offshore facilities ?

During the FIM phases there are specific tasks which are more often sources of human oversights and human error related accidents:

- Communication between different groups of personnel (boundary communication); construction and drilling, construction and office operations, construction and field operations.

- Simultaneous operations; construction and production as well as construction and drilling

- Hot work (welding and burning)

- Need for communication between field construction work and office

- Construction work performed by drilling rig

- Contingency planning for rough weather

- Operations of cranes on barges as well as platform cranes including their maintenance and possible modifications

- Rigging operations including certification of riggers and responsibility of riggers and supervisors

- Tripping hazard

- Decommissioning; noting that the centre of gravity may have changed during the period of operation and due to modifications, and noting that the state of the structure is not fully known.

It is important to make all personnel involved aware of specific critical tasks where human errors are more likely to occur as compared to other tasks.

Unfamiliar Events

Even when the best planning possible has been exercised, and even when experienced personnel are involved, unfamiliar events are likely to occur in the FIM phases of an offshore facility. It is of importance to prepare for such events through emergency planning and emergency exercises, although it in general is felt that highly competent personnel and general training will reduce such events to a minimum. For certain difficult operations, in particular in the installation phase, simulator training is considered useful (see Gudmestad et al., 1995, conf. discussion in Ch. 6.3).

Weather Criteria

Question 19
Is there evidence of undue pressure to perform FIM operations under weather conditions which cause high risks for the offshore facilities?

The effect of weather on offshore installation work is obvious. Specific criteria should be set in the design phase (see Chapter 4) in order to reduce the pressure for exceedance of the criteria during actual operations in the case of tight schedule or reimbursable contracts. The role of the warranty surveyor, the owner's senior representative or contractors' supervisory personnel who is responsible for the conduct of the jobs, to stand fast not allowing operations to start or to continue in bad or worsening weather situations should be acknowledged. Furthermore, rough weather contingency planning represents an important safety measure.

Regulatory and Official Approvals

Question 20
Is it possible that the human factor element could be regulated to provide safety in the FIM phases of an offshore facility?

This paper points to the fact that the human factors element is particularly important in the FIM phases of offshore facilities. Would there then be scope for increased regulations and further requirements for official approvals?

Although certain provisions could be regulated, like setting competence requirements for those involved in any safety related activities (NPD, 1996), it is generally felt that the human mind can not be regulated to function as one wishes. It is the attitude of the organisation, the management, the supervisors and the individual workers which must address safety and it is the training of all those involved which ultimately leads to less human errors in the FIM phases of offshore facilities. In this respect, working environment objectives could be defined for the various phases and activities (NPD, 1995).

Interfaces between organisations

Question 21
How can HOF be recognised in interfaces between organisations at various levels involved in the FIM phases?

To improve the understanding of the interfaces between organisations involved in the FIM phases of an offshore facility, trust diagrams can be presented to help us to identify weak links, see Appendix III.

6. QUANTIFICATION OF HUMAN ERRORS

To what degree can HOF be accounted for in the safety analysis of FIM phases? Are HOF adequately addressed in :

a) major hazard safety analysis?
b) occupational safety analysis?

Such questions need a review of possible databases to qualify/quantify the human errors.

Furthermore, in regard to major safety analyses, are the standard methodologies of FMEA, HAZOP and QRA adequate or do they require modification for application to the FIM phases?

6.1 Qualitative versus Quantitative Risk Analysis

There are uncertainties as to whether it is possible to **quantify** the human factors element. In general, a **qualitative** assessment of the risk incurred by the human factors element should represent very valuable information and attempts should in many instances not be made to push the failure databases used in risk analysis too far (Gudmestad, 1995). Several companies, however, are inclined to carry out quantitative risk analysis and then in the absence of experience data, the Bayesian approach which allows for subjective probabilities and updating of probabilities could be adopted.

6.2 Human error data

Question 22
Would it be relevant to use data bases to quantify the human factor element in the FIM phases of an offshore project or is it more relevant to use subjective probabilities?

Human Error Probability

The method of quantifying operator error is often based on *Absolute Probability Judgement* which is one of the most effective methods in Human Reliability Assessment (Safety and

Performance Shaping Factors

Although a great deal is known about the effect of different conditions on human performance, their qualification in terms of the extent to which error likelihood is affected is poorly researched. Human Reliability Assessment techniques often provide a database of the effects of PSFs, and these are generally based on judgement. The PSFs with the biggest influence, such as high stress or lack of training are broadly estimated to result in an order of magnitude increase in error likelihood. Other effects relate to performance over time such as a decrease in the ability to remain vigilant over long periods and hence detect changes in the environment.

Some data on the factors that shape the performance of an individual when carrying out a task are shown in Tables 2, 3 and 4. The data shown in Table 2 are based on experimental evidence.

6.3 Use of Simulator Training

Question 22
Could further use of simulator training be efficient to determine and reduce the human factor element in the FIM phases (and in particular the I-phase) of an offshore facility?

Although the human error databases referred to above could possibly be used for the FIM phases of an offshore facility, these databases are taken from different industries (nuclear and process industries) and specific data for the FIM phases of offshore facilities do not exist. Nielsen, et al. (1995) have therefore pointed out that simulation training might be useful for establishing data bases. Furthermore, Gudmestad et al. (1995) have indicated the usefulness of simulator training to reduce the human errors as the personnel obtain *skills* regarding how to handle difficult situations.

7. CONCLUDING REMARKS

This paper has covered a large number of topics without a great deal of attention to details. Its purpose is to highlight HOF aspects of the offshore working environment which influence safety during FIM phases.

The topic which begins the paper (safety culture) is one which is proving difficult to measure and is controversial in its definition and its content among industrial psychologists. However, it is necessary for industry to become involved in this debate as practitioners have first hand experience of safety culture. The organisation, management, supervisors and individual workers all play a part in the safety culture of an organisation. However, each of these have been addressed separately in this paper.

Reliability Directorate, 1988). The method uses judgement to assign a generic error probability to identified opportunities for error. This judgement must be supported by assumptions which can later be used as a basis for making recommendations as to how the error probabilities can be reduced.

Based on Rasmussen's (1993) three performance levels, Reason (1990) developed the following three categories of human errors:

Skill based slips and lapses - (Slips = Actions which are carried out incorrectly. Lapses = Errors which have resulted by the omission of an action).

Rule based mistakes - (Mistakes = The result of the failure of intended actions to achieve their desired consequences).

Knowledge based mistakes

Table 1 and Figure 4 give the generic human error data upon which judgements could be based. Figure 4 shows how the type of task influences the range of probabilities:

Skilled based - Tasks are performed without conscious control (after an intention has been stated). Distraction or preoccupation with another task can lead to slips and lapses.

Ruled based - Rule based tasks are procedural (IF conditions are .... THEN do .....), e.g., deciding whether the weather conditions are OK for lifting, or raising the hook only when instructed to do so.

Knowledge based - In an unfamiliar situation where there are no procedural rules or clear criteria for responding, the operator must base his actions upon his existing knowledge and experience. This usually involves trying to predict the consequences of actions, e.g., trying to work out what to do if an item gets stuck.

The ranges shown in Figure 4 and Table 1 demonstrate that a particular error probability is dependent not only on the type of task but also on the nature of the task demands and the characteristics of the individual (e.g., their skills and knowledge, perception of risks, stress).

Therefore, in assigning a particular error probability, a number of factors have to be assessed. These factors are described in more detail below.

Management and supervisors have been shown to play a major role in safety improvements and thus the training of them in HOFs is important. In addition they need to be given the resources (in particular time and money) to carry out their job effectively. Time constraints often lead to cutting corners and financial constraints often lead to a reduction in availability of correct safety protective equipment. In this respect contract format and selection of contractors are particularly important.

Group factors, such as communication between crew members, are becoming more important in the causal analysis of accidents and thus more emphasis should be placed on the investigation into this aspect of accidents. This could be done by drawing influence diagrams and identifying weak links between individuals and their organisations.

The emphasis on role of the individual in accident causation has been replaced by more emphasis on the responsibility of the organisation for safety. Emphasis is here put on organisational learning and new organisational trends. However, the worker at the front line is directly involved in the accident and they too are part of the overall defence plan against accidents. Training like using the BBSM method could be very fruitful in order to improve safety. Particular critical tasks could be identified for specific training programmes.

ACKNOWLEDGEMENTS

Additional Co-chairs and Core-group members of Work Group 2 are acknowledged for comments to the draft version of this paper:

Bernie Stahl, Amoco, USA, Stig S. Sand, DHI, Denmark, Karlene H. Roberts, Univ. of California, Berkeley and Catherine Hoffmann, MMS, USA.

Furthermore, those contributing to the discussion at the Workshop in New Orleans are acknowledged for their comments.

The authors and the co-authors would, express thanks to their organisations for permission to publish this Paper. It should, however, be noted that all statements made in the paper may not fully reflect the official opinion of their organisations and that these statements should be considered as basis for interesting and stimulating discussions.

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FIGURES

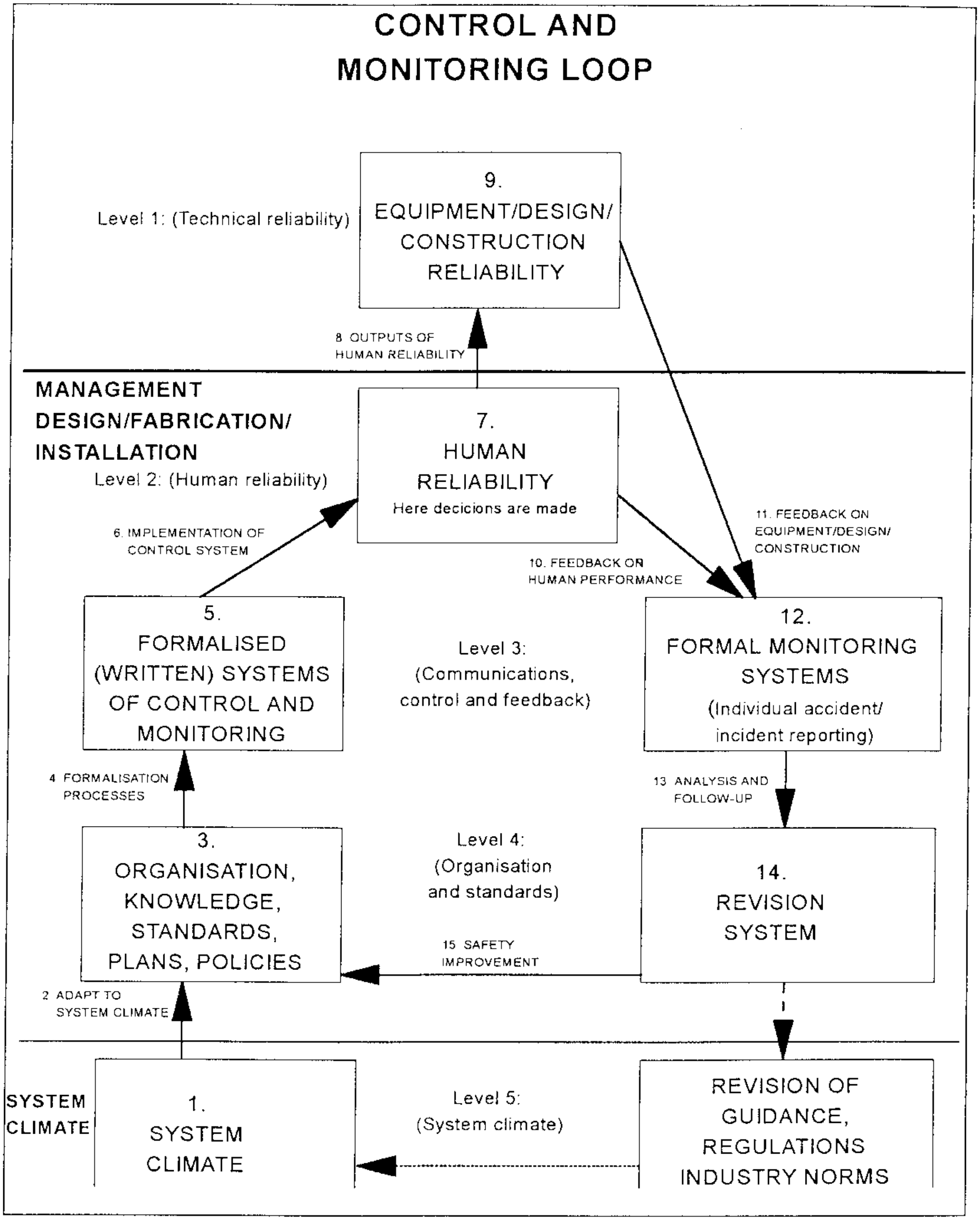


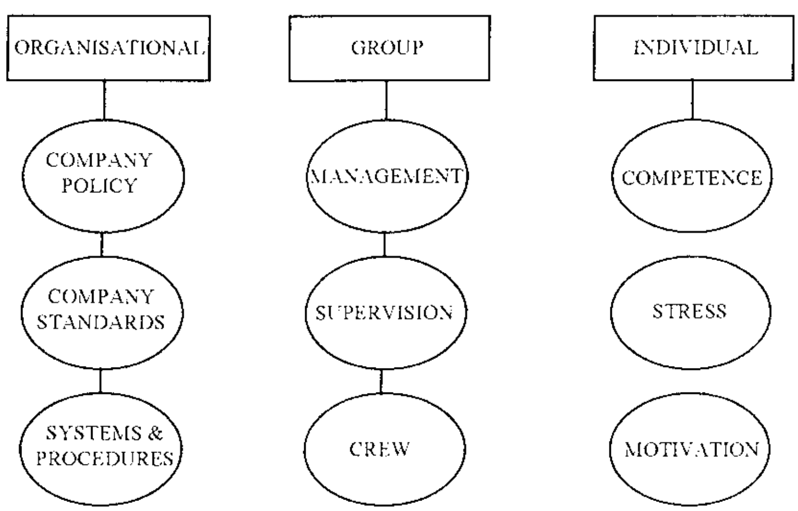
FIG. 1CONTROL AND MONITORING LOOP

(ADAPTED FROM THE AVRIM2 PROJECT, MINISTRIE VAN SOCIALE ZAKEN EN WERKGELEGENHEID, THE NETHERLANDS)

Figure 2
Relationships between
Human Error & Human Factors

- Human Errors
  - used to determine the immediate cause of the accident
    - skill, rule, knowledge errors
- Human Factors
  - used to determine the underlying cause of the accident

Figure 3
Proposed Coding Scheme



Note: from looking at accident reporting forms from various high reliability industries (aviation, marine and nuclear industries) the above coding scheme for the possible underlying causes of accidents has been proposed (Gordon, 1996).

Underlying causes of accidents could be coded under organisational, group and individual factors:

Organisational causes of accidents would include: faults in company policies, low company standards, systems and procedures.

Group factors would include: management weaknesses, supervisory faults and crew factors.

Individual factors would include the competence of the worker involved, possible causes for stress and whether the worker has the proper level of motivation to carry out the job.

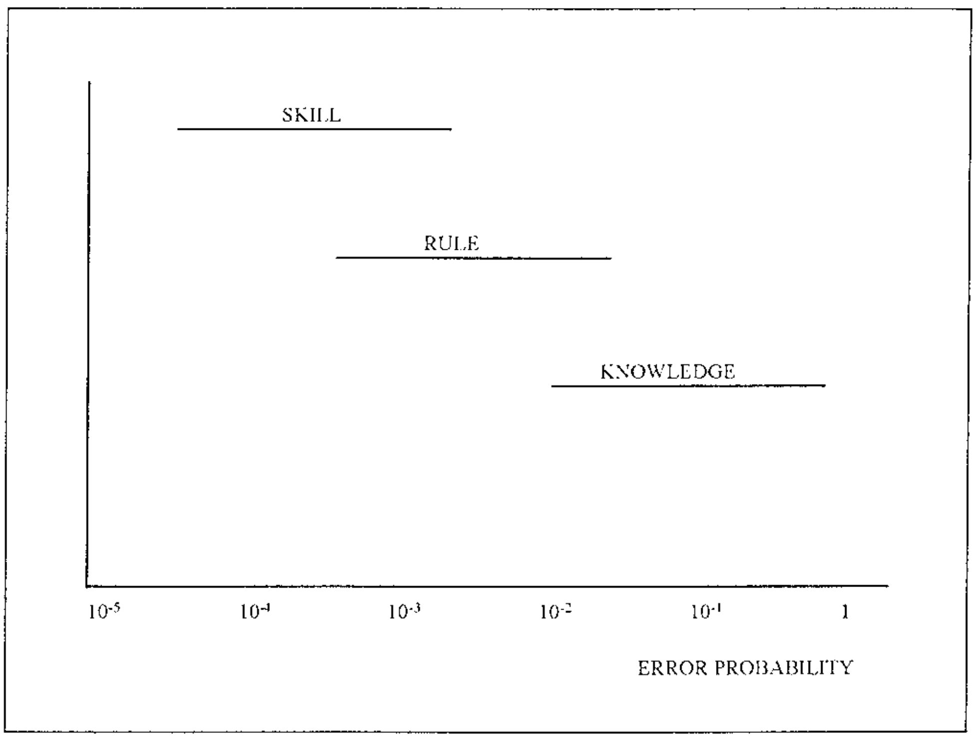


FIGURE 4

ERROR PROBABILITY PER TASK DEMAND ASSOCIATED WITH HUMAN BEHAVIOUR (WATSON 1986)

TABLES

Table 1: Selected Generic Human Error Rates (after Hunns and Daniels, 1980)

ERROR TYPE	TYPE OF BEHAVIOUR	NOMINAL HUMAN ERROR PROBABILITY
1,00	Extraordinary errors of the type difficult to conceive how they could occur: stress free, powerful cues initiating for success.	10^{-5}
2,00	Error in regularly performed commonplace simple tasks with minimum stress.	10^{-4}
3,00	Error of commission such as operating the wrong button or reading the wrong display. More complex task, less time available, some cues necessary.	10^{-3}
4,00	Errors of omission where dependence is placed on situation cues and memory. Complex, unfamiliar task with little feedback and some distractions.	10^{-2}
5,00	Highly complex task, considerable stress, little time to perform it	10^{-1}
6,00	Process involving creative thinking, unfamiliar complex operation where time is short, stress is high	10^{-1} to 1

Table 2: Multipliers for Performance Shaping Factors (From the Heart Technique - Williams, 1988; SRD, 1988).

Error-Producing Condition		Maximum predicted nominal amount by which unreliability might change going from "good" conditions to "bad"
1.	Unfamiliarity with a situation which is potentially important but which only occurs infrequently or which is novel	x 17
2.	A shortage of time available for error detection and correction	x 11
3.	A low signal-noise ratio	x 10
4.	A means of suppressing or over-riding information or features which is too easily accessible	x 9
5.	No means of conveying spatial and functional information to operators in a form which they can readily assimilate	x 8
6.	A mismatch between an operator's model of the world and that imadinged by a designer	x 8
7.	No obvious means of reversing an	x 8

	unintended action	
8.	A channel capacity overload particularly one caused by simultaneous presentation on non-redundant information	x 6
9.	A need to unlearn a technique and apply one which requires the application of an opposing philosophy	x 6
10.	The need to transfer specific knowledge from task to task without loss	x 5.5
11.	Ambiguity in the required performance standards	x 5
12.	A mismatch between perceived and real risk	x 4
13.	Poor, ambiguous or ill-matched system feedback	x 4
14.	No clear direct and timely confirmation of an intended action from the portion of the systems over which control is to be extended	x 4
15.	Operator inexperience (e.g. a newly-qualified tradesman, but not an "expert")	x 3
16.	An impoverished quality of information conveyed by procedures and person/person interaction	x 3
17.	Little or no independent checking or testing of output	x 3
18.	A conflict between immediate and long-term objectives	x 2.5
19.	No diversity of information input for veracity checks	x 2.5
20.	A mismatch between the educational achievement level of an individual and the requirements of the task	x 2
21.	An incentive to use more dangerous procedures	x 2
22.	Little opportunity to exercise mind and body outside the immediate confines of a job	x 1.8
23.	Unreliable instrumentation (enough that it is noticed)	x 1.6
24.	A need for absolute judgements which are beyond the capabilities or experience of an operator	x 1.6
25.	Unclear allocation of function and responsibility	x 1.6
26.	No obvious way to keep track of progress during an activity	x 1.4
27.	A danger that finite physical capabilities will be exceeded	x 1.4
28.	Little or no intrinsic meaning in a task	x 1.4
29.	High-level emotional stress	x 1.3
30.	Evidence of ill-health amongst operatives, especially fever	x 1.2

31.	Low workforce morale	x 1.2
32.	Inconsistency of meaning of displays and procedures	x 1.2
33.	A poor or hostile environment (below 75% of health or life-threatening severity)	x 1.15
34.	Prolonged inactivity or high repetitious cycling of low mental workload tasks	x 1.1 for 1st half hour x 1.05 for each or thereafter
35.	Disruption of normal work-sleep cycles	x 1.1
36.	Task Pacing caused by the intervention of others	x 1.06
37.	Additional team members over and above those necessary to perform task normally and satisfactorily	x 1.03 per additional man
38.	Age of personnel performing perceptual task	x 1.02

Table 3: **Time as a Performance Shaping Factor: Initial Screening Model of Estimated HEPs and EFs for Diagnosis within Time T by Control Room Personnel and Abnormal Events Annunciated Closely in Time (From Swain & Guttmann 1983)**

	T (Minutes after T^{+}_{0})	Median joint HEP for diagnosis of a single or first event	EF
(1)	1,00	1.0	--
(2)	10,00	.5	5,00
(3)	20,00	.1	10,00
(4)	30,00	.01	10,00
(5)	60,00	.001	10,00
(6)	1500 (= 1 day)	.0001	30,00

+ T_0 is a compelling signal of an abnormal situation and is usually taken as a pattern of annunciators. A probability of 1.0 is assumed for observing that there is some abnormal situation.

Table 4: **Modification of Estimated Human Error Probabilities (HEPs) for the Effect of Stress and Experience Levels (From Swain and Guttmann, 1983)**

		Modifiers of Nominal HEPs	
	Stress Level	**Skilled**	**Novice**
Item		(a)	(b)
(1)	Very low (Very low task load)	x 2	x 2
	Optimum (Optimum task load):		
(2)	Step-by-step+	x 1	x 1
(3)	Dynamic+	x 1	x 2
	Moderate high (heavy task load):		
(4)	Step-by-step+	x 2	x 4
(5)	Dynamic+	x 5	x 10
	Extremely High (Threat stress)		
(6)	Step-by-step+ Diagnosis	x 5 .25 (EF = 5)	x 10 .50 (EF = 5)
		These are the actual HEPs to use with dynamic tasks or diagnosis -- they are NOT modifiers	

+ Step-by-step tasks are routine procedural tasks. Dynamic tasks involve a higher degree of man-machine interaction such as monitoring and controlling several functions simultaneously.

APPENDIX I ACCIDENT REPORTING FORMS

Under Personal Factors, the codes on the majority of forms were listed under four headings:

- the capability of the person (mentally and physically)
- their level of knowledge
- whether they were under stress
- and whether they had the proper motivation to carry out the job properly

Under Job Factors, the codes were not generally listed under any particular heading, but we have divided the codes into:

- organisational factors
- management
- supervision and
- task factors

PERSONAL FACTORS CODES

- Capability
  - psychological
  - physical
  - concentration
  - memory failure
- Knowledge & Skill
  - inadequate training
  - lack of experience
  - lack of instruction
  - inadequate practice
- Stress
  - fatigue
  - monotony
  - frustration
  - health hazards
- Improper Motivation
  - lack of incentives
  - inappropriate attempt to save time
  - peer pressure

The codes listed under each of the four Personal factors include above items.

JOB FACTORS CODES

- Organisational
  - safety plan
  - working hour policies
  - competence standards
  - adequacies of systems
  - adequacies of procedures
- Management
  - planning/organisation
  - management job knowledge
  - bad management example/practices
  - staffing/resources
  - communication

The job factors were listed under 4 main headings. The first two were organisational and management factors.

JOB FACTORS CODES, CONT.

- Supervision
  - work planning
  - inspection
  - instruction/training
  - unclear directions
  - responsibility
  - performance feedback
  - supervisory job knowledge
- Task
  - poor job description
  - confusing directions
  - conflicting goals
  - time problems
  - unqualified or untrained worker
  - inadequate match of the person to the job

The second two were supervision and task factors.

APPENDIX II

MARS CASE STUDIES

The BBSM process was implemented for the Mars project at three different construction yards which, for the purposes of differentiation in this document, have been designated at yard Nos. 1, 2, and 3 respectively.

Yard No. 1 - Representatives of each craft area associated with the project made up the design team for the BSPs and the implementation thereof. The Steering Committee was responsible for all of the decision making in the process development and served to ensure successful implementation of the BSPs. Approximately 10% of the workforce was trained as observers and asked to perform a minimum of 20 observations per month.

BBSM Software, provided a system for observation data input, tracking and assessment. Yard No. 1 chose not to specifically recognise its worker's involvement with BBSM, however, at the end of the project, a luncheon was held to recognise all workers.

Yard No. 2 - Subsequent to an analysis of an anonymous survey, representatives of each craft were chosen to assist in the development, design, and implementation of the behavioural safety process, the majority of the process being developed and designed by Yard No. 2 safety personnel. The craft representatives were selected on the basis of their potential impact on the success of the process. In order to provide fresh input and to educate a greater number of workforce, craft personnel were rotated on a regular basis.

While data from personnel interviews was collected, the applied Correct Behaviour Inventory (CBI), was developed by the safety department. Having a management designed CBI made it less acceptable to the workforce. The CBI was also too general for use as a proper training tool and had approximately one-fourth the number of items used at other fabrication sites.

Approximately 10% of the workforce were trained as observers. There was an average of two observations per employee per month. Software was used to document the status of the process. A recognition process was implemented in conjunction with SOI's safety department.

Yard No. 3 - Since Yard No. 3 already was involved in the OSHA Volunteer Protection Program (VPP), much of the behavioural safety process was implemented at an accelerated rate and, in some cases, out of sequence. Major portions of the BBSM was developed by the existing Safety Committee who also functioned as the Steering Committee. Having a group of craft personnel already involved in the management of safety proved to be a great asset in the success of the BBSM process. Approximately 10% of the workforce was initially trained as observers and a semi-annual rotation of observers allowed expanded workforce participation. The observers were expected to complete 20 observations each month.

There were some initial problems in implementation due to a general lack of understanding of the process by the workforce. As was the case with Yard No. 2, subsequent to an initial survey, representatives from each craft were chosen to develop, design and implement the behavioural safety process. These representatives were selected based upon their commitment to safety, communication skills, and level of capability in their crafts.

Yard No. 3 decided to use a thorough CBI, (nearly 300 items in five safety performance areas), since it was to be used as a training tool for existing personnel, new hires, and contract labour. This approach assured a general awareness of the in-place safety performance standards. There was some initial concern about the observation cards being used as a disciplinary tool. Management assured the workforce that this tool would only be used in a positive manner.

BBSM software was used to record observation data. A quality control team was developed to maintain observer participation and observation quality. A recognition program was established to recognise observer performance on a monthly basis.

One of the yards made reference to workers regarding the use of observation cards as a disciplinary tool. In these cases, management must assure the workforce that this tool will only be used in a positive manner. In the past, safety programs which have rewarded only positive safety results have generated negative consequences in that people are reluctant to report minor injuries or near misses. This, in turn, generates inaccurate accident rate statistics. Therefore, *the program must be used to positively reinforce correct behaviours rather than to punish incorrect behaviours*. In addition, while conventional wisdom might indicate a goal of eliminating unsafe behaviour, such a massive task would be difficult to manage. Rather than attempting to eliminate all possible types of unsafe behaviour, it is a far easier task to enforce a limited number of acceptable behaviours. Finally, if the program is integrated with other tasks, the observation process will also appear to be less obtrusive.

SUMMARY

Data indicates that all of the programs were successful in affecting the workforce behaviour in a positive manner both short-term and long-term. The involvement in BBSM type processes has positively effected the percentage of employees not having an incident as compared to the fabrication industry as a whole. These employees worked at a 96 to 97% **accident free level** versus a bench marked level of 76 to 78% for fabrication yards in general.

[The accident free rating is based on SOI's desire to emphasis the positive aspect of the contractor's safety performance versus the traditional emphasis on incident quantities. The incident rate has been reformatted as a percent and subtracted from the number 1 (or 100%). An example would be a contractor's incident rate of 4.6 would become .046 (or 4.6%) and after subtracting from 100% would result in a 95.4% safety performance (1.0 - .046 = .954). Appropriate industry benchmark incident rates for fabrication contractors were also used as a comparison. This new scorecard measurement focuses, *in a positive aspect,* on the safety performance or the percentage of employees not having an incident.]

Still, common safety measurements related to the number of accidents or number of days without injury, while useful, can be misleading. When the accident rate is low, these statistics can lull people into a false sense of security even if risk taking exists within the organisation. This, in turn, can lead to more risk taking. On the other hand, if the ratio of safe behaviours to unsafe behaviours is used as a primary safety measurement, then the interest is on counting the number of instances of people acting safely and assuring that there is no risk taking. In this regard, the previously noted non-accident rates can be used primarily to determine if the correct unsafe behaviours are being addressed.

Observer participation increased an average of 33% by the end of the Mars project. This level of observer improvement indicates the positive effect that BBSM type processes have had on employee involvement in the safety process. Participation is the foundation for success in the observation process. The three yards improved the ratio of overall observed safe work behaviour by an average of 53% over the life of the project. Through the observation process, it is estimated that approximately 7000 unsafe acts/conditions were eliminated and approximately 3000 safety suggestions were made.

Sometimes it may be more difficult to justify the expense of a major change in safety programs when indecent rates are low. However, low incident rates make it increasingly more difficult to measure how safe an organisation is. By measuring safe behaviours, safety or a lack thereof can be monitored in the absence of incidents. This measurement can also dispel a false sense of security.

In addition, the expense related to the safety program should be considered to be an investment. Safety is good business. A strong safety program is justified by the related reduction in the potential risk for human suffering and the related direct and indirect costs. While the BBSM type programs require an initial investment in time, over the long-term, these proactive programs may actually require less time than the older reactive safety programs while offering a superior opportunity for reducing incident rates. Like bad habits, once safe habits are established, they are difficult to break. This should significantly reduce the level of required retraining. The BBSM also integrates the safety program into the overall day to day business process.

By implementing BBSM, these fabrication yards have decided to use the level of safe activities as well as employee participation and involvement as indicators to measure the success of their safety programs. Improvements are indicated by the amount of safe work behaviours being performed. Since, as a function of their participation in the behavioural safety process, workers are capable of self-evaluation, what is being effected is not only the worker's attitude toward safety, but also their habits. The end result should be a work environment free from unsafe conditions and unsafe acts as a matter of practice.

APPENDIX III INFLUENCE DIAGRAMS

a) **Influence diagram for relations between**

Regulator (R) - Operator (O) - Contractor (C) - Subcontractors (SC)

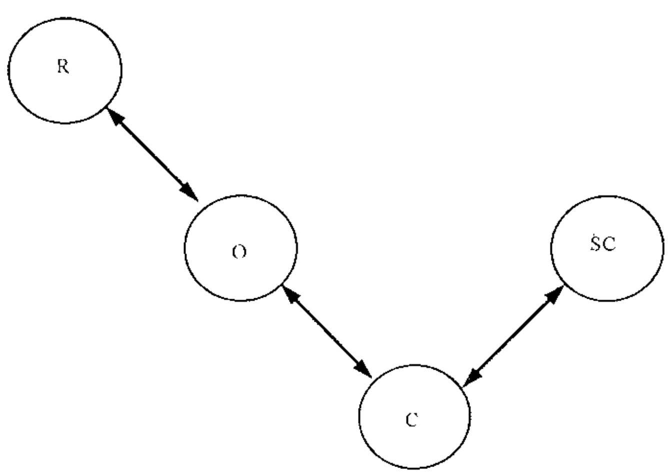
Weak HOF Links:

R ↔ O:
Communication
Trust
Education on regulatory issues
Decommissioning

O ↔ C:

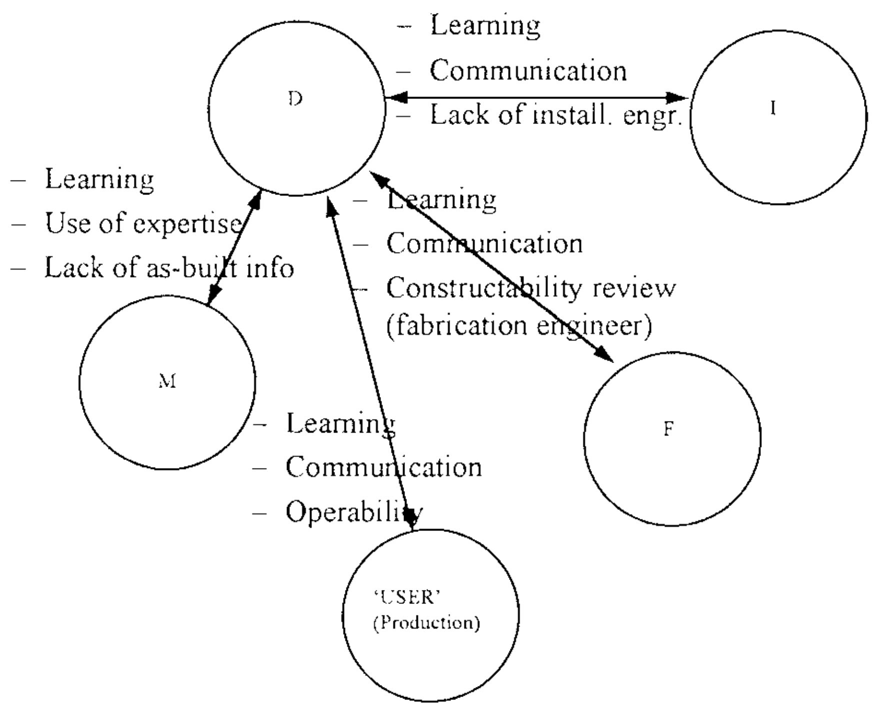
- Contract format
  - Selection of C
  - Incentives
  - Stress (schedule/budget)

- Goodness of info
- Communication
- Trust
- Experience of operator



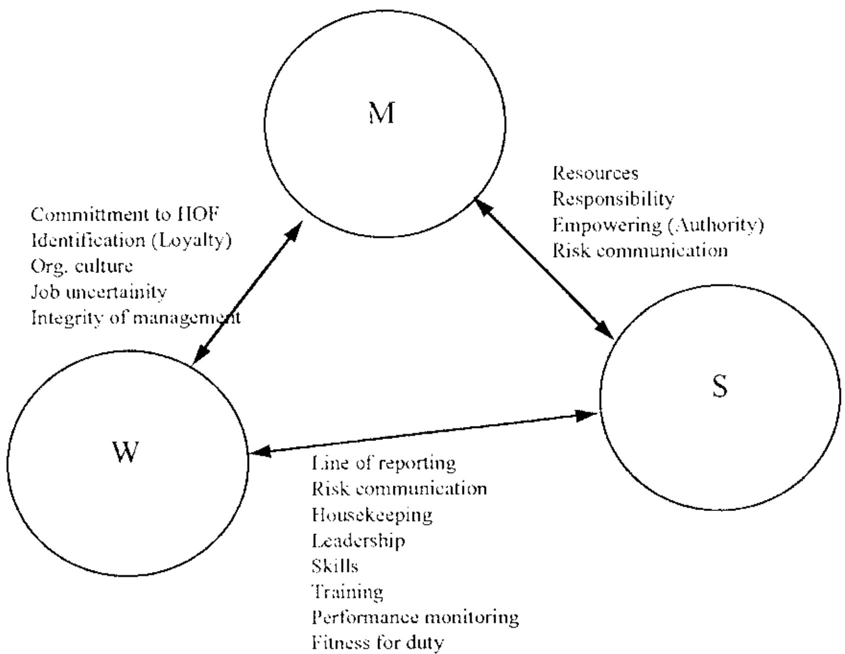
b) Influence diagram for relations between

Designers (D) - Fabricators (F) - Installation engr. (I) - Modification (M) - Users (U)



c) **Influence diagram for relations between**

Management (M) - Supervisor (S) - Worker (W)



V Contributions from Working Group Members

	Resposible
* HOF in Contracting (Guidance)	D. Aattwood
* Feedback to Designers (Practical recommendations)	B. Stahl
* Effective HOF in Alliances (Pros. and Cons. of HOF)	R. Gordon et. al.
* Mgt., supervisors and workers	R. Gordon et. al.
* Critical Tasks (list and identify)	M. Craigh

Improving offshore drilling, workovers, production operations and maintenance through practical application of human and organizational factors

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Abstract

The subject of this working group differs from the other groups in this book because improving offshore drilling, production operations and maintenance through human and organizational factors is not a well established branch of human factors as opposed to including human factors in design. This subject is in its infancy in terms of accumulated knowledge and good practice. As human factors professionals, we hope to be asked to contribute in a proactive way to engineering facilities i.e. design. Unfortunately, the more common approach of the offshore community is to include human factors reactively i.e. after the facility has been constructed. The group assigned to address this topic, has been essentially asked to make the best out of an existing facility by optimizing what is still able to be changed. Aside from the design, communications, management of change, and procedures can be optimized even after the facility is in operation. The tools which need to be applied in an existing facility are much more oriented towards organizational management and applied psychology rather than "hard science" human factors engineering tools.

To sort out some of the confusion of the wide range of topics which are addressed, there are two main categories of papers in this session:
1) facilitating offshore management and policies
2) facilitating actual operations on the offshore platform.

1. Facilitating offshore management and policies

1.1 Management of contract crews and policies

A. Scope of "contract crews".

There are a number of different types of contract crews working in the offshore Exploration and Production industry. The arrangement of exploration contracts is significantly different than those found on production facilities.

1. Contract Relationships Offshore

Production

Production facilities are generally run by the lease holder (operator) and might include "contract" employees that are supplied via a labor contractor and who fill positions that might be occupied by operator employees on other platforms and with other operators. In addition, there are a number of other subcontract employees who may spend very short to relatively long periods on the facility engaged in specialty work. Such work ranges from well servicing companies to repair calls for air conditioning, plumbing, etc.

Production Model

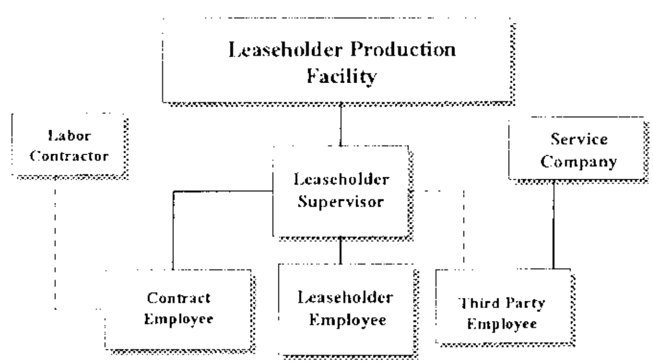


Figure 1.1 -1

Exploration

Exploration (drilling) facilities are generally owned and operated by the drilling contractor under contract to the operator. The drilling contractor, as owner of the rig (usually classed as a "vessel"), employs the large majority of people on board. The operator will have as few as two employees and, at times, ten to fifteen employees on board. Both the operator and the drilling contractor are held to be responsible for various facets of the safety of all employees on the vessel by different federal and international regulatory agencies.

During the course of the well or contract a large number of subcontractors, variously referred to as "third party contractors" are required on the site for services required by either the operator or the drilling contractor. As can be seen in Fig. 1.1 -2, both the operator and the drilling contractor can be using the services of third party contract employees on site. The situation can be somewhat confusing as to the lines of safety authority and responsibility.

Exploration Model

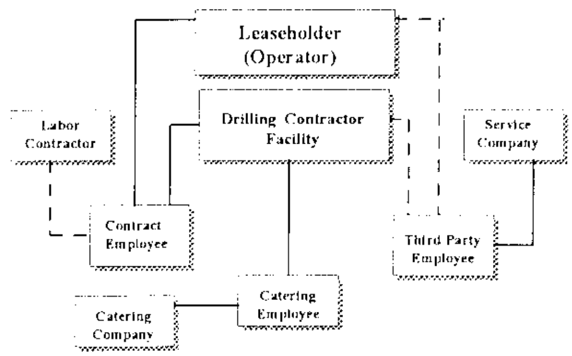


Figure 1.1 -2

2. Operator/Contractor

The interlocking relationship between a lease holder and a contract driller is extensive and generally lasts for the duration of the project (well or series of wells). There is generally a "bridging" process which is formal in some areas of the world and informal in others. That process defines the differences between the safety and operating procedures of the lease holder (operator) and the drilling contractor. Whether this process occurs before the start up of the well (spudding in) or during the initial working phases, both parties usually settle into a mutually acceptable pattern of responsibilities and operating procedures. Employees of both parties can become comfortable with their working teams and the schedule of safety meetings, pre-tour meetings, audits, etc. Depending upon the quality and safety expectations of both the operator and the contractor, this arrangement has the potential for developing long term mutual goals and procedures that stress safe operating practices in a team environment. Employees, once empowered by both parties, can take charge of their own safety "destiny".

3. Third Party Contractors

Problems arise with third party contractors who appear on the rig from anywhere from just few hours to, in some cases, several weeks. They frequently are given a brief orientation, given their room and lifeboat assignments, asked to stay out of the TV lounge during specific parts of the day and shown their work location. The very short term third party contractors usually belong to no work teams, form no friendships and have very little incentive to care for the safety of the rest of the crew.

Longer term third party contractors may form bonds with some of the crew and might even function on a team level within their area of work. However, there are few formal efforts to try to integrate the third party contractor into the daily safety system of the rig.

Supervision of third party contractors can be very confusing. Their supervision may be land based and hundreds of miles away, they may come with supervisors supplied by the third party company or they may be temporarily supervised by operator or drilling contractor personnel. Or it may be a combination of all three.

Frequently, third party contractors have just left someone else's rig with a different operator and a different drilling contractor. They are expected to work as quickly as possible using different procedures and with contrasting safety methods than used on the prior rig.

3. Scope for this Paper

For the purposes of this paper we will deal with only the exploration mode and the relationship of third party contractors to the operator and the drilling contractor. In general, there are significantly more employees required on a drilling rig as compared to a production platform and many of the situations can be adjusted to the production platform mode.

B. Examples

If this all sounds rather confusing, it is. It is often just as confusing to the people who have to make it work. Perhaps a few examples of operator/drilling contractor/third party contractor relationships might serve to explain further:

Short Term Third Party - Operator

A rig arrives on location and, after spudding in (starting the drilling process), a Welder is required to preheat the surface blowout preventer stack and assist in connecting the stack. The Welder must hold very specific qualifications and be experienced in the process. The certification and liability coverage provided by the various service companies that contract this kind of work make it outside the skill range of the usual rig-based Welder.

The Welder is contracted by the operator, arrives on the rig after spud, participates in the stack connection and is generally finished and gone from the rig in one to two days. Although contracted by the operator, the Welder works on or near the rig floor and is subject to the supervision of the Driller, an employee of the drilling contractor.

Short Term Third Party - Drilling Contractor

A Fire Equipment Inspector is hired by the drilling contractor to provide inspection and maintenance services for the rig's fire prevention and control systems. He spends two or three days on the rig, has unlimited access to most of the rig's areas and works with very little supervision. While on board he liases with the rig's Safety Representative.

Mid-Term Third Party – Operator

A Directional Driller is contracted by the Operator. He arrives shortly after the well is begun and he and his crew stay on the rig for 60% to 80% of the duration of the well drilling process. He reports directly to the operator's Company Man for general well progress and direction but is still subject to the authority of the drilling contractor's Driller while working on the rig floor.

Mid-Term Third Party - Drilling Contractor

A new Silicon Controlled Rectifier (SCR) system is installed on the rig. A representative of the Original Equipment Manufacturer (OEM) stays on the rig through the first 75% of the well drilled immediately after the installation in order to trouble shoot the system and to train the system operators and maintenance people. His activities are generally confined to the SCR room and the engine room. He works with the Rig Electrician but responds as high as the drilling contractor's Offshore Installation Manager (OIM) when there are system problems.

Long Term Third Party – Operator

Remote Operated Vehicle (ROV) Operators are hired by the operator to maintain a watch on a Semi-Submersible drilling rig's sub surface blowout preventer stack. They arrive on the rig during spud-in and stay until the well is drilled and ready for testing. They work under the general instructions of the operator's Company Man but must coordinate their activities with the drilling contractor's Offshore Installation Manager.

Long Term Third Party - Drilling Contractor

Typically, catering on board a drilling rig is contracted out to a catering company. Such companies provide skilled galley crew as well as cleaning crew for the quarters and the laundry. A "Chief Steward" or catering company supervisor is also provided. The Chief Steward will plan menus, order food and cleaning supplies, supervise the catering crew and will be the catering company's liaison with on board Drilling Contractor management. Catering companies generally report directly to the Drilling Contractor's Offshore Installation Manager. Their only involvement with the Operator's representative is making sure his favorite food is on board.

Special Cases

There are always "Special Cases" in every work situation. In the Operator/Contractor arena some are not that "Special" and occur with some regularity. Two are mentioned here to further describe the scope of the problem.

The first involves the fairly widespread use of "Contract Company Men" on offshore drilling rigs. The Company Man is the Operator's highest authority permanently assigned to the rig and he (or she) has the direct responsibility for all those areas affecting the Leaseholder. Even large Operators use the services of Contract Company Men on a regular basis. Such personnel are found through companies specializing in their placement or are independent consultants. Depending upon the current economic state of the industry, the work contracts are either well-to-well or they involve a longer term commitment.

The second crosses over the contractual relationship. On occasion, the Operator will request the Contractor to hire third party personnel to perform services for the Operator. The reasons vary from ease of accomplishing the task (it's quicker than going through the Operator's call-out system) to a greater understanding of the work to be performed on the part of the Contractor. This puts a Third Party employee (s) in the position of working for one company but reporting to another.

B. <u>Things Impacting Management of Third Party Crews</u>

1. Length of Contract

Third Party crews are often given only a few days or hours to go to a rig, complete the job and leave the rig to move on to another. They have very little time or motivation to learn and understand the safety management system of the rig and what is expected of their safety performance while they are on board. Even if they did, the probability is good that the last rig on which they worked was owned by a different contractor working for a different operator. There would be difficulties in shifting gears that quickly and remembering whatever safety system is currently in force.

Longer term contracts allow for greater integration of the Third Party crews into the safety management system of the Operator and Contractor. In addition, they have more time to form bonds with other on-board crew members and are much more likely to care about each other's safety.

2. Legal Responsibility

Most offshore contracts for direct or third party service include a "knock-for-knock" clause. Although it can get considerably more complicated in the explaination, it basically states that *"you're responsible for yours, I'm responsible for mine and we're both responsible for our appropriate third parties"*. In the event of an accident, the casing crew hand who is injured may sue his company, the Operator and the Drilling Contractor. The casing company will indemnify the Operator against loss and assume the costs of defense. Because the indemnity agreement between the Operator and the casing company extends to all those working for the Operator, the casing company will also usually indemnify and defend the Drilling Contractor. What has this got to do with the safety attitude and performance of all of those involved? Simply put, the more you directly control the actions of your third party personnel, the more you put your indemnity contract in jeopardy. While any legal opinion is certainly anything but absolute, it is safe to say that an Operator that ordered a third party employee to violate a safe procedure that the sub-contractor has informed him is unwise has certainly abrogated a substantial portion of his indemnification from the sub-contractor.

Any involvement by third parties in your safety management system must take this legal responsibility in account.

3. Delegation

The extent to which work activity is delegated to a third party must involve consideraton of the training and experience of the personnel involved. During usual activities on a rig it is not uncommon for supervisors to ask other third party employees to perform additional services.

4. Moral Obligation

No matter what the legal or regulatory implications are of an installation's Safety Management System, both the Drilling Contractor, as the owner of the vessel, and the Operator, as the leaseholder, have an obligation to all personnel on-board to provide a safe working environment.

Similarly, all personnel on-board have an obligation to each other to maintain safe working practices and to watch out for each other, no matter the employer.

5. Degree of Specialization

A number of functions offshore have become highly specialized. In our examples in Section B the ROV Operator and the SCR Manufacturer's Rep are specific instances where a Third Party Contractor's services are unique within tightly defined parameters. Although their general safety conduct while on-board can be addressed it is very important that their work activity be understood and integrated into adjacent simultaneous operations so that safety can be maintained. For example, the SCR Reps' need to shut down and re-start power in a particular area must include an assessment of operations in that area and a full understanding of Lock-Out/Tag-Out procedures. Also, because of the technical aspects of the job, the Operator and/or Drilling Contractor might have to take extra steps to assure the competency of the specialist.

6. Control of Process

Along with Degree of Specialization comes the question of who controls the actual conduct of the work. Certainly, within a highly specialized area, the actual control of the work must rest with the contractor sent out to complete the task. However, this does not abrogate the Drilling Contractor's nor the Operator's responsibility to coordinate that work with simultaneous operations that are affected. Similarly, the Operator may be conducting its own simultaneous operations that must be coordinated with the Drilling Contractor. An example might be a Drilling Contractor drilling over an Operator's platform while the platform is flowing gas. Extensive controls must be in place to safely conduct this kind of work and the control of process activity must be shared by both sides.

7. Size of Contractor

The size of the contractor may be a general indicator of the safety awareness of the contractor's employees. While there are small companies with excellent safety training programs and large companies with less than adequate safety performance, the opposite is more frequently the case. With some experience, an OIM or Operator's Company Man may take some training and knowledge for granted on the part of, for instance, a Halliburton employee. More care should be taken in assuring the safety competency of an employee of a firm without the apparent resources to conduct effective safety and technical training.

8. Motivation of Contractor

Certainly the amount of motivation a contractor has to create, conduct and monitor safety programs has a lot to do with the performance of its employees. The Drilling Contractor and the Operator can affect this motivation significantly by including safety performance as a strong factor in the bid process. Contractors with effective programs have made significant investments in these programs and this is reflected in their pricing structure. To accept less than minimum standards from your contractors in order to keep the price down will result in an unequal playing field for those who have made the commitment to dedicate resources to safe operations. Significant motivation can be found in a pre-bid assessment of vendor safety management systems with placement/removal of companies on an "approved vendor list" as the result of the assessment.

9. Turnover Rates of Employees Within the Same Contractor.

A high turnover rate of employees can certainly be an indicator of lower safety performance. Analyses of incidents and turnover certainly demonstrate a strong relationship between the two factors. Recently, the drilling industry has experienced very broad and rapid expansion after years of depressed activity. The pool of available experienced labor is non-existent and turnover at the entry level is very high. It is not unusual to see current turnover rates at the entry level of 75% or higher. Assessing a contractor's turnover performance in this market can be difficult and misleading. Perhaps the best way to proceed is to research the industry average at any particular time and then look at the relative performance of your contractor to gauge its performance. Certainly, a turnover rate of 1.5 to 2 times the industry average is an indicator of many performance issues, not the least of which is safety.

10. Geographical Location / Frequency of Use of Contractor

Of course, stability and long term relationships with a contractor will strengthen the mutual respect for safety between employees of the various parties on an offshore location. When the location of a MODU (Mobile Offshore Drilling Unit) changes, this quite frequently alters the "mix" on-board when contractors or their personnel change as a result of the move. Rather than break up the "crew", it might be more advantageous to work out an arrangement with individual contractors to maintain the same personnel. This might cost a bit more in travel expense and time but would be well worth it to maintain the "mix". Long distance moves put considerable stress on the teamwork built up between the rig crew and third party contractors.Start-up procedures at the new location should include particular attention to team building the new crew members to maintain a high quality of safety performance.

Of additional concern is the frequency with which a contractor is used at the same site. A contractor that conducts frequent business on your site is more likely to understand your approach to safety and the systems used to maintain a safe work environment. Contractor employees who work only occasionally at a site need extra attention in orientation and in the day-to-day conduct of the work until it is sure that they are familiar enough with the system to work on their own.

11. Cultural Differences/Political Climate

MODU's can work anywhere in the world subject only to water depth and harsh environment limitations. Cultural differences must definitely be taken into account for all employees on-board. It usually takes a significant amount of time to integrate local employees into your safety systems. In some areas of the world it may take significant time to just convince employees of the need for a safety program or safety management system. In addition, the local political climate may seriously interrupt employees' focus on the safety requirements of their jobs. It is difficult to keep one's mind in the game if their family is in jeopardy from civil uprisings, military action, political repression and the like. These conditions are undesirable for everyone on board and particularly for the contract employees, who are less connected to any support groups that may be on the rig.

12. Corporate Philosophy and the Contractor's Commitment to It.

A crucial element of any successful Safety Management System is top management's commitment to that success. Beyond the commitment, this corporate philosophy must be communicated fully to all employees and must be seen by employees to be a sincere commitment. A concept that is difficult to impart to employees is certainly much more difficult to pass on to contractors, who are not, by definition, a part of the internal communications system of your company. It has to be up to on-board management and, especially, on-board company workers to pass on their belief in the commitment to the contractor. We surely need to inform contractors of our commitment prior to awarding the work but, if feedback on-board doesn't support the philosophy, the contractor's commitment cannot be expected to be significant.

13. Participation Requirements and Recognition Systems

Most Operators and Drilling Contractors have requirements for their employees to participate in a number of routine safety related activities. These include Safety Meeting, Pre Tour Safety Meetings, Pre-Job (for Job Safety Analysis Review) Meetings, Safety Training, etc. Policies have been developed to provide extra time and pay for these activities and to log and monitor their occurrence. However, the same might not be true for the contractor. Participation should be required of the contractors on-board and this requirement should be worked out ahead of time with the contractor so that suitable provision may be made for the extra time and expense. We cannot hold the contractor responsible for participation and, therefore compliance with our programs, unless notification is made in advance and the subject of responsibility for time and expense is also worked out ahead of time.
As an adjunct to participation, contractor employees should be included in any recognition given to the rig for safety accomplishment. This is not an easy task, given the number of contractors who simply pass through from one rig to another, spending varying amounts of time on the rig. To the best of our ability, however, we should endeavor to select contractor employees who have a significant time investment in the rig's accomplishment and to include them in our recognition activities. If we are to foster a team effort on the rigs then we can't exclude a portion of the team when it comes time for the pat on the back.

14. Motivation Incentives

A number of Drilling Contractors have ongoing programs to reward employees for successful safety performance. They range from cash to apparel to gift certificates. As in the case of the need for inclusion in any recognition events as described in #13 above, contract employees deserve to be included in any motivation awards if they have made a significant time investment to the rig's success. Once again, this is easier said than done from a tracking standpoint and represents a considerable investment on the part of either the Drilling Contractor, the Operator, or both to conduct such a program.

15. Regulatory Requirements - Skill Competency

A number of regulatory jurisdictions have adopted an approach that requires leaseholders, drilling contractors and other offshore employers to verify the skill competency of those working on their sites. This takes a step beyond simply checking to see a license or other certifying document and asks that the employee actually demonstrate that competency to a supervisor who is, himself, qualified to assess that competency. Regulatory inspectors may also ask for a demonstration of that competency during the course of an audit/inspection of the site. This opens up some heretofore uncharted territory in the ability of an Offshore Installation Manager or Operator Rep.to assess the competency of a contractor's employee when it is in a function or discipline with which no one on board is totally familiar. Beyond questioning a contractor's employee as to his experience and training the OIM or Company Rep must currently rely on the contractor to actually assess the employee's competence.

To formalize this assessment process with contractors many companies have strengthened their pre-approved vendor lists by auditing the contractor's Safety Management Systems, their training and assessment programs, and their history and experience in providing qualified employees. Once established, the vendor list must be intact and must constantly be monitored.

D. A Suggested Approach to Working With Contract Employees

At a recent gathering of Contractors, Drilling Contractors and Operators at an operator sponsored safety conference, a working committee was formed to discuss the issue of contractor safety and how to integrate the many contractors on a site into the team already formed by the Operator and the Drilling Contractor. This working committee included representatives from two Operators, one Drilling Contractor and one Contractor.

In assessing various methods that had already been tried, the committee found a basic flaw in trying to integrate the short term contract employee into the whole rig's safety management system. Either the process was too overwhelming and compressed into a unacceptably short time span or too specific and limited to a rig entry/induction session that concentrated principally on what to do in emergency situations.

While a rig entry/induction is certainly necessary, it doesn't fit the need for integrating the contract employee into the rig's system for operating safely on a personal level. Programs that attempted to bring a contract employee up to a "rig team safety level quickly frequently only served to confuse the employee.

The committee decided that one approach would be to establish safety teams on the rig based on functional lines. Thus, a "Drilling Mechanics Team" might include the operator's Drilling Engineer, the Toolpusher, the Driller, Asst. Driller, Derrickman and Floormen. Similar functional teams might be Crane Operations, Engine Room, Maintenance and Marine. Each rig type would develop its own team definitions.

When a contract employee arrived on-board, he would receive a general induction and then be assigned to one of the functional teams. The team would then be responsible for integrating the contract employee into the safety system on the rig. Usually, the contract employee is asked very quickly learn how the whole rig is proceeding from a safety standpoint. The "team" concept will let the new contract employee can interact with the people with whom he will work to find out what simultaneous operations are occurring that are of concern to him, and what specific conditions will exist at his specific work site. He will also learn if "rookie" drilling contractor new employees are involved so that he may become part of the "buddy system" looking out for such employees.

The contract employee will attend all the different kinds of safety meetings affecting the team. He will be asked to participate as well a listen and to keep the team informed of the progress of his own work and the safety impacts of the work.

The obvious benefit of such an approach is to deal with the contract employee on a micro level rather than trying to assimilate him into the Safety Management System of the whole site. Thus, the "team" becomes instantly responsible for the contract employee and vice versa.

Thus far, the idea is simply theory. The intent is to implement this approach on an upcoming project. The largest hurdle to implementing the project will be to determine the nature of the "Functional Teams". They are definitely not that clear cut and will it will require some work with Operations personnel from both the Operator and the Drilling Contractor to develop workable teams.

1.2 Shift change and work schedules

Introduction

Exploration drilling rigs and production platform facilities run 24-hours a day. The remoteness of the operations from traditional living accommodations requires that workers live, eat, sleep, and work at the facility for extended periods of time. These schedules typically run from one week to multi-week schedules depending on the economics of transporting workers to and from shore.

Within these extended schedules, there are many variations of shift schedules, some similar to the rotational shifts for onshore 24-hour facilities. The most common shift duration used offshore is 12 hours on duty followed by 12 off duty (called a "12/12"). Some of these "12/12" schedules incorporate rotations from days to nights, while others do not. Local regulatory standards may limit or otherwise dictate the use of other schedules.

The design and implementation of rotational shifts is a significant human factors consideration which affects both safety and productivity. Studies have shown that shiftwork can have an adverse effect on worker health, performance and satisfaction. Human body functions are naturally regulated by a diurnal physiological system resulting in peak alertness during the day and peak sleepiness at night. Night and rotating shift schedules reverse normal wake/sleep cycles, resulting in reduced alertness at night which can impact night-time performance and disrupted sleep during the day. Reduced sleep can result in fatigue which can further reduce night-time performance. Human error is a primary consideration and is a major component of worker performance. In addition to these potential effects of shift work, the extended periods of time away from home which are necessary for offshore work schedules can also disrupt family and social relationships, causing domestic disturbances and increased stress.

The goal of selecting shift schedules is to arrange the working hours of employees in a way that will increase the performance of the worker and minimize the impact on their quality of life, while meeting business objectives. There is no ideal schedule - the design of an optimum shift schedule addresses physiological, social and operations requirements, as well as any applicable local regulations. Selection and design of shift schedules should be developed with worker input regarding length of the shift and rotation schedules before being implemented. Shift schedules should also developed by those with training and awareness of the effects of shift schedules on employee health and safety.

The objectives of this workshop are to discuss:

- the common types of shift schedules,
- potential problems with the schedules,
- ways to select shift schedules, and
- ways to help workers cope with shift schedules

reduce the potential human error associated with the fatigue of shift workers offshore.

Features of shift schedules

The most common shift schedule used in offshore oil and gas drilling production operations is the "12/12." Starting times may vary, although many use a 6 am to 6 p.m. schedule, resulting in day and night shifts. Some operations rotate the shift at mid-tour, so that a worker may begin on one shift and then switch to the other during a tour. There are various means of handling call-outs and overtime, all of which have important human factors implications related to fatigue and sleep deprivation.

A shift schedule is defined by the:

- length of the shift: number of scheduled consecutive hours in one shift (usually 12)
- length of tour: number of consecutive days of the shift schedule
- rotation pattern: way that the schedule rotates from day to night shift

Length of tour

Perhaps most influential on worker safety and productivity is the length of tour. Common tours include 7 days on and 7 days off, 14 on and 14 off, and so on up to tours which in rare cases may last a month or more. Variations also include "unbalanced" tours, such as 14 on and 21 off, although these are exceptions rather than the rule. Other variations in tour and shift schedule are made necessary by laws and regulations governing working conditions and may become the key determinant for schedule design. For example, in Australia the minimum rest between days or shifts is usually 10 hours, and 1.5 to 2 days of rest are required per week. Norwegian law allows no more than 36 hours per week on continuous shift work. Similar prescriptive limitations may apply in other locales.

The choice of tour length may also be influenced by economics. The longer the tour, the fewer crew changes necessary and thus the lower the cost of transportation to and from shore, and in many cases, to and from the workers home base which may be several thousand miles distant.

Some types of work such as hard physical labor, or work that involves exposure to severe environmental elements such as noise, vibration, or extreme temperatures, may not be suitable for 12-hour or 8-hour shift schedules unless adjustments are made to reduce exposure to physical risk factors. Adjustments could include reduction of the physical risk factors by design modification, or adjustment of the work schedule to control exposures.

Length of time off

Offshore platforms are complex facilities. The complexity of the operation may influence how critical the length of time-off is to worker performance. The more complex the process and the longer the length of time-off, the more resources may be needed to bring the worker up to speed on the events and current status of the facility. The length of time-off also may also be a factor in the deterioration of job skills and knowledge.

Day-to-night rotation pattern

On the typical offshore schedule of 12 on/12 off, the question comes up as to whether it is preferable to keep workers on the same shift for the entire tour, say two weeks, or to rotate. Although rotating shifts provide the opportunity for the worker to vary their schedule from day to night, there is no definitive physiological study which supports one option over the other. Some data suggest that night workers, who must sleep during the day, thus in conflict with the human body's normal body clock cycle, will gradually develop a sleep deficit, grow increasingly irritable, and have more trouble concentrating. This may be related to a lower quality of sleep for the night shift worker, or to other factors. Also, personnel who are permanently on night shift must continuously re-adjust for day schedules during their time off the installation. This suggests that a rotation to a day shift may be appropriate at some point in the tour.

However, there are other data which indicate problems of adjusting to a different sleep cycle at mid-tour may offset any benefits gained by limiting the length of the night shift schedule. Offshore operators have various approaches to the problem of dealing with the human body's circadian rhythm, each of which has its pros and cons. More data on the effects of shiftwork on human performance are needed to select a schedule that best meets physiological constraints of the human body. In addition, overtime and on-call arrangements have the potential to magnify the effects of sleep loss and fatigue.

Criteria for developing shift schedules

Shift schedules and tour length should be selected which best meet the following criteria:

- Physiological
- Social
- Applicable regulations/contractual agreements
- Business (e.g., costs, distribution of experienced personnel, time to "re-connect" to process)

Suggested processes for selecting and evaluating shift schedules

Workers should be surveyed approximately every two years to determine if the work schedule remains satisfactory. In addition, near miss reports and other types of audit systems can be monitored to identify potential problems related to shift work schedules. If a change in work schedules is required or under consideration, personnel who will be involved in the decision about shift work should be trained and provided with objective criteria to evaluate the current schedule based on physiological, social, and operations requirements, and local regulations.

Issues in supporting shift workers

It has been said that the offshore platform provides the ideal living environment for shiftwork. The sleeping quarters typically have no windows to let light in to disrupt the daytime sleeper. The noise and vibration level on a platform are uniform and constant and may even facilitate sound sleep for many workers. The eating and recreational facilities are designed to accommodate 24 hour a day operation and there is little or no change from night to daytime shifts. There is no family to disrupt sleep, no phone calls, no household repair jobs. Often when a shift is completed, there is nothing else to do but sleep. There is a good case that the offshore platform, like an Arctic outpost or a space shuttle mission, is the ideal environment for shift work.

Counselling can help workers adjust to shift schedules

The same factors that make the offshore platform ideal for shift work, are poor for supporting family and social lives of personnel. These same factors, of course, can have a negative influence on human performance. The sense of isolation of being away from family and loved ones for extended periods of time, of worrying about the welfare of the family, and the general feeling of being removed from the mainstream of daily social activity, all can have a depressing effect on the offshore worker. Well thought out shift and tour schedules give due consideration to these factors, make allowances in the work tasks expected of the workers, and include strategies to lessen the negative impacts on worker performance and safety.

Workers may be counselled on ways to cope with shift work. Specifically, the counselling should have covered the recommended diet and eating schedules and the importance of keeping physically fit and advice about how to get good quality sleep. Families should also receive counselling on how to support the shift worker in their life during the periods when they are home.

Coping with shift work is a rapidly evolving field. There has been a lot of research during the past few years. This research has resulted in many changes in recommended practices for coping with shiftwork. The content of the counselling regarding strategies to cope with shiftwork should be based on the most recent information.

Conclusions
In summary, it will undoubtedly continue to be true that shift work, and night work in particular, will represent a challenge in adapting the human to non-traditional working conditions. However, the offshore oil and gas industry has an overall enviable record in addressing these challenges. Continued effort to research and understand the human factors implications of shift work will be necessary to sustain a productive and accident-free record.

1.3 Auditing Techniques for Field Operations

Using tools for finding latent system induced errors in existing offshore facilities

The prevention of accidents depends on identifying existing site problems before they develop into situations that could result in severe adverse consequences. Problems are identified and detailed during in-depth accident investigations and reports, but since accidents are infrequent this type of information is relatively limited. Information about potential problems is also available from other sources such as near-miss reporting systems, or other auditing systems that function to identify problems before they are associated with an actual adverse consequence. Auditing systems are a general technique for checking how a particular system is working and for identifying potential areas of improvement. Existing auditing systems can be modified to incorporate techniques for identifying human factors related problems, or auditing systems can be developed to address human factors related problems directly.

An auditing technique should include the following features:

- Practical to apply
- Reliable
- Has resolution to identify important problems
- Incorporates a complete feedback loop that includes features such as:
    - initial benchmark
    - measured performance
    - periodic or as needed audits
    - comparison of measured performance to benchmark
    - analysis that points to potential improvements
    - tools that assist in prioritizing and evaluating alternative solutions
    - approaches to judging the effectiveness of implemented improvements

Effective auditing techniques can be used at each of the organizational levels. Auditing techniques at each of the organizational levels accomplish different objectives as described by the table.

Organizational Levels
Government
Multi-company groups
Companies
Sites
Workgroups
Individuals

Table 1 Auditing Techniques that can be used at various Organizational Levels

Organizational Level	Technique or Tool	Example of Technique or Tool	Function	Potential Advantages of the technique (from site point of view)	Potential Problems with the technique (from site point of view)
government	required accident report required program elements	SEMP PSM	standardize critical information across industry basis for formal investigations such as accident causation or safety case	in depth investigations yield much technical information investigations can be distributed to public domain for sharing information identifies situations that do not meet legal requirements	may be time consuming without direct benefit to a site for up to years emphasis place on specific incident rather than general patterns does not usually address human factors issues in detail
multi-company "consortium"	accident and incident database	Synergy Database (Rogaland Research Institute-Stavanger)	collection of human-factors details of incidents	historical data available for trending learnings available to member sites voluntary participation	no feedback/ assistances may be time consuming without direct benefit requires company support for database maintenance and distribution of information

continued Table 1

Organizational Level	**Technique or Tool**	**Example of Technique or Tool**	**Function**	**Potential Advantages of the technique (from site point of view)**	**Potential Problems with the technique (from site point of view)**
company proprietary	accident and incident database	GUARD (Shell)	collection of human-factors details of incidents	historical data available for trending learnings available to member sites	may be time consuming without direct site benefit (e.g., direct problem solving) requires support for database maintenance and distribution of information
site	incident investigation system	site incident reporting and investigation system	learn from site incidents proactively identify and solve potential problems	learn from site incidents analysis and response to incident directly affects site can direct site improvement efforts toward site trouble areas	may not satisfactorily include human factors considerations
	Site reporting systems that identify potential for error	Site's near miss reporting system DUPONT STOP program	proactively identify and solve potential problems (latent errors)	potential for much data because events happen more frequently can direct site improvement efforts toward site trouble areas	success is dependent on site culture and system

continued Table 1

Organizational Level	Technique or Tool	Example of Technique or Tool	Function	Potential Advantages of the technique (from site point of view)	Potential Problems with the technique (from site point of view)
	Tools to help site identify potential for error	TRIPOD (Shell) HFAST (Exxon)	proactively identify and solve potential problems (latent errors)	does not rely on events for analysis can direct site improvement efforts toward site trouble areas	requires personnel time away from operations
site systems and work groups	HF considerations incorporated into safety audits	HAZOPS with HF considerations	incorporates HF considerations into an existing site process	captures potential for error in relation to process-specific conditions	requires training or specialist support
	Audits of other systems	many tools depending on the work system of interest: work permitting, lock-out/tag-out, housekeeping, training, procedures, etc.	checks existing safety systems to determine if site/workgroup systems are functioning properly	confirms that site systems are working as intended identifies site specific problems with safety systems	success is dependent on site culture and system
individual personnel	observation and reporting on individuals	programs for safe behavior observation and reporting independent verification techniques	identifies potential problems with safety procedures, work practices, etc. that individuals choose to use	can fine tune individual safety behavior	success is dependent on site culture and implementation approach

Since the focus of this workshop is auditing of field operations, the remainder of this paper addresses auditing techniques and tools that are used for the site, workgroups or individuals, to identify and fix existing or potential latent errors in field operations, which will be further explained in section 1.5.

Potential Issues with Implementing Auditing Techniques

There are several potential issues with implementing auditing techniques. Issues concern the design of the auditing technique itself (such as type of data collected and how it is analyzed and used) as well as how to introduce the technique to site operations. The implementation plan should include an exercise in which potential barriers to successful implementation are identified and then the implementation strategy can be adjusted to overcome the barriers.

Employee perceptions

One typical barrier is that site personnel may perceive the auditing technique a "flavor of the month," or "another program" that will come and go. Approaches to overcome this type of barrier include: integrating the technique with existing site systems, and using a good employee involvement strategy to develop and implement the technique. Other potential barriers include how employees perceive that the data will be used, how operations will be affected, and the level of technical expertise or time commitment required of the participants.

Selecting scope of implementation: site, site system, work group

With regard to the technique itself, several potential issues such as how the technique will be introduced and how/if it will be tested. Testing gives the opportunity to adjust and improve the implementation of the technique and the technique itself before it is applied widely. In addition, sites should consider resources needed for the preparation, training, and follow-up that may be required to implement the various auditing techniques.

Auditing techniques for field operations at site level

Identification of latent errors

At least two types of tools have been developed to help sites identify situations that could contribute to latent errors, TRIPOD (Shell) and HFAST (Exxon). Both tools are designed to be used by site personnel, and categorize the situations to help sites identify underlying safety problems and conditions that could contribute to latent errors.

TRIPOD (Shell)

The following description is excerpted from Gordon's chapter on Contribution of Human Factors and Human Error to Accidents.

TRIPOD was developed to highlight the importance of underlying factors in the causation of accidents. Underlying latent failures are central to the ideal of how accidents happen and are referred to as General Failure Types, which include

- hardware
- maintenance
- error enforcing conditions
- incompatible goals
- communication
- defences.
- design
- procedures
- housekeeping
- organization
- training

These General Failure Types often lead to specific unsafe acts and triggering events. In order to assess the state of an organization or activity in terms of its underlying latent problems, an instrument was developed, called a Failure State Profile, to measure the extent of the underlying problems on the basis of a sample of the General Failure Types.

TRIPOD is a tool in which rig personnel can rate their rig with a questionnaire. For example, in previous uses of TRIPOD, rig personnel rated training, defences and hardware as the least important General Failure Types. In other words, the responses of the rig personnel to the questionnaire indicated that they did not consider training, defences and hardware as significant underlying potential problems for safety. TRIPOD is also used in a more proactive approach for predicting human errors and is explained in section 1.5.

HFAST (Exxon)

The HFAST tool is composed of several statements that are rated by a site team. The statements are designed to identify various situations from design to behavioral that could contribute to latent errors. (These situations are also known as factors that can influence human performance, or Performance Influencing Factors). The team response is compiled and opportunities for improvement are categorized into the following topics:

- process control system
- task preparation & job design
- training
- work practice verification
- work group support
- new design & modifications
- control room design
- field workplace
- procedures
- feedback to personnel
- communication
- shift schedules
- information systems
- near miss systems

Each section of the report explains the significance of the topic in relation to potential for human error, summarizes the issues relevant to the site, and suggests how to follow up on issues and plan improvements. More detail on HFAST can be found in another paper.[5]

Near Miss Reporting

A near-miss system defines a near miss and specifies how near misses are to be reported and managed at the site. An important human factors aspect of the near miss system is how the near miss reports are analyzed, and how they are used to identify potential for error in operations. A near miss reporting system may have the following objectives:

- Gives insight into methods for reducing the likelihood of incidents by reducing error inducing factors and improving the potential for recovering from an error
- Increases the set of possible incident scenarios through discussion and awareness. Promotes a preventive, rather than reactive, mind set.
- Functions as a reminder to act safely through the acts of recognizing and reporting near misses.

The construction of the near-miss system should be based on guiding principles. These principles should be in place or attainable if the site wishes to pursue an effective near miss reporting system.

Examples of guiding principles for a near miss system
Provides learning at all organizational levels.
Focuses on systems, not individual people.
Integrated in existing systems.
Includes near misses that involve technical/human/organizational/managerial factors.
Requires feedback loops at all levels.
Requires management support.

There are three key components of a near miss system:

1. Near Miss Reporting Process
2. Near Miss Analysis
3. Communication and Follow-up

There are basically two approaches to near miss systems: a thorough reporting process which captures many details of the near miss occurrence and takes time to complete, or a quick reporting process which indicates broad areas that relate to the

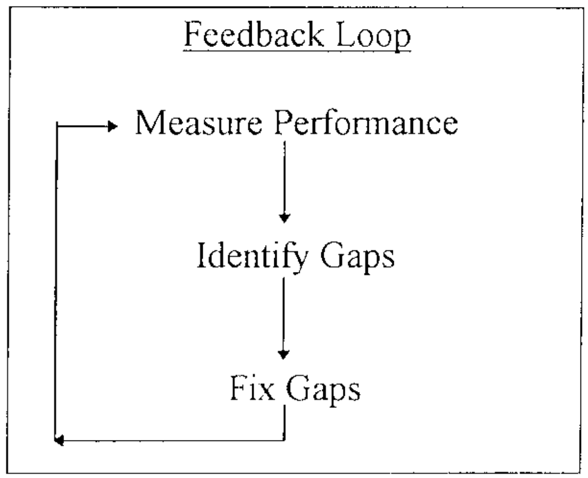
[5] Pennycook, W. & Danz-Reece, M. Practical Examples of Human Error Analysis in Operations. 1994 Society of Petroleum Engineers Conference Proceedings.

near miss occurrence. Depending on the type of near miss reporting process, the analysis process also varies. Whatever the near miss analysis process involves, it should provide tools for identifying trends of potential problems and for prioritizing them.

Auditing techniques for field operations at site systems/workgroups level

Feedback loops

The key to success in auditing site systems is to apply a feedback loop that:
1) measures performance,
2) identifies gaps by comparing actual performance to desired performance and,
3) fixes the identified gaps.



Then, the loop starts again with Step 1.

The expected result is less potential for error, achieved by closing the gaps between expected and actual performance.

Site systems that are in place and operating may be missing the "check" step of the feedback loop that verifies that the systems are working properly. Completing the feedback loop provides confidence that systems are actually working and provides a basis for improving the system. This approach can be used to ensure that site systems such as work permitting, lock out tag out, and effectiveness of maintenance performance are functioning properly.

Measure performance

Common problems:
- selected measurement is not specific enough
- measurement is not objective
- measurement is affected by many other variables

Collecting meaningful data is the foundation of the feedback loop. One must know exactly what to measure so that performance can be objectively evaluated against criteria, so that improvements can be measured. Measurements that indicate how the system is working should be defined with input from users of the work practices systems. A site procedure for collecting measurements on work practices can help ensure that measurements are consistent and can be accurately compared. Periodically the measurement techniques should be assessed to make sure errors are not creeping into the measurements.

Identify Gaps

Common problems:
· structure is not in place to periodically identify gaps
· desired performance has not been defined

A gap is the shortfall between the actual performance and the desired performance. With assessments, it is important to think about tests of both people and the system. If a person is not using the work system properly, retraining may be the answer. However, if several people are not using the work system properly, then fault may lay with the system itself and more fundamental changes may be required. If more than one person is having problems with a site work system, it is probably not the fault of the individual person, but rather the fault of the system itself.

Develop Appropriate Solutions

Common problems:
· the effectiveness of solutions are not systematically evaluated
· insufficient plans in place to share lessons learned

Develop and implement solutions that are targeted to close the gap. Check the effectiveness of each solution by measuring the system performance when the solution is implemented. Compare this performance with the desired performance. Then, adjust the solution to address the remaining gap.

Examples of site systems that would benefit from feedback loop

The feedback loop is well suited as a framework for implementing auditing techniques that can identify potential problems in many site systems, for example, work permit, lock out tag out, and procedures.

Work Permit

The feedback loop can be used to audit the work permit system and potential human factors related problems with the work permit system. For example, test the use of hot work permits by contractor personnel. Although construction personnel are given initial training for the use of hot work permits, only through follow up can one verify that this initial training is adequate, and that aspects of hot work are being complied with.

Lock out - Tag out

The feedback loop can be used to audit the lock out tag out (LOTO) system.

- Define measures that can be used to indicate the performance of the LOTO system.

Examples of Measurements
Number of violations on inspection
Number of LOTOs executed properly over a specified time period
Number of near misses and/or incidents in which use of the LOTO system identified as a contributing factor
Scores by LOTO users on tests about their knowledge of work permit practices

- Develop a process to compare measured performance to criteria for effective LOTO systems. The process should include methods to collect and address feedback from the users of the system.

- Ensure that an established methodology exists to address gaps and implement improvements to the system.

One approach is to ask a supervisor to review the LOTO of the most recent work performed by a member of the crew. Some things that may be identified are poor training, improper locks, inadequate number of locks, unclear or poorly written tags, or poorly documented procedures. One test each week by a different supervisor will provide enough data to verify that this system is working properly.

Procedures

Procedures should be periodically audited to ensure that they are being used as intended. There are six types of audits that can be conducted on procedures:

1. Technical - Determine if procedures are accurate and complete.
2. Quality - Determine if the appropriate format and style is used.
3. Effectiveness - Determine if procedures are used as intended and are errors infrequent.
4. International Standards Organization (ISO) - Determine if you are doing what you wrote. (Note: ISO audits don't address if what you are doing is right, only if you are doing what you wrote.)
5. Compliance - Determine if you are complying with the letter of the law and industry practice/norms.
6. Combined - Includes two or more above the above types.

To identify potential human errors that may be overlooked by the more traditional audit techniques and those arising from a failure to follow the intended procedural steps, a process hazard evaluation technique may be needed. A HAZOP or what-if analysis that is structured to address procedures can be used effectively for this purpose.

Auditing techniques for field operations at individual personnel level

Behavioral

The feedback loop can be used to help improve compliance with safety practices. Check safety practices to determine if there are problems with implementing them. For example, personnel may not perceive some safety practices as practical to apply.

- Define measures that can be used to indicate compliance with safety practices.

Examples of Measurements for Site Safety Practices
Percentage of work observations where personnel are using proper safety practices
Number of near misses or incidents in which "safety practices" was a contributing factor
Scores by personnel on tests about their knowledge of site safety practices
Number of safety practices identified as not practical to apply
Number of safety practices identified that could be improved

- Develop a process to compare measured actual performance of site safety practices to the desired performance. The process should include methods to collect and address feedback from the users of the system.

- Establish a site process to address gaps and implement improvements to the system. For example, behavior modification programs contain components which modify behavior through positive reinforcement to employees for proper safety behavior.

Independent verifications

A more structured observation approach called "independent verification" can be used for monitoring LOTO of equipment with potentially severe consequences, such as high voltage equipment. Independent verification is the practice of checking the LOTO for conformance to established criteria by a qualified person other than the one who performed the LOTO. It is preferable that the verifier checks the LOTO after it has been set up, instead of observing the other person setting up the LOTO. The independent observation by the verifier increases the probability that he/she will detect a problem with the LOTO. If independent verification is not possible, then the verifier and the person who is executing the LOTO can simultaneously check the LOTO steps as they are performed and concur that each step has been completed correctly.

Closely related to the practice of independent verification is self-checking, a risk management tool designed to reduce human error. By teaching workers to focus their attention on the details of the task at hand self-checking becomes an ingrained work practice. Self-checking helps to ensure that the correct unit, train or component is identified for work, and the intended action and expected responses are reviewed before performing the task. One example of self checking is called STAR: Stop--Think--Act--Review.

Example: STAR
Stop -- Think -- Act -- Review

1. **Stop** before performing the task to eliminate distractions and focus attention
2. **Think** about the task, the expected response, and the actions required if the response does not occur
3. **Act** by reconfirming the planned task and then perform the task
4. **Review** by comparing the actual response to the expected response

1.4 Using human error classifications schemes to predict error and improve behavioral safety processes in offshore operations

Research has shown that in the oil and gas industry there is a continual presence of error-producing factors. These factors do not cause incidents but they do indirectly contribute to their occurrence. In recent years most organisations have implemented comprehensive safety measures. Initiatives such as ESM and Unsafe Act Auditing (UAA) have contributed to a fall in recordable incidents. However, almost no organisation has reached a consistently flawless level of incident occurrence. This is because no matter how well an operation is run, error producing factors will always exist. Factors include time pressure, continual operational changes in a dynamic environment and the fact that over time, known risks are underestimated.

Although these factors ensure that incidents will continue to occur their end result can be controlled to a certain degree. If the organisation is working safely and efficiently the potential of incidents arising from such factors will be reduced. High quality operations are more adept at dealing with crises than organisations pushed beyond their limit. In poor quality operations a small crisis is often the straw that breaks the donkey's back, and something that started out as relatively insignificant becomes a full scale disaster.

Addressing the problem

Error-producing factors can result in either technical or human failures. Over the years much work has been done to improve the technical aspects of operations. As technology has progressed machinery and equipment have become more reliable and safer to operate.

Very little, however, has been done with regard to failures of a human nature. If anything, human error has been used as a scapegoat when no other causes for an incident could be identified.

Research has confirmed that humans will always commit errors. This does not mean that all humans commit the same types of errors. Inexperienced people, for instance, tend to make slips or lapses, e.g. fumbled gear change, exiting a motorway one junction too early or late. Highly experienced people, on the other hand, are more likely to commit violations. Violations are deliberate deviations from a planned action sequence. They are often caused by a persons superior understanding of an operation. It is therefore impossible to label a particular type of individual as prone to making errors. Often, the best personnel make the worst mistakes.

However, since errors can never be entirely eliminated, organizations must learn how to manage them systematically. An organization can either take a proactive or reactive stance against errors. Two proactive approaches are auditing existing systems and redesigning systems to be human error tolerant. A reactive approach would take the form of identifying generic root causes in incidents that can give rise to similar problems in the future.

The proactive approach of auditing existing systems along with examining types of human error is the primary focus of this section.

Incident causation: active and latent failures

Analysis reveals that there is rarely one single cause for an incident. Most incidents are caused by a combination of two types of failures. Those that are made at the sharp end of the organisation (active failures) and others that have their origins in the decision-making part of the company (latent failures).

Although incidents are caused by a combination of active and latent failures they are often blamed on human error as it is easier to find fault in an individual rather than with an organisation.

Active failures (human errors) come in many different forms, and are therefore hard to predict. Active failures occur at the worksite, e.g. rig or production floor and most are attributable to human errors, committed by shop floor personnel. Since active failures are hard to predict, they are and therefore hard to eradicate.

Latent failures are continually present in the organisation and normally remain hidden until an incident occurs and draws attention to them. Latent failures often stem from decisions made at a much earlier time. These decisions may have been correct at the time they were made, however, in a dynamic environment such as the oil and gas industry, yesterday's best decision can be tomorrow's worst source of error.

Even though the occurrence of some active failures will be inevitable, their effects can be reduced considerably by eliminating as many latent failures as possible. An organization should aim at identifying and reducing latent failures so that when the inevitable active failure (human error) occurs, it does not result in an incident.

By examining a typical incident the difference between the two types of failure becomes clear:

Example: Accident description

To meet a production deadline a supervisor assigns a man to help another team of workers loading sacked chemicals. The man has been newly employed, and has not yet received his full HSE induction. Due to the urgency of the work he is given only a brief site induction and is not aware that the chemicals are corrosive. One sack is damaged, and while cleaning up the spillage the worker suffers burns to his hand from coming in contact with the chemicals through a torn working glove.

Active failures

- damage to the sack containing chemicals
- failure of the glove to protect the worker's hand

Latent failures

- lack of competence (failure in HSE induction and site induction)
- production goals promoting short cut in site induction

In the example there is questionable work practice and poor decision-making. The reasons for this may be numerous, e.g. lack of procedures, pressure from management to meet deadlines, lack of training, etc. Furthermore, over time in a changing world with work practices continually advancing the effects of decisions previously made can be reduced.

Human error classification schemes

Part of being human is to err. Extensive research in the field of human error has revealed what we all know; that human beings have always and will continue to make errors. There are several types of human errors:

Slip:	An unintended deviation from a correct plan of action, e.g. knocking over a glass while attempting to pick it up.
Lapse:	Omission/ repetition of a planned action, e.g. forgetting to wear a hard hat.
Mistake:	Intended action inappropriate to the circumstances, e.g. attempting to open the front door with the back door key.
Violation:	Deliberately breaking a rule to achieve a goal; e.g. exceeding the speed limit.

Human error is often the trigger of an incident and is implicated in four out of five active failures. Another error classification scheme by Embry (1990) categorizes error into these categories:

Action errors: Examples include actions which are too long or too short, right actions carried out on the wrong object, actions, omitted, etc..
Checking errors: Omissions of required checks, carrying out the wrong check on the right object, etc.
Retrieval errors: Errors concerned with the retrieval of information from visual displays, procedures or memory.
Transmission errors: Errors which occur during the transmission of information between individuals.
Selection errors: Errors in situations where an object has to be selected or a choice made when there are alternative objects which could be erroneously chosen.

Embry uses a Human Error Analysis combined with a task analysis for systematically predicting errors in tasks which lead to quality lapses.

The task steps which are selected for evaluation are first subjected to a pre-analysis to eliminate broad classes of errors which are ruled out by the specific task conditions. For example, if no checking is involved during a task step such as closing a valve, then checking error is not possible. The detailed analysis then asks the analyst a series of questions relating to each of the task steps i order to identify whether any of the error modes specified in the error classification described is possible.

This method of analysis identifies hum errors <u>within a task</u> but does not directly deal with outlining solutions.

In order to help an organization systematically prevent human error, a more macro approach rather than a task approach must be used. The macro approach must analyze the organization/operation as a whole unit in order to understand where the major classes of error lie, so that predicting error does not have to be task dependent.

Some of the major classes of latent errors or faults in an organization can be easily linked back to human error, while others are much more difficult to trace but are ultimately the result of human error.

Assessing error and systematically tackling it within an organization

One of the most well cited error classification schemes is called Tripod. Shell International Exploration and Production sponsored this research effort. The Tripod Theory originated from research by the Rijks Universiteit Leiden in the Netherlands and the Victoria University, Manchester England into the contribution of human behavioural factors in accidents. Currently, two applications have been developed based on the research: Tripod-DELTA, a diagnostic tool for accident prevention and Tripod-BETA, a PC-based tool for analysis during accident investigation, explained in section 1.3.

Tripod-DELTA distinguishes itself from other safety approaches in that it does not concentrate on preventing active failures. It concedes that humans are bound to make errors and that equipment can fail. Instead it focuses on latent failures that cause incidents. Tripod-DELTA is a system that exposes latent failures and facilitates their removal from an organisation.

Accident Causation Sequence

The line of causality connecting from errors to latent failures and the main intervening factors are illustrated in Figure 1.

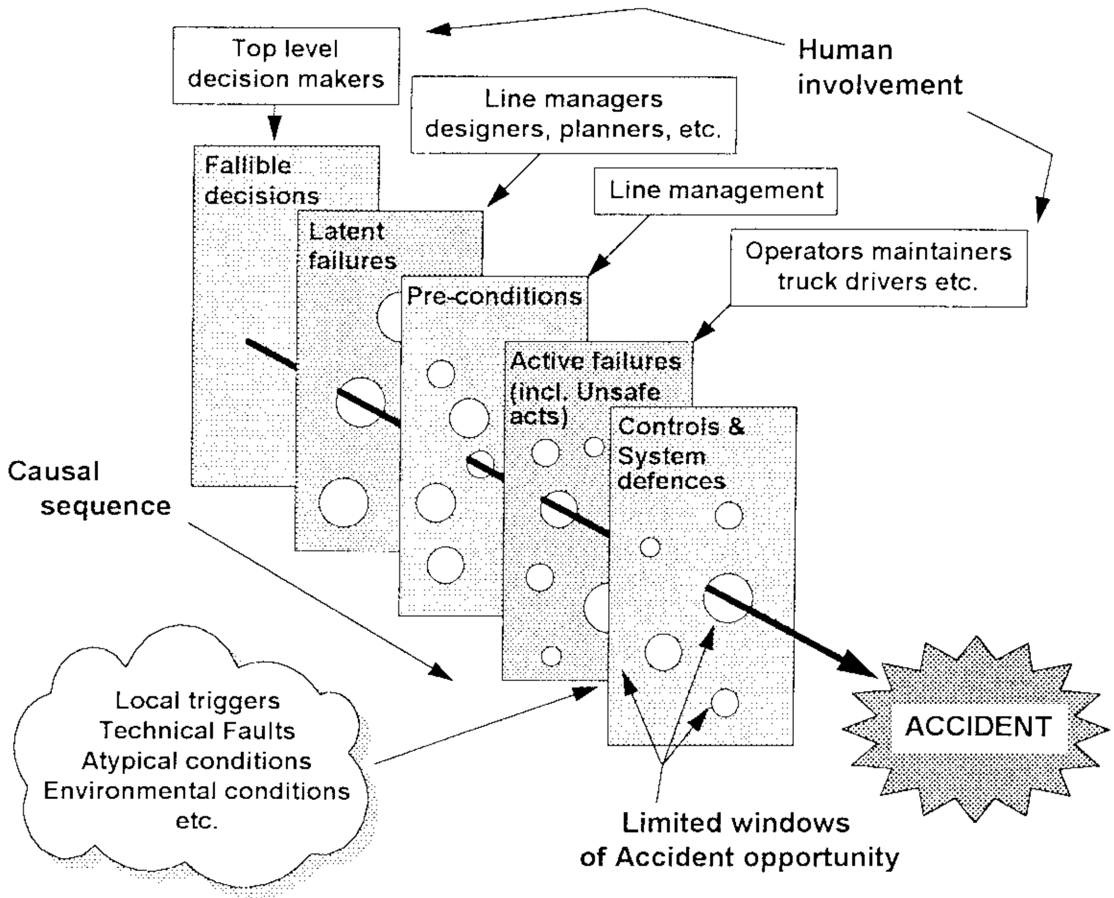


Figure 1: Accident causation sequence

Top level decision makers and fallible decisions

The people responsible for initiating, designing, constructing and resourcing of a particular company, facility or activity are the strategic apex of the system. Because their decisions have a wide-ranging impact, they are the principal organisational sources of latent failures. Their decisions measured against risk management objectives may have unfortunate consequences, often years later, which may or may not have been foreseen at the time.

Line management and latent failures

The decisions of top management are translated into specific forms and disseminated throughout the organisation along departmental pathways (technical, production, training, maintenance, hazard management, etc.). It is here that fallible decisions impose the constraints (e.g. lack of time or financial resources) that can lead to the seeding of latent failures, as in design, poor procedures or inadequate training. These latent failures need to be seen in conjunction with, or as causing, preconditions that lead people to commit unsafe acts.

Line management and preconditions

Preconditions are the psychological and situational (e.g. technical) precursors of unsafe acts. They comprise such things as poor motivation, inadequate perception of hazards, high work load, ignorance of the system, poor tasking, distracters, dangerous working conditions. They are the ingredients from which individual unsafe acts are made.

Operators, maintenance crews and local triggers

Local triggers are the inherently unpredictable events which interact with unsafe acts to circumvent the system defences. Triggering events may be due to a wide variety of causes (atypical conditions, technical faults, environmental conditions), but are usually outside the control of those directly involved.

General Failure Types

Tripod research has classified latent failures into 11 General Failure Types (GFTs), which provide a comprehensive hazard management picture that is valid across the diversity of offshore activities:

Hardware	Error-enforcing Conditions	Organisation
Design	Housekeeping	Training
Maintenance Management	Incompatible Goals	Defences
Procedures	Communication	

Some of these GFTs reach back over the development history of the organisation (e.g. incompatible goals and organisational failures); others assess the current quality of its specific functions (e.g. design, maintenance, procedures, etc.).

GFT Definitions

Hardware (HW)
Failures due to inadequate quality of materials or construction, non-availability of hardware and failures due to ageing (position in the life cycle).

Design (DE)
Deficiencies in layout or design of facilities, plant, equipment or tools that lead to misuse or unsafe acts, increasing the chance of particular types of errors and violations.

Maintenance Management (MM)
Failures in the systems for ensuring technical integrity of facilities, plant, equipment and tools, e.g. condition surveys, corrosion controls and function testing of safety and emergency equipment. Issues relevant to the execution aspects of maintenance are considered in the GFTs: Error-enforcing Conditions; Procedures; Design; Hardware; Communication.

Procedures (PR)
Unclear, unavailable, incorrect or otherwise unusable standardised task information that has been established to achieve a desired result.

Error-enforcing conditions (EC)
Factors such as time pressures, changes in work patterns, physical working conditions (heat, cold, noise, shift patterns, etc.), acting on the individual or in the workplace, that promote the performance of unsafe acts - errors (unintended deviations) or violations (intended deviations).

Housekeeping (HK)
Tolerance of deficiencies in conditions of tidiness and cleanliness of facilities and work spaces or in the provision of adequate resources for cleaning and waste removal.

Incompatible goals (IG)
Failure to manage conflict; between organisational goals, such as safety and production; between formal rules such as company written procedures and the rules generated informally by a work group; between the demands of individuals, tasks and their personal preoccupation or distractions.

Communication (CO)
Failure in transmitting information that is necessary for the safe and effective functioning of the organisation to the appropriate recipients in a clear, unambiguous or intelligible form. Transmission failures (system) means the necessary communication channels do not exist or the necessary information is not transmitted.
Reception failures (local) means the communication channels exist and the information is transmitted, but the message is not understood (e.g. because of language), is misinterpreted by the recipient, or is sent too late to be of use.

Organisation (OR)
Deficiencies in either the structure of a company or the way it conducts its business that allow safety responsibilities to become ill-defined and warning signs to be overlooked.

Training (TR)
Deficiencies in the system for providing the necessary awareness, knowledge or skill to an individual or individuals in the organisation. In this context, training includes on-the-job coaching by mentors and supervisors as well as formal courses. Awareness means the process of understanding the hazardous conditions present at the worksite.

Defences (DF)
Failures in the systems, facilities and equipment for control or containment of hazards or for the mitigation of the consequences of either human or component failures.

Failure State Profiles

Tripod research has demonstrated that assessments of the degree to which these GFTs are present in an activity or facility provide an accurate picture of its overall 'health'. These assessments may be quantified in several ways. The relative presence or absence of each of the 11 GFTs may be represented by the height of a bar in a histogram format (see Figure 1.3). This histogram is called a Failure State Profile (FSP).

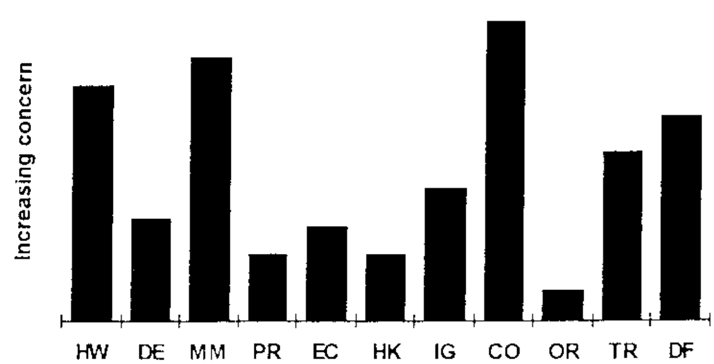


Figure 2: Failure State Profile

The two main applications of Failure State Profiling, proactively in the Tripod-DELTA technique and retrospectively in Incident Analysis, Tripod-BETA, are described briefly below.

Interpreting and Using FSPs

Examination of the FSP for a given activity by the activity manager can generate the following results:
1. Determine the organisation's performance in the individual GFTs and establish in which order of priority the GFTs should be tackled for improvement.

2. Compare profiles of the same activity taken from previous assessments to determine if improvements have been made.

3. Compare profiles for one site, or activity against another similar site or activity.

In the case of the lower-order GFTs, it is often possible to spell out precise corrective actions within the operational unit, particularly where the problems arise from failures to appreciate human strengths and weaknesses. In the case of the higher-order GFTs, such clear-cut prescriptions are neither possible nor desirable. The aim here is to make clear the adverse hazard management effects associated with these more strategic decisions, normally requiring management involvement.

The importance of management action against GFTs is that it demonstrates corporate motivation to improve hazard management performance and shows that hazard management and production goals are compatible - both involve doing the job well.

Conclusions

Humans will always make mistakes, that is unavoidable. However, an organization can manage human error by several approaches. These approaches fall into two broad categories: proactive and reactive.

The two proactive approaches are design and auditing existing installations. Designing a system should consist of making the system human error tolerant. This means that the system should accommodate and moderate incorrect operator actions. However the design option is only relevant for offshore field operations when there is a major upgrade on the installation. A proactive measure which can occur is an audit of a the existing system or installation with a tool like Tripod in order to identify characteristics (latent errors) which can induce quality failures.

The reactive approach consists of performing a detailed analysis of incidents to identify generic root causes that can give rise to similar problems (errors) in the future.

References:

1) Tripod-DELTA, Shell International Exploration and Production HSE Manual, Issued October 1995.
2) Embry D.E. (1990). "An integrated approach to the management of human error in the chemical process and offshore oil and gas industries". Proceedings of the Human Factor in Safety: Implications for the chemical and process industries. Novemeber 20-21, 1990. Manchester, England.

1.5 Using management systems to improve field operations

An effective management system typically has at least three key elements: a data-based feedback system, management involvement, and a process for involving employees in continuous improvement efforts. The feedback process is a system of communicating performance data through all levels of the organization. Such data is usually summarized in a simple, easy to understand report that provides a profile of key measures that reflect each of the following measurement parameters:

- Safety
- Quality
- Production
- Costs
- Schedule

The purpose of the feedback process is to provide information about current performance that guides future performance. The information helps those within an organization know when they are on track and when they need to do something different. It helps clarify responsibilities and establish priorities within the organization. Generally, the information is summarized in a weekly or monthly report that is distributed through all levels of the organization. The primary purpose of the information is for use by employees, while the secondary use is for management review.

In safety, the feedback system provides information from three different sources: statistics on accidents and injuries, results of audits conducted by management and staff personnel, and data from observations conducted by employees. The true value of this information comes from how it is used by teams of employees. Employees should review data from all of these sources and use it to develop action plans to improve safety on their rigs or in their work areas. Of the three types of data mentioned above, the observation data collected by the employees themselves are the most important. Observation data helps employees identify practices that are putting employees at risk of injury. The team can then decide whether the risk is a result of a failure to follow procedure, a procedure that needs to be rewritten, a poorly designed job task (for example, poor valve placement that requires bad body position), or other root cause, and develop appropriate action plans for improvement.

Employees can use the data more easily when it is presented on graphs. Pareto charts that reflect the areas of concern that occur with the greatest frequency or in the greatest percent of observation can help the team identify the areas that need the most attention. In addition, run charts illustrate trends and can help anticipate problem areas or show that improvement efforts are working.

Often these data are reviewed by safety teams that function at two different levels. The first level is the natural work team of employees that works together on the rig or within an area. The natural work team is usually the same group of employees that gets together for safety meetings. The second level is a Steering Committee that reviews the data for an entire region or division. This team takes a broader look at the risks that are affecting the entire organization and develops action plans appropriate for this level. The Steering Committee also is responsible for maintaining the safety observation process, so they review data on how well the process is function on each rig and in every location and develop action plans accordingly. Thus, in addition to reviewing data from observations, they review data on the number of observations being conducted versus the number planned, and the percent of employees conducting observations on each rig or location.

Data from incident and accident investigations are also important for several reasons. First, the accident investigation obviously provide information on practices and conditions that need attention. Such information must be shared throughout the organization, usually through discussion in safety meetings so that everyone has the opportunity to learn from the incident . Often, such investigations will have implications for the safety observations process and the Steering Committee should modify the observation process to emphasize a particular practice or condition that contributed to the incident. The investigation may reveal that this particular task was not one that was commonly observed, or it may suggest a safety practice that should be added to the observation checklist. Second, they allow a team to assess the extent to which the observation process is identifying the practices that are causing incidents and accidents.

The observation process is distinct from safety audits conducted by management or the safety staff. Observations are conducted by employees who then review their observation checklist with the co-worker they just observed and give feedback on their observations. The focus of such observations is practices first, conditions second. Safety audits on the other hand, are conducted by line management or the safety staff and typically focus primarily on conditions. In addition, unsafe conditions identified during audits are formally tracked until they are resolved. The audit process is part of the organization's formal safety system and focuses on addressing regulatory requirements, while observations are less formal and looking for ways to reduce risks that typically are not addressed formally in written procedures or regulatory requirements.

2. Facilitating operations on the platform

2.1 The management of change in upstream exploration and production

Introduction

It has been said that the only constant in life is change. While change may be constant, it comes in many different shapes and sizes, though most forms can be categorised as either radical or incremental. Radical change (such as Business Process Re-engineering) involves the rapid removal of the old ways of doing things and replaces them with new or unique ones, this type of change represents a complete break with the past for the entire organisation. Incremental changes tend to be small scale and localised often designed to solve a specific problem. This type of change is likely only to bring about ad hoc and localised improvement in performance (Burnes, 1992). There are numerous different motivations for change, some of which may be perceived as positive (i.e. company expansion) others as negative (i.e. reduction in profitability). Irrespective of the size of the change or whether it is perceived as positive or negative it will still need to be managed effectively to avoid having a negative impact on safety.

In the current economic environment in the UK, the primary aim of most corporate change is to do more with less, due to increased competition and the need to increase profitability. In the oil industry these economic pressures have lead to an oil industry initiative called CRINE (Cost Reduction Initiative for the New Era). The primary aim is to ensure the continued existence and profitability of oil and gas production in the North Sea. It's two primary objectives are to achieve a thirty percent saving in capital costs and halve operating costs within three years. An initial report by the CRINE working group produced six key recommendations: 1) Use standard equipment, 2) Use functional specifications, 3) Be more critical in deciding documentation needs, 4) Simplify and clarify contract language, avoiding adversarial clauses. 5) Rationalise regulations on certification production consents, pipeline works authorisation and field development programs. 6) Make quality qualifications more credible. Specialist groups have been set up to establish best industry practice in a number of specific areas: Culture change, Safety and environment, IT systems, Quality, Specification, Technical, Project and Documentation. In addition to this, CRINE has encouraged oil companies to form partnering alliances to move away from the adversarial style which characterised the way the operating companies worked with their contractors. The existence of the CRINE organisation in itself is not making companies restructure their organisations but it is a clear manifestation of the pressure oil companies are under to find new and more effective ways of managing their business. This paper is going to focus on the issues surrounding the challenges in managing some of the radical changes which many oil companies are currently experiencing. Initially the relationship between economic factors and safety will be discussed, then some of the changes that have occurred offshore will be described, following this suggestions on the management of change will be given and finally an example of effective change will be presented.

The relationship between economic factors and safety performance

Investigations into a number of major disasters such as Piper Alpha, Zeebrugge, Flixborough, Clapham junction and Chernobyl has revealed that they were not caused by a coincidence of independent failures and human errors but by a systematic migration of organisational behaviour toward disaster under the influence of pressure toward cost-effectiveness (Rasmussen, 1993, 1994). It is therefore vital that high hazard organisations effectively manage change and cost reduction. It is likely that cost reduction and organisational change could also increase the likelihood that an individual worker will have an accident. Figure 1 describes the dynamic relationship between economic, workload and safety boundaries and the possible effect of increased economic pressure. It can be seen that increased economic pressure for cost effectiveness moves the boundary of economic failure downwards, which will increase management pressure on the work force toward efficiency. As workers have great freedom to select their level of performance within the boundaries of economic failure and workload, this increase in workload on employees (who tend to migrate toward least effort) will lead to a migration toward the boundary of safe operations, which could lead to an increase in the number of accidents.

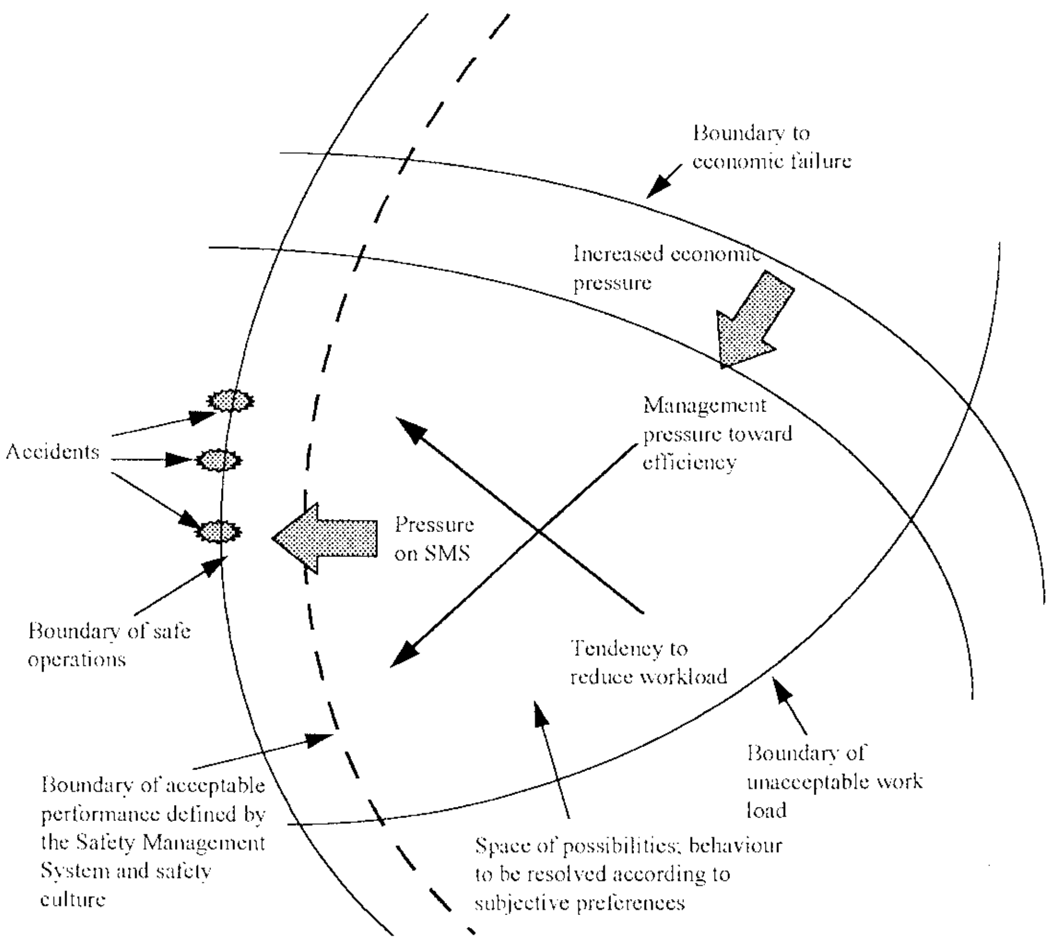


Figure 1: A dynamic model of the boundaries of operation
(adapted from Rasmussen, 1996)

Activity in a work situation will show great variability due to individual, situation and organisational factors. Activity will then be characterised by freedom of movement within the workspace (similar to the movement of gas molecules). This will provide ample opportunity to the work force to identify "an effort gradient" and for the management to identify "a cost gradient". The result is likely to be a systematic migration toward the boundary of acceptable safety performance (Rasmussen, 1996).

Recent research into risk perception and safety in the UK offshore oil industry carried out by Flin, Mearns, Fleming and Gordon, (1996) provides some empirical support for the above theoretical model. This study involved sending a self completion questionnaire to 1550 offshore employees on six participating installations, 40% of which (622 questionnaires) were completed and returned to the research team. The data from the questionnaires was statistically analysed and a number of LISREL models were developed, figure 2 is one model from the study. This model indicates the direct effect of management commitment, the balance between production and safety, management priorities, fatalistic attitude to safety and social support have on the abstract concept (latent variable) safety satisfaction. Reliability of the variables were found to be satisfactory for all the variables in the model. Please refer to Flin et al (1996) for a full description of LISREL analysis and for a more complete description of this model.

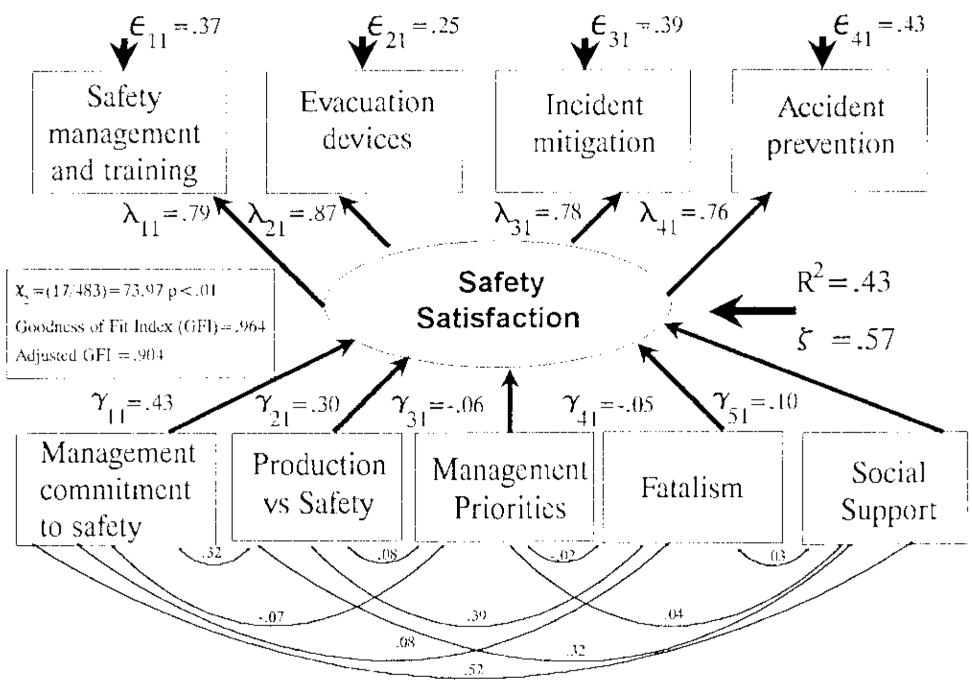


Figure 2: Associations between safety attitudes, social support and satisfaction with safety and contingency factors

The results of the analysis indicate that the respondents' perception of management commitment to safety, their perceptions about the balance between production and safety, their perceptions about management priorities, fatalism and the amount of social support they received explained nearly half the variance in satisfaction with safety and emergency response measures (R^2=0.43). The two most important predictors were perception of management commitment to safety (γ_{11}=.43), and perceptions about the balance between production and safety (γ_{21}=.30). Respondents' attitudes to management priorities and fatalism were found to contribute the least to their satisfaction with safety (γ_{31}=-.06, γ_{41}=-.05 respectively).

It has been argued by Flin et al (1996) that work force perceptions of safety can be taken as an indictor of real level of safety. If this argument is taken further then it could be suggested that the factors that influence their perceptions are also some of the factors that influence the actual level of safety on the installation. Thus the above LISREL model suggests that management commitment to safety and the balance between safety and productivity have a direct effect on level of safety. Which indicates that economic factors can have a direct impact on safety. These conclusion is consistent with the theoretical model proposed by Rasmussen (1996).

Specific changes in the UK oil and gas exploration and production industry:

1. In recent years a common factor in nearly all organisational change in the oil industry has been to reduce staff costs. Staff costs have been cut by i) reducing the number of offshore posts by delayering (removing an entire tier of management) or redundancy (reducing the number of positions), ii) changing the offshore rotations to reduce the amount of time onshore (e.g. going from two weeks on and three weeks off to two on two off), iii) replacing operating company staff with contracting staff on the installation iv) reducing the onshore support staff by redundancies.

2. The adoption of multi-skilling to maximise the productivity of the work force and reduce the number of staff on the installation.

3. Out sourcing of entire functions such as logistics to reduce the number of staff employed, reduce cost and increase efficiency.

4. Set up partnering arrangements with major contracting companies to reduce waste, reduce the amount of duplication of effort and to remove the need to have operating company personnel to supervise contractors. These relationships encourage contracting companies to reduce the overall cost of a project as they will get a share of any savings made.

5. Alliances with other operators to share project and operating costs (e.g. sharing supply boats).

6. The number of helicopter flights are reduced by extending the period of time workers spend offshore (e.g. from two weeks to three weeks).

7. The maintenance program may be changed from a planned maintenance schedule to a reliability based maintenance or to a breakdown repair only.

8. Procedures may be revised to reduce down time

9. Reduction in amount of money spent in training or career development,

10. Change in the reward structure by increasing the amount of performance related pay while also reducing some bonuses (e.g. safety bonus)

It is clear from the above that the Oil industry in UK has been going through a period of change. This change has been managed differently and with varying amounts of success across the industry. The impact that this change has had on safety is difficult to establish as accident rates for the entire UKCS are published as the number of accidents per 1000 employees and not as a rate per man hour exposed. There has been a certain amount of debate about the accuracy of the figure for the numbers employed offshore. It is difficult to know if the figure considers individuals who have only worked for two weeks in a year in the same way as they consider an individual who has worked 24 weeks. If they do then the figures for those employed are going to be inflated, because in recent years there has been an increase in the numbers who are only employed when they are required. This may therefore give a distorted picture of the accident trend for the UKCS. It is clear from the above discussion of the relationship between economic factors and safety that it is vital to manage the change process effectively in order to avoid an increase in the likelihood of accidents or a major disaster occurring. There have only been a limited number of articles which have addressed the potential effects of organisational change on safety and none, that the author is aware of, that have focused on the oil and gas industry.

Considerations which may aid in the management of change

The theoretical model developed by Rasmussen would suggest that the two factors which should be considered are the effects of the organisational change on the safety management system and on worker motivation. Rasmussen's model suggests that their will be increased likelihood of individuals violating the procedures specified by the SMS, which may lead to an increased number accidents. This suggests that the SMS needs to be adapted and developed in light of any changes to the organisation. The changes to the SMS may include a review of procedures to see if they are still practicable or an increase in the number of audits to the system. In addition it is important to maintain or increase work force motivation to combat the work forces' tendency to minimise their work load which may lead them to taking short cuts or violating procedures.

The literature on the safety implications of organisational change appears to be very sparse. One article by Witheral and Kolak (1996) entitled "Is corporate re-engineering hurting your employees?" has identified five factors that increase risk during re-engineering.

1. Fear in the organisation

The primary fear for most employees is loss of their job. In the early stages of most reorganisations, the senior management announces that significant cost reductions are required to keep the business competitive. The employees realise that this usually translates to a reduction in the work force, this fear increases as the lay-offs begin. To reduce their internal feelings of tension employees will attempt to obtain some sense of control over the situation, this may lead to workers believing that the only way to secure their job is to become more productive even if this requires them to compromise their personal safety. Because accidents are a combination of exposure and risk then compromising safety procedures will pay off in the short term as it is likely that they will be able to complete the task faster by ignoring some rules, thus employees will continue to break procedures until an accident occurs.

Fear of losing one's job can lead to stress, and stress can lead to increased accidents (Dessler, 1991). Fear can also cause employees at all levels to refrain from identifying problems for fear of being seen as negative and resisting change. To combat these problems management must clearly communicate that safety is of primary importance and that no punitive actions will be taken against anyone who reports a safety problem. It may be useful to emphasise that the safest way of performing an activity is also likely to be the most efficient in the long run, but that if any employee has identified a more efficient method of performing an operation that this will be examined and the safety implications assessed. The change team should have safety performance as one the factors which their success is measured against. People only tend to attend to safety if it part of their performance evaluation (Wygal, 1975).

2. Employees can become confused and frustrated

The act of restructuring implies that employees roles, responsibilities and reward structures are likely to change. Unfortunately due to the iterative nature of the change process individuals job tasks responsibilities and reporting structures may change many times during the transition period. These changes increase the demands on employees who are likely to be learning new skills and being asked to work harder. This may lead to an increased number of errors which in turn increases frustration. The tone of this type of environment can be felt from a quote by an employee experiencing these conditions "we never have the time to do it right, but we always have time to do it over" (Witherill and Kolak, 1996). This frustration needs to be addressed in some way possibly by having an open form for employees and management to get together to discuss problems and allow the management to update the employees on progress to date.

3. Morale declines

The above situations are likely to reduce employees morale as the fear of losing their job increases and as they feel incompetent in their constantly changing roles as they encounter frustrations. A direct relationship has been found between decreasing morale and increasing accidents (Byars and Rue, 1991). Senior managers must become aware of the fear that a proposed change process may cause in some employees. Management must endeavour to reduce this fear by providing time for employees to voice their concerns and address these concerns honestly and as accurately as possible.

4. Employees become overwhelmed by work loads

As employees workloads increase they will attempt to prioritise their tasks and responsibilities to cope with their increased work load. This may lead to 'cutting corners' or a reduction in safety monitoring. These types of behaviours are likely to be reinforced because as Heinrich (1959) indicated, an employee will be able to breach safety procedures numerous times before any negative consequences are realised. Thus the employee will feel that they have become more productive at no cost. In fact it is possible that the employee will be rewarded for breaching safety procedures. To avoid this management must stay focused on safety and convince the work force that effective performance is more important now that previously for the companies survival. The management must highlight the cost of accidents to the company.

5. Accountability for safety can be lost

Supervisors and managers may be taken away from their usual responsibilities to form part of the redesign group. Their responsibilities may be shared among other supervisors or others may be temporally promoted into their position. There are a number of potential risks with this situation, firstly there is going to be a loss of knowledge that only the moved person had, also activities that this individual performed on an informal basis may no longer be performed. The loss of this type of informal corporate knowledge can have a significant impact on safety. If the supervisors responsibilities are shared among a number of other supervisors it is possible that accountability for safety is lost. Employees who are temporally promoted to supervisor may feel intimidated by the position and be unable to voice safety concerns to senior management.

Additional risk factors identified during confidential semi-structured interviews which were held with a number oil industry experts, which included safety manages from both operating and contracting companies and members of the Health and Safety Executive.

1. The increased amount of communication and focus on cost reduction and increased productivity can dilute the safety message even if safety has not decreased in importance. If the work force is continuously bombarded with cost reduction information and attending courses to improve efficiency, it would not be surprising if the believed that increased efficiency at any cost was what senior management wanted.

2. A primary objective of certain radical organisational change processes is to develop a new corporate culture. A number of research studies such as Donald, Canter & Chalk, (1991); Lee (1993); Zohar, (1980) have concluded that safety culture is one of the main determining factors for the level of safety in an organisation.

It is therefore very important when attempting to alter the culture of an organisation to consider the impact that this will have on the existing safety culture which is a subcomponent of the organisational culture. It may therefore be useful to measure the safety and organisational culture prior to any change process and attempt to identify how they interact so that the organisational culture change does not have a detrimental effect on the safety culture.

3. With delayering and redundancy it may no longer be possible to follow procedures because the position (e.g. Senior mechanical technician) that is supposed to be consulted no longer exists. This can lead to confusion and it is possible that it may lead the individual to ignore the set procedure. It is therefore important to review all the company safety procedures to ensure that they can still be adhered to after the changes.

3. An additional risk with the loss of individuals and positions from an organisation is the associated loss of informal activities which may be critical for safety. The increase in the adoption of multi-skilling (workers performing tasks in more than one discipline) is particularly prone to the loss of informal safety checks. For example if a mechanical technician has been trained to perform isolations, so that when they remove a valve they will be able to perform their own isolations. This may remove the informal checks that the mechanical technician may have done on the production department's isolations as he has done the isolations and therefore may feel that they are unnecessary.

5. With restructuring it is important that individuals who are given new responsibilities are aware of what they are required to do and that they have the required skills to perform their duties in a competent manner. If it has been identified that individuals will require additional training, it is important that this is provided during the transition period.

Example of best practice in the Oil Industry: A case study

To illustrate how radical organisational changes can be effectively managed to prevent a negative impact on safety a brief summary of how one North Sea operator has succeeded will be presented. This company under went a radical restructuring without increasing their accident rate, in fact their accident rate actually decreased. This company is part of a large multi national oil corporation which operates a number of production platforms in the North Sea. Over the past five years it, like many other North Sea operators has undergone a number of cost reduction and reorganisation exercises. The most recent reorganisation involved direct changes to the safety department, including redundancies and the outsourcing of some activities. Other sections of the organisation including the offshore installations also saw redundancies, outsourcing of complete departments, changes in work processes, a decrease in the ratio of company to contract staff and the establishment of partnering and alliances relationships.

As this organisation had been through previous reorganisations, the process of change was managed by an internal team as opposed to external consultants. This small multi disciplinary team (which included an individual from the safety department) was put together to focus on changing the organisation to reduce operating costs. The optimisation team considered a wide range of changes to the organisation that would achieve the desired cost reduction, such as: decreasing number of employees; increase outsourcing; examination of all procedures (including safety procedures); reducing the number and size of onshore support groups; Setting up partnering agreements (i.e. one large contracting company to manage all contractor agreements) and alliances with other operators (e.g. sharing supply boats). As the team were considering the most effective way forward, representatives from each department met with the optimisation team to identify ways their departments could change to reduce costs.

Through the above process the optimisation team developed a defined plan of how the organisation would be in the future. Once the team had identified the changes that were going to be made for each department a safety transition plan was developed. The safety department had an input into the plan and a reviewed the final draft. The safety transition plan provided a structure to manage the possible effects that the changes may have on safety. Firstly it clearly set out the changes that were going to be made and the possible safety implications of these changes. It identified any additional training that people may require to fulfil any new responsibilities. It clearly identified individuals responsible for specific aspects of safety during and after the period of change. A SMS audit was performed at the end of the change process to ensure that nothing had been lost or had slipped through the net. Then the system was audited again after nine months to ensure that the new systems were still in place and functioning correctly.

Conclusions

The above clearly indicates the complexity of issues surrounding the management of change. It is difficult to provide list specific guidelines for the management of change as each organisation will approach the change process from different perspectives and motivations. Having said that there are a few factors that should be worth of consideration for the majority of situations. These are: i) Safety performance should be one of the indicators of change teams performance, ii) Consideration of the possible safety implications of any implications of structural changes for procedures and guidelines changes, iii) Awareness that the change process may effect morale and motivation, iv) The safety culture of the organisation may be damaged by the change process (productivity at any cost may be perceived as the objective of senior management), v) Open and honest communication with the work force can minimise the potential effects of the change process. To monitor the effects of the change process it may be useful to survey work force opinion prior to any announcement about the organisational change and to re-survey the work force at set intervals or after change milestones have been reached.

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2.2 Using behavioral techniques to ensure safe operating practices

Creating a process that actively involves employees in conducting safety observations helps ensure that employees work safely in several ways. First, observations benefit both the observer and the employee being observed. The more obvious benefit is for the employee being observed who benefits from an independent observation. The feedback makes the employee more aware of the risk of injury that results from a particular approach to the task is at hand, and ideally will prompt a different approach that reduces the risk. In addition, the observer benefits from conducting the observation. Conducting an observation sensitizes the observer to such risk for the next time he has to do that task. In addition, our culture values "walking the talk" and once the observer has been talking to other employees about a particular safety practice, the social dynamics increase the likelihood that the observer is going to perform the job in a safe manner. In other words, for most of us, if we preach to others about using fall protection, we are more likely to use fall protection the next time it is required, even if no one is around to observe us.

Further, a behavioral observation process benefits both new and seasoned employees. It ensures (1) that experienced employees remain aware of the risk associated with short-cutting safety procedures; and (2) that new employees come gain a better understanding of the risks involved in their work.

The key to an effective behavioral observation process is designing a process with a high level of employee ownership. The way to ensure employee ownership is to involve employees in designing the behavioral safety process. This is done by selecting employees that are representative of all aspects of the operation to serve as a design team. Design team members should generally be employees that have a strong personal commitment to safety and are informal leaders among their fellow employees. Typically the design team will complete the following steps:

1. Assess the organization to identify factors that must be addressed to ensure the success of the new process.

2. Design an observation checklist based on (a) an analysis of accidents that have occurred within the organization over the past three to five years, (b) accidents experienced by similar organizations, and (c) input from employees and safety professionals within the company.

3. Develop a procedure for conducting observations that is realistic give the nature of the work.

4. Plan a team process for using the data that includes reviewing the data in safety meetings and sending the data (or a summary of the data) to the Steering Committee for review and analysis.

5. Create an observer training workshop and plans for training all employees on how to conduct observations.

6. Devise a plan for recognition to support the process. This plan should encourage participation,

completion of observations, quality feedback during observations, and improvements achieved as a result of the process. Ideally, it should provide recognition to both individuals that champion safety and teams that achieve success through the process.

7. Gain management's support for the process by planning their role, reviewing the process with, and incorporating input from the management team

(For a more detailed treatment of the design process, see McSween, 1995.)

A behavioral safety process usually has several key elements:

- A systematically developed checklist
- A process for conducting observation
- Immediate behavioral feedback based on observations
- A review of observation data in team safety meetings on each hitch
- A Steering Committee that reviews data and develops plans for continuous improvement that meets quarterly at the base camp or division headquarters.

A Fictional Example

The following story illustrates a typical observation process.

At the end of Monday's safety meeting, the tool pusher, Randy, announces that on Tuesday he will conduct a safety observation of the rig. On Tuesday afternoon Randy gets Jim, one of the hands, and says "Come along with me. I want to do a safety observation of our rig and would like for you to come see how these are done so that you can do them later on. Your participation is completely voluntary but it'll help ensure a safer place to work for all of us."

Jim agrees to go along. As they start their tour of the rig, Randy and Jim discuss the fact that very soon, every employee on their hitch will finish observation training and be participating in the observation process. Everyone will be partners in safety and sharing responsibility for achieving it.

When Randy and Jim arrive on the rig floor, Randy takes a detailed, one-page checklist out of a folder. Without referring to it, the two men first scan the work area and ask themselves (after Randy explains the procedure to Jim) "What do we see the employees doing that could cause someone to get hurt?" They note one such practice on the checklist. They then review the checklist and mark each safe practice and check areas of concern. They do not record the names of any of the employees they observe on the checklist.

After completing their observation, they approach the employees and review the checklist with them. "We noticed that you were 100% safe on the your use of personal protective equipment." Randy says. "Your tools are well organized and you were using the right tools for the work you were performing. However, we also noted a small puddle of oil of to one side your work area. I was concerned that someone might slip in the oil and injure themselves." Randy and Jim answer a few questions after which Randy asks the group to clean up the oil. Randy and Jim then return to the office where Randy shows Jim how to complete the checklist by calculating a "% safe" index. He records the safety percentage on a running graph on the safety bulletin board and put the completed checklist into a three-ring binder. All told, the two men spent about 30 minutes completing the observation and documentation process.

On Monday morning at their safety meeting, Randy shows his team the data from the previous week's safety observations. Jim and another employee who had served as an observer report the data from their observations, beginning with naming those practices on which employees were 100% safe during all observations. Randy tells them he appreciates their efforts and to keep up the good work. He then discusses his and Fred's concern about keeping the work areas clean of oil that could create a slipping hazard and importance of not allowing oil to be released into the environment. The employees as a group agree to try to eliminate such hazards for their next four tours. One of the crew summarizes the observation data at the end of the month and sends it into the division office where a secretary enters it into a data base.

At the end of the quarter, the division's Steering Committee meets at the base camp to review the observation data and any accident or incidents that occurred during the quarter. The Steering Committee is made up of an employee representative from each rig. While this is normally their time off, they are paid to come in for the meeting. The data base provides a summary report to the Safety Steering Committee. After reviewing the data and comments about spilt oil on different observation forms from several different rigs, the committee decides to provide a video and training materials on cleaning up hazardous materials for review in safety meetings on each rig during the following month. They hoped these training materials would assist rig personnel in their efforts to provide a safe work place and protect the environment.

Final comments

While this fictional case study illustrates many of the key elements of the process, the actual logistics vary extensively depending of such factors as the size of the crews, the remoteness of the rigs, and a host of other factors. In some cases, for example, employees have to conduct self assessments because the number of employees is too small to allow peer observations. Never-the-less, such observation based, behavioral safety processes have proven to be an effective tool for achieving continuous safety improvement in a wide variety of organizations both on-shore and off-shore.

2.3 Facilitating Better Communications Between Operations Personnel

Systematic communications between operations personnel is an integral component in our efforts to improve safety and productivity of offshore operations. Substantial and relevant improvements can only result through a team based approach to the communication effort. Teamwork, the co-operative effort to realize a common goal, requires a unified commitment to achieve and maintain effective communication. When considering operations in the oil and gas industry, this challenge is even greater because of barriers such as cross functional areas, contract labor as well as crew and shift changes. These types of barriers require clearly established communication matrices designed to maintain performance drivers such as understanding, co-ordination, continuity and commitment among all operations personnel.

Performance Drivers

In offshore operations, teamwork is an all-important concept. It is critical that all members of the team move toward a shared objective. This is accomplished by utilizing performance drivers such as those listed above. A performance driver may be described as an objective that guides a member's individual actions and specifies a protocol for team interactions.

One of the most fundamental performance drivers is understanding. Each member must have a clear understanding of the shared goal and the role that they play in accomplishing that goal. Also, there must be an understanding as to the interrelationship between all team members and each functional area. In most cases, the implementation of a comprehensive training program directed towards familiarizing workers with the overlap that exists between various job descriptions is an integral part of facilitating their understanding of these relationships. Recommended practices for development of a safety and environmental program suggest that the synergistic progression towards the integration of process and safety issues is crucial to its effectiveness.

Oil and gas related operations require a tremendous amount of co-ordination between all functional areas. There must be continuous status reports at predetermined intervals followed by evaluations and adjustments in projections to ensure safe and productive operations of facilities. Also, continuity in process must be maintained from shift to shift and during each crew change. Establishing modes of communication that are required as a function of changes in personnel is the primary area of concern with respect to maintaining continuity of process. These avenues for exchange of information should limit the possibility for miscommunication and at the very least ensure that a smooth transition occurs with a minimum of disruption in process flow.

Finally, there must be commitment from each member to maintain the continuity of the team and its efforts. This is the most challenging of the drivers because of the functional barriers associated with offshore operations such as crew and shift changes.

Communicative Drivers

Effective team communication is the impetus behind safe and successful offshore operations. The key to effective communication is the selection and use of a proper communicative driver. That is, the most effective method of transferring pertinent information to each team member. A communicative driver is any means of transferring information from one source to another. In operations, this can range from a flow level indicator to tool-box meetings which communicate safety concerns. As with the proper selection and placement of equipment read-outs, choosing the proper driver in interpersonal communication is fundamental to its success. Two things must be determined when choosing the appropriate driver: What is the message which needs to be communicated; and who needs to know the information?

In a team approach, communicative drivers provide a pathway for the conveyance of the objectives and roles and responsibilities leading to team proficiency. Some of the typical drivers for communicating this type of information are shown below:

- Team meetings
- Memorandums
- E-mail
- Bulletin boards
- Newsletters
- Progress reports

As team members, we should constantly assess how personal behaviors relate to the team's efforts. In an effective team environment, other team members are consulted during the decision making process to ensure that affected cross-functional areas are involved when necessary. This requires a tremendous amount of effort and co-ordination. To assist in accomplishing this objective, most teams have clearly defined networks for the effective flow of information. The key to the success of these networks is their ease of use and limited time requirements.

One aspect of team communication which is typically overlooked is the "why" factor. When a communicative driver with limited interactive features is utilized, the reasons for the decision are usually not expressed. Too often this results in a breakdown of team communication which hinders mutual understanding and team cohesiveness. There is no other solution to this problem than providing explanations for decisions which impact team members. This can be accomplished by assigning an accessible point of contact who can effectively detail the events or reasons leading to the decision. Additionally documentation may include a brief summary of these same reasons to accomplish the same effect.

Currently, there are world class organizations who have refined methods and drivers which assist in maintaining a team based operation. These matrices have proven very effective in addressing aforementioned areas of concern. We offer a selection of these methods and suggest potential improvements that may be incorporated based on team needs.

World Class Team Communication Matrices

- Pre-shift team meetings — An open meeting is held before each shift with required representation from all functional areas. This ensures that current and projected operational status is communicated to all affected areas.
- Standard meeting agenda — A standard meeting agenda is used which solicits input from each functional area. Also, open discussion is encouraged to answer any questions which may arise.
- Point of contact — Contingency planning should be a factor in maintaining a designated source of information in the event of disruptions in the scheduling of personnel changes.
- Rotation of facilitator responsibilities — Some organizations are now realizing the importance of utilizing trained facilitators to maintain the flow of meetings. These organizations offer and encourage their employees to take advantage of this training. This allows total team involvement while maintaining productive meeting flow.
- Posted meeting minutes — Meeting issues are maintained on a large eraser board for easy reference by all team members. Each day these minutes are updated as necessary. Minutes also include a look ahead for projected operations and operational contingencies. This component is a wonderful tool in maintaining the performance drivers.
- Information sharing — Representatives from each functional area is responsible for sharing all pertinent information with their co-workers. They must be committed to their role of maintaining the communication link both during and after the meeting.
- Maintaining operations log — Documenting progress, problems, procedural changes, etc. is key to maintaining the performance drivers when considering crew changes. Team members who have been "out of the loop" for as much as two weeks need to know what has occurred during their absence.
- Formal crew-change meetings — Helicopters and crew boats are grounded for a short period of time during crew changes for team updates. Outgoing team members have a tremendous amount of information that must be shared with incoming members. This requires preparation on the outgoing team members part but it is time that is well invested toward the success of the operation.
- E-mail —With the accessible nature of home computers, teams can maintain contact during their off time. Another avenue which can be used is providing computer terminals at various transportation terminals so that team members can download information before heading offshore. Both of these enable team members to orient themselves before reaching the platform. In the end, this approach facilitates a more effective transfer of information during crew changes with minimal down-time of transportation.

The key to achieving world class organizational success is a concerted effort towards maintaining the highest level of productivity and safety through effective team communication. This can be accomplished through development of communication networks which focus on a sensitivity to the inherent differences in the abilities of work force personnel to assimilate information. With this in mind, it is evident that variations in modes of communication can assure that the process remains evergreen.

A SAFETY MANAGEMENT ASSESSMENT SYSTEM (SMAS) FOR OFFSHORE PLATFORMS

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Many different types of safety management assessment methods have been used by offshore structure engineers. These range from qualitative (Hazard Operability Studies, Failure Mode and Effects Analyses) to quantitative (Quantified Reliability Analyses, Probabilistic Risk Analyses, Formal Safety Assessments) (Center for Chemical Process Safety, 1995; Bea, Roberts, 1995; Bea, 1994). The method that will be discussed here is identified as a Safety Management Assessment System (SMAS) for offshore platforms.

SMAS is a Safety Indexing Method (Bea, 1996) that is intended to provide a level of detail between the qualitative / less detailed methods (Arnold, et al, 1995) and the highly quantitative / very detailed methods (Groeneweg, 1994). SMAS has been based on an approach similar to that used in the Tripod Delta and Tripod Beta systems (Groeneweg, 1994; Hudson, et al, 1996a, 1996b). SMAS includes a qualification and training protocol for platform operations assessors. These assessors include representatives that have daily responsibilities for safe operations of the offshore platform. SMAS serves as both an external and internal auditing instrument and provides a bais for continuing improvement of the safety of offshore platform operations.

SMAS is based on the precepts developed in the U.S. Minerals Management Safety and Environmental Management Programs (SEMP) (Bartholomew, 1995; Federal Register, 1991), the American Petroleum Institute Recommended Practices for Development of a Safety and Environmental management Program (API RP 75) (1993), the U. S. Coast Guard Prevention Through People (PTP) program (U.S. Coast Guard, 1995), the Health and Safety Executive (1996) Prevention of Fire and Explosion and Emergency Response (PFEER) Regulations, the International Standards Organization Health , Safety, and Environmental Management Systems (1995), and the International Maritime Organization International Management (ISM) Code (1993).

SMAS encompasses two levels of safety assessment: 1) coarse qualitative, and 2) detailed qualitative. The objective of SMAS is with the least effort possible, to identify those factors that are not of concern relative to safety, to identify those mitigation measures that need to be implemented to improve safety, and to identify those factors that are of concern that should be relegated to more detailed quantitative evaluations and analyses.

COMPONENTS

The SMAS system is comprised of three primary components:

1) a laptop computer program and documentation that is used to help guide platform assessments and record their results,
2) an assessor qualification protocol and training program, and
3) a three stage assessment process that is started onshore with information gathering and identification of FOC, then proceeds offshore to observe platform operations, and is concluded onshore with a final assessment and set of recommendations.

The surveying instrument is in the form of a laptop computer program that contains interactive algorithms to facilitate development of consistent and meaningful evaluations of existing facilities. The instrument includes evaluations of the categories of facility factors defined earlier: operating personnel, organizations, hardware (equipment, structure), procedures (normal, emergency), environments, and the interfaces between the categories of factors.

Standardized and customized written, tabular, and graphical output reporting and routines are provided. This instrument is intended to help identify alternatives for how a given facility might best be upgraded so that it can be fit for the intended purposes.

The SMAS process has been developed so that it can be used effectively and efficiently by those that have daily involvement and responsibilities for the safety of offshore structures. The SMAS system is intended to help empower those that have such responsibilities to identify important loss of containment hazards, prioritize those hazards, and then define warranted or needed mitigation measures.

EVALUATION STEPS

There are five major steps in the SMAS (Fig. 1). The first step is to select a system for assessment. This selection would be based on an evaluation of the history of Loss of Containment (LOC) events and other types of high consequence accidents on the platform, the general likelihood and consequences of LOC, and the schedule of assessments for the facility.

The second major step is to identify an assessment team. This team would be comprised of qualified and trained SMAS assessors indicated as Designated Inspection Representatives (DIR's). These DIR's normally would come from the owner / operator organization, regulatory or classification agencies, or consulting engineering service firms. As in the commercial aviation industry, appointment of DIR's would be approved by the responsible regulatory agency. DIR appointment would be based on technical and operations experience. DIR's would be qualified based on SMAS specific training and experience. To avoid conflicts of interest, DIR's would be allowed to request replacement by the responsible regulatory authority when such conflicts arose.

The third step consists of a coarse qualitative assessment of the seven categories of elements that comprise a platform or terminal system. This assessment is based on the general history of LOC of similar types of facilities and operations, and details on the specific system. These details would consist of current information on the structure, equipment, procedures (normal operations and maintenance, and emergency / crisis management), operating personnel (including contractors), and organizations / management. Results from previous inspections and hazard studies would be produced and evaluated in this step. Interviews would be held with representatives of the owner / operator organization and the operating crews.

The product of Step #3 is identification of the Factors of Concern (FOC) that could lead to LOC events. As a part of the assessment process that will be described later, the assessment team records the rationale for identification of the FOC. The assessment may at this stage also identify suggested LOC mitigations. The results are reported in user selected standard textural and graphical formats (SEMP, PFEER, ISM) and in user defined textural and graphical formats (that can be stored in the computer or produced each time).

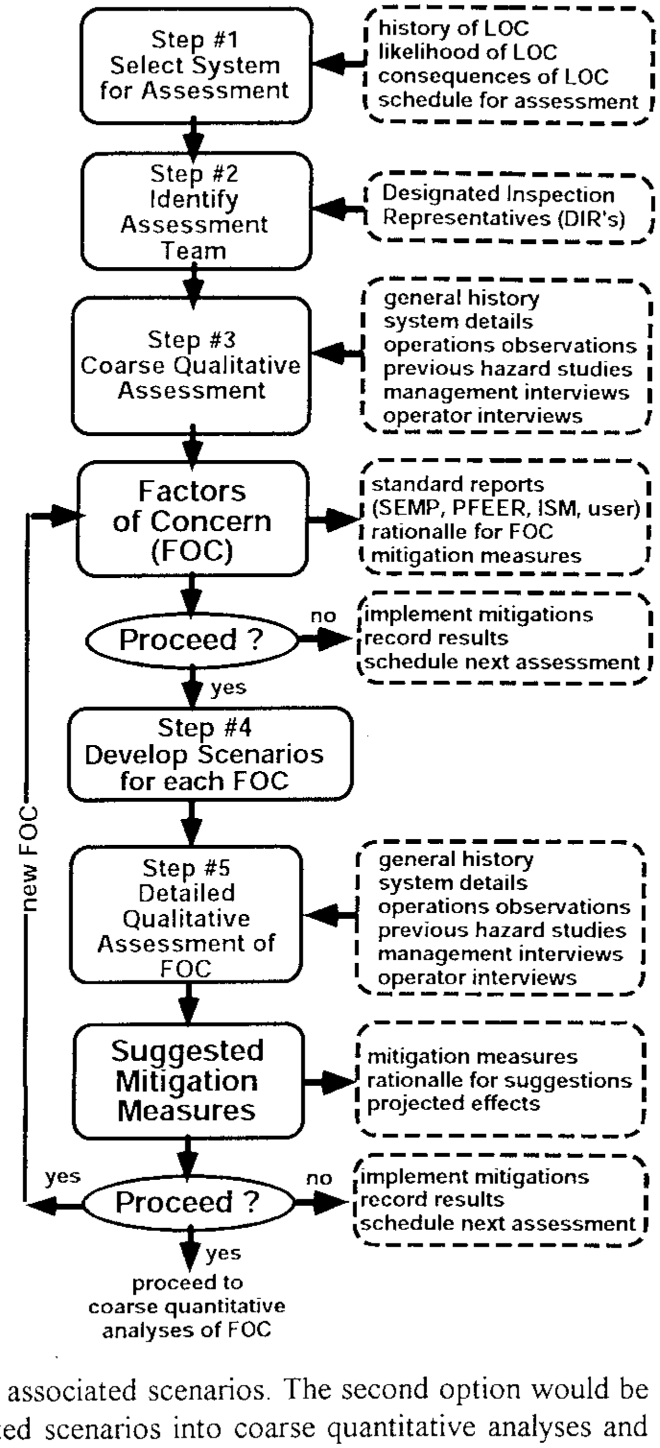
For some systems, the information at this stage may be sufficient allow the system to exit the SMAS with the implementation of the mitigations, recording the results, and scheduling the next assessment.

If it is deemed necessary, the SMAS proceeds to Step #4; development of scenario/s to express and evaluate the FOC. These scenarios or sequences of events are intended to capture the initiating, contributing, and compounding events that could lead to a LOC. They help focus the attention of the assessors on specific elements that could pose high risks to the system.

Based on the FOC and the associated scenarios, Step #5 proceeds with a detailed qualitative assessment. Additional information is developed to perform this assessment and includes more detailed information on the general history of the facility, its details, results from previous inspections and hazard studies, and management and operating personnel interviews. In recording results from the interviews, provisions are made for anonymous discussions and reporting.

The product of Step #5 is a detailing of the mitigation measures suggested for mitigation of the FOC confirmed in Step #5. The rationale for the suggested mitigations are detailed together with projected beneficial effects on the FOC. As for the results of Step #3, the results of Step #4 are reported in standard and user defined formats.

At this point, the assessment team could elect to continue the SMAS in one of two ways. The first option would be to return to the FOC stage and repeat Step #5 based 'new' FOC and the associated scenarios. The second option would be to proceed with some of the FOC and the associated scenarios into coarse quantitative analyses and evaluations.



If the assessment team elected, the SMAS could be terminated at the end of Step #5. The results would be recorded, and the next assessment scheduled.

EVALUATION PROCESS

The SMAS evaluation process is organized into three stages: (1) background information development and initial assessment (onshore), (2) visiting the facility and observing operations (offshore), and (3) final evaluation (onshore).

The first stage is organized into three activities. The first activity is to assemble background information on the facility. The second activity is to identify FOC in the facility. The third activity is to develop preliminary evaluations of the FOC.

Information for Phase comes from both verbal briefings and written material. Verbal briefings by personnel from both the corporate office and the platform, followed by a question-and-answer period, provide insight into the organization. Written information, such as oil process flow diagrams, maintenance procedures, results from previous assessments and inspections, information on previous loss of containment events, and emergency action plans, are examined to determine FOC and to familiarize assessors with the platform / terminal. General background on accidents and failures associated with similar types of facilities are used to sharpen perspectives and insights of what to look for.

The purpose of the second stage, visiting the platform / terminal, is to confirm information gathered during the first phase and to observe the actual operation of the facility. A typical visit will include a tour of the entire facility, followed by observing, at a minimum, the following critical procedures: (1) maintenance, (2) emergency drills, (3) shift changes, and (4) contract crew operations. A tour is conducted to familiarize assessors with the characteristics of FOC identified during Stage #1 and perhaps reveal additional FOC. Maintenance FOC will be the first component focused on because poor or improper maintenance is the cause of many accidents on marine systems. The second component, emergency drills, focuses on how the platform personnel respond to loss of containment events, because once it has started, humans must act either to bring the loss of containment under control or to escape. The third component, shift changeover, is observed to examine communication between platform operating crews and personnel. Of particular concern are communications between contract crews and platform operating personnel and coordination of their work activities.

During the final evaluation stage, the evaluations and comments are re-examined, and the final assessments are developed. These assessments are input to the SMAS computer instrument and output reports generated that summarize the results of the assessment in appropriate formats (e.g. SEMP audit report). This report contains a summary of the FOC that were identified together with a summary of the rationale for their identification. The assessors notes on justifications are included in the final report together with suggestions for reducing the risks of LOC through, lowering likelihoods, consequences, or a combination thereof.

SMAS LEVELS

SMAS is organized into three sections or 'Levels' (Fig. 2). The first Level identifies the seven components: 1.0 - operators, 2.0 - organizations, 3.0 - procedures, 4.0 - equipment, 5.0 - structure, 6.0 - environments, and 7.0 - interfaces. Table I summarizes the major factors that are included in each of the seven components. These seven components comprise 'modules' in the SMAS computer program.

The second Level identifies the factors that should be considered in developing assessments of the components. For example, for the operators (1.0), seven factors are

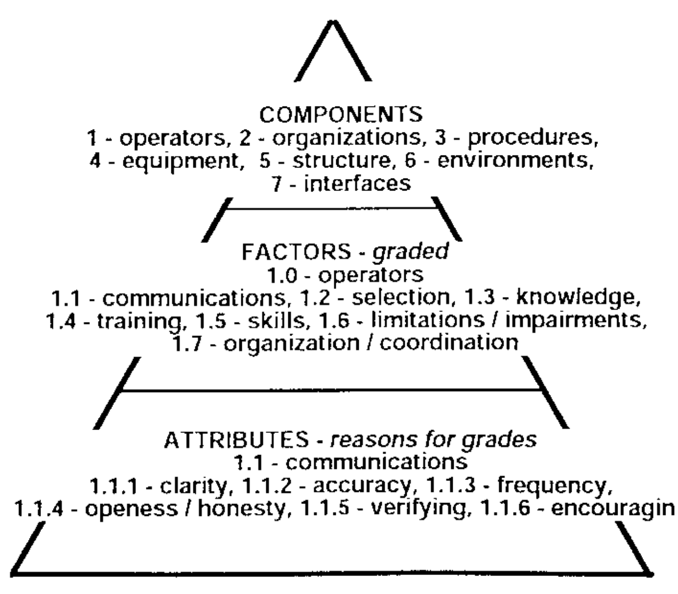


Figure 2 - Safety components, factors, and attributes

identified: communications (1.1), selection (1.2), knowledge (1.3), training (1.4), skills, (1.5), limitations / impairments (1.6), and organization / coordination (1.7). If in the judgment of the assessment team, additional factors should be considered, then they can be added. Using a process that will be described later, the assessors develop grades for each of these factors.

The third Level identifies attributes associated with each of the factors. These attributes are observable (behaviors) or measurable. These attributes provide the basis or rationale for grading the factors. For example, for the communications factor (1.1) six attributes are included: clarity (1.1.1), accuracy (1.1.2), frequency (1.1.3), openness / honesty (1.1.4), verifying or checking - feedback (1.1.5), and encouraging (1.1.6). Again, if in the judgment of the assessment team, additional attributes are needed, they can be added to the SMAS.

Four sources of information were used to compile these component factors and attributes: regulations and industry guidelines (ASTM, API, ISO, MMS, HSE, ISM, USCG; Center for Chemical Process Safety), individual company guidelines, experience and history with LOC on offshore structures (Moore, Bea, 1993; Bea, 1994), and results from current research (Bea, Roberts, 1995; Bea, 1996; Groeneweg, 1994; Hurst, et al, 1992).

Table I - Level 1 evaluation categories and factors

Operating Teams Communications Selection Knowledge Limitations & Impairments Management Experience Training Skills	**Organizational** Process Auditing Safety Culture Risk Perception Emergency Preparedness Command & Controls Training Communications Resources
Procedures Operating Maintenance Safe-work Contractor coordination Shift / Crew change Emergency response Management of change	**Hardware / Equipment** Drilling systems Production systems Piping, hoses Pumps / compressors Flanges / gaskets Electrical systems Pressure vessels Storage tanks Lifting / crane facilities Fire protection facilities
Structure Operational loadings (vertical) Operational loadings (horizontal) Environmental ldgs. Fire / explosions prot. Collision protections	**Interfaces** Operators & other Organizations & other Procedures & other Equipment & other Structure & other comp.
Environmental External Internal	

GRADING FACTORS

The method for addressing SMAS factors and attributes relies upon experienced and trained assessors who assign grades for each component factor and attribute.

Each of the attributes for a given factor are assessed based on a seven point grading scale (Fig. 3). An attribute or factor that is average in meeting referent standards and requirements is given a grade of 4. An attribute or factor that is outstanding and exceeds all referent standards and requirements is given a grade of 1. An attribute or factor that is very poor and does not meet any referent standards or requirements is given a grade of 7. Other grades are used to express characteristics that are intermediate to these. The assessor is allowed to indicate upper and lower bounds to the grade for each factor. This allows a variance on the grading of each factor to be developed.

The grades for the attributes are summed and divided by the number of attributes used to develop a resultant grade for the factor. The assessors review this resultant grade and if it is acceptable, the grade is recorded. If it is not, it is revised and the reasons for the revision noted.

In the same manner, the grades for the factors are summed and divided by the number of factors to develop a resultant grade for the component. Again, the assessors review this resultant grade and if it is acceptable, the grade is recorded. If it is not, it is revised and reasons for the revision noted.

A 'Braille' chart is then developed that summarizes the mean grades developed by the assessment team for each of the factors (Fig. 4). The 'high' grades (those above 4) indicate components and the associated factors that are candidates for mitigation. Based on the upper and lower bounds identified by the assessors for each of the factors, a resultant variance expressed as a coefficient of variation is given for each of the resultant grades. This gives the assessor an understanding of the overall uncertainty associated with the gradings.

ASSESSORS

The single most important element in the SMAS system is the assessor. It does not matter how good the SMAS assessment instruments and procedures are if the personnel using the instrument do not have the proper experience, training, and motivations. The SMAS assessor must have experience operating platforms, blowout, fire and explosion training, safety auditing experience, and training in human and organization factors.

An important aspect of the qualifications of assessors regards their aptitude, attitude, and motivation. It is very desirable that the assessors be highly motivated to learn about human and organization factors and safety assessment techniques, have a high sensitivity to safety hazards ('perverse imaginations'), be observant and thoughtful, have good communication abilities, and have a willingness to report 'bad news' when it is warranted.

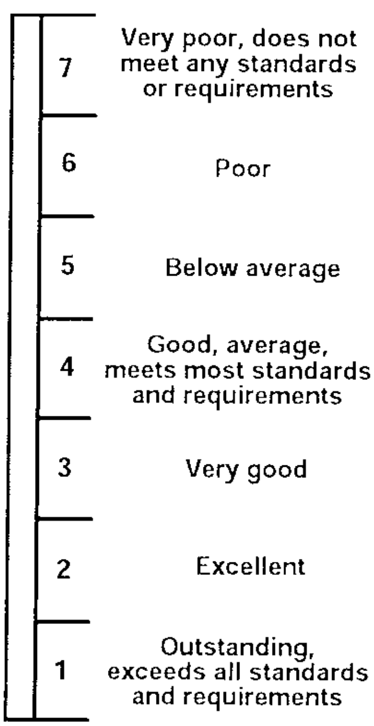


Figure 3 - Grading scale

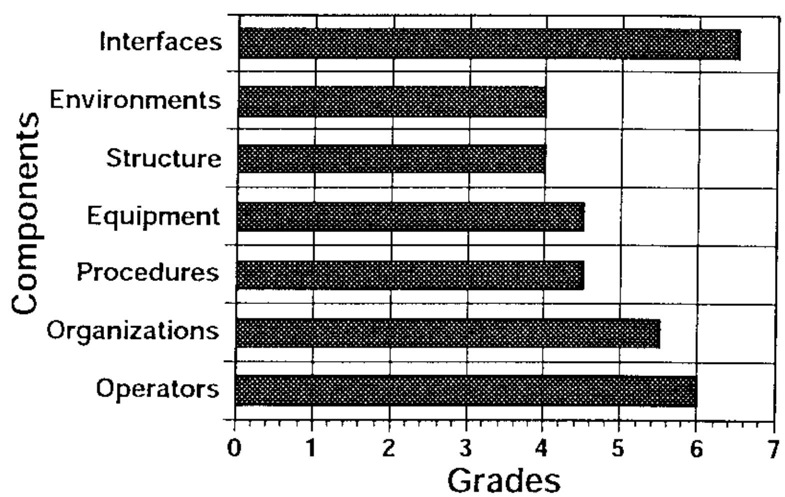


Figure 4 - Example component mean grades

An assessor 'just-in-time' training program has been developed. This program includes basic training in human and organization factors and the SMAS assessment process. Example applications are used to illustrate applications and to help reinforce the training. A final examination is used to help assure that the assessor has learned the course material and can apply the important concepts.

The assessor training program has two parts: 1) informational, and 2) practical exercises. The informational part contains background on the SMAS assessment process and computer instrument,

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REAL-TIME PREVENTION OF PLATFORM DRILLING BLOWOUTS: MANAGING RAPIDLY DEVELOPING CRISES

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INTRODUCTION

The single largest cause of major accidents on offshore platforms today is blowouts that occur during drilling and workover operations (Fig. 1) (Bea, 1993). There has been a significant reduction in blowout related accident rates over time. Most of this reduction has been achieved through improvements in drilling and workover equipment, operating procedures, and training of drilling and workover personnel.

Examination of the causes underlying current drilling and workover accidents (Sonneman, 1992; Rosenbert, et al, 1994; Lefebre, Muir, 1996; Andersen, 1996; Miessner, 1996) indicates that they have 'root' causes founded in errors committed by operating personnel, deficiencies in drilling and workover equipment, and operating procedures. Figure 2 summarizes the distribution of *initiating* causes in drilling and workover blowouts that have been investigated. The single dominant initiating cause is due to errors made by the drilling and workover operating personnel. The single largest source of personnel errors are mistakes. These mistakes are errors that develop due to incorrect cognitive processing of information or signals that develop during the drilling and workover operations.

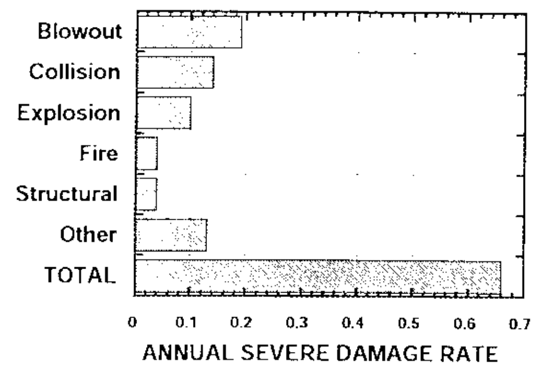

Figure 1: Major accident rates on fixed offshore platforms (1983-1993)

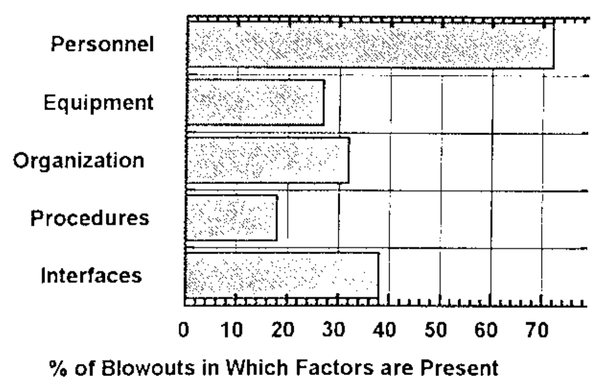

Figure 2: Blowout initiating factors

Figure 3 summarizes the distribution of contributing influences that background the initiating causes. Contributing causes are the influences that played major roles in the initiating events. In this case, organizational influences and deficiencies in procedures and equipment are all about equal contributors. Most of the deficiencies in equipment are due to neglected maintenance and inappropriate design / configuration of the equipment. The majority of procedure factors are associated with use of early warning signals that the well is kicking. The majority of the organizational factors are associated with conflicting incentives that are provided to the drilling and workover personnel. These conflicting incentives most often are those of production and safety.

Figure 4 summarizes the distribution of propagating factors. Propagating factors are those elements that allowed the initiating event/s to continue to develop and escalate until there was a blowout. Again, the leading factors are due to organizational and procedural deficiencies. The majority of the procedural deficiencies are failure to use appropriate emergency responses. The majority of the organizational deficiencies are associated with deployment of personnel (team work) and communications.

Figure 5 summarizes the results of current drilling rig inspections and shows the distribution of equipment deficiencies that have safety implications (Lefebre, Muir, 1996). The vast majority of the drilling equipment deficiencies are associated with the derrick (30 %). The safety deficiencies are chiefly due to drilling facilities (20 %) and extinguishing facilities (15 %). The well control deficiencies are primarily due to BOP system deficiencies (54%). Mud pump deficiencies account for 48 % of the mud system deficiencies.

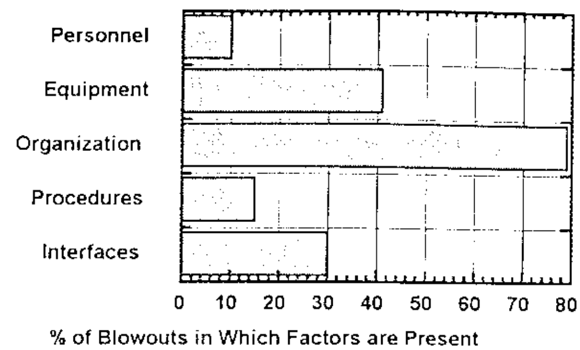

Figure 3: Blowout contributing factors

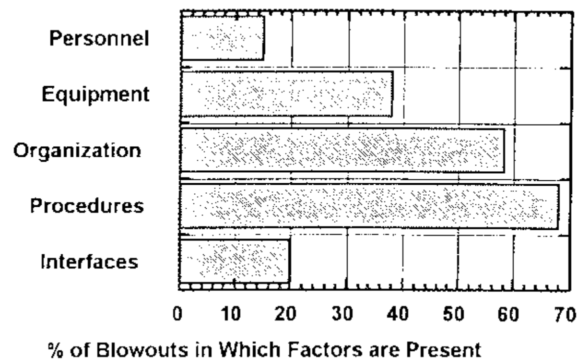

Figure 4: Blowout propagating factors

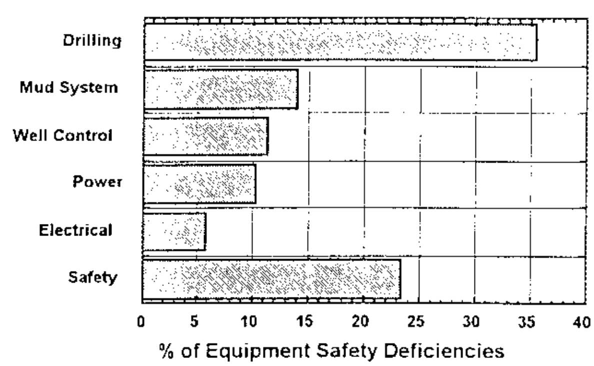

Figure 5: Rig equipment safety deficiencies

This information clearly indicates that the primary factors that result in blowouts are due to Human and Organizational Factors (HOF). If significant improvements are to be made in the frequencies of these accidents, then the implication is that the HOF involved in initiating, contributing, and propagating phases of blowouts must be addressed. The major challenge posed for equipment is to improve the human 'interface' aspects (micro ergonomic aspects).

STRATEGIES

Development of safety in complex technological systems has traditionally used two fundamental approaches: proactive and reactive (Rasmussen, 1996). The proactive approach is analytical, depends on the predictability of the system, and is focused on infrequent accidents. A major difficulty with most proactive approaches (e.g. probabilistic risk analyses) is that they can not adequately characterize and analyze complex future human and organizational interactions with systems. How can one develop an analytical model of what one can not characterize and predict? Hudson, et al (1994) have developed an instrument and protocol identified as Tripod-DELTA that has been used in proactive safety management of drilling operations.

The reactive approach is fundamentally empirical, based on experience, focused on fixing the last accident, and primarily addresses frequently occurring accidents. Much of the field of worker and system safety has been built on the reactive approach.

The author proposes that there is a third approach to achieving safety in complex technological systems. This is real-time management as the accident unfolds. This is management based on OODA (Observe, Orient, Decide, and Act) 'loops' (recursive trials), migrating decision making, divide and conquer deployment, and requisite variety in problem identification and solving. This is management of rapidly developing crises that can have significant consequences, such as a blowout on an offshore platform (Bea, Roberts, 1997).

Experience with complex technological systems indicates that behind each major accident is something of the order of 10 to 100 near-misses, and perhaps 100 to 1000 hazardous acts or events (Groeneweg, 1994). It is obvious that people frequently interact with systems to produce safe operations. We want to learn how to increase the proportion of successful interventions, particularly as potentially high hazard or consequence events unfold.

CRISIS DEFINED

A crisis is defined as a rapidly developing sequence of events in which the risks associated with the system rapidly increase to a hazardous state (Fig. 6) (Huey, Wickens, 1993). The crisis begins with a surprise warning of some type that the system is moving from a safe to an unsafe state. Crises involve potentially grave life and property threats.

Lagadec (1993) describes crises as "events that do not play by the rules." These destabilizing breakdowns seem to feed on themselves and overwhelm normal problem solving resources. Crises are characterized by a threatening of normal values and goals, pressures to decide quickly, short times to

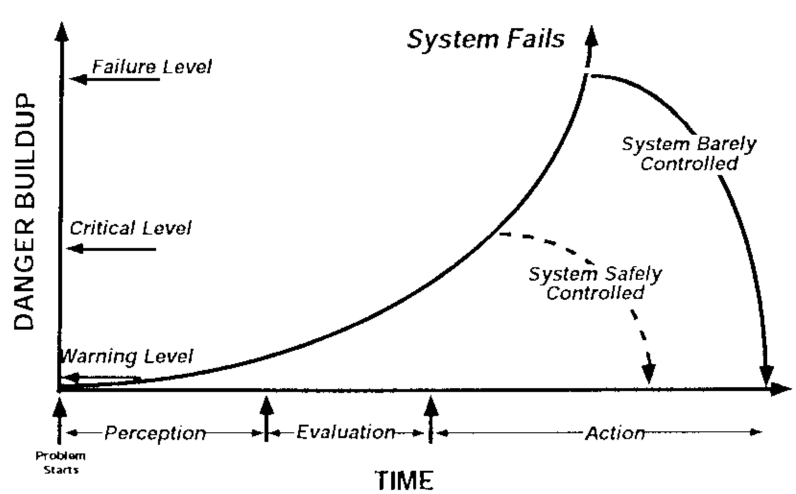

Figure 6: Evolution of a crisis

act, unexpected events that shock, confusion, pressures to innovate in solving the crisis, development of limited options, developments in which inaction produces undesirable consequences, incomprehensible developments, information overload, ambiguity and uncertainty, increased numbers of important demands, conflicts, limited resources, problems lumped together, exaggerated deviations, intense scrutiny, and loss of critical functions. Crises are traumatic affairs.

Lagadec further observes, "the ability to deal with a crisis situation is largely dependent on the structures ...developed before chaos arrives. The event can in some ways be considered as an abrupt and brutal audit: at a moment's notice, everything that was left unprepared becomes a complex problem, and every weakness comes rushing to the forefront. The past settles its accounts." Sarna (1996) characterizes crises as "...not the kind of incidents that occur on a regular enough basis to allow incident commanders to build a personal data base of experience."

In its simplest terms, a crisis can be divided into three general stages (Fig. 6): 1) perception, 2) evaluation, and 3) action. The first stage requires individuals to perceive and recognize warning signs of the evolving crisis. The second stage involves processing information to identify problems and causes, alternatives that might bring the system back into a safe state, consequences associated with each alternative, evaluation of alternatives, and the choice of alternative or alternatives to be implemented. The third stage involves implementing the alternative, and observing the results. If the observation indicates that the alternative is not working, the process must be repeated selecting a different alternative. If the system cannot be brought back to a safe state, an accident happens. If the system can be brought back to a safe state, a 'near-miss' or 'incident' occurs.

This characterization of crisis raises issues about strategies that can more frequently bring marine systems back to safe states and to understand how to have more 'near-misses' than 'direct hits' (accidents). To do this, we will explicate in greater detail what we have learned from the various communities how they have learned to successfully manage rapidly developing crises.

Rasmussen (1986) defined a crisis decision making model involving six steps: 1) monitoring and detecting, 2) interpreting the current state, 3) determining its implications, 4) developing a control plan, 5) implementing control actions, and 6) observing and obtaining feedback on the effectiveness of the control plan. This is a process that has been identified as OODA (Observe, Orient, Decide, Act) loops (Orr, 1983).

Fig. 7 summarizes the key steps in managing rapidly developing crises, based on Rasmussen and results from our research. Fig. 6 can be interpreted as a more detailed breakdown of Rasmussen's six steps and the three phases identified in Fig. 6. Figure 7 details several additional important aspects of crisis management that are focused on the critical decision making and implementation aspects of developing a successful crisis management strategy. These include such activities as integrating information, establishing goals and priorities, reflecting and debriefing, etc. Weick (1995b) summarized this process as: "1) here is what I think we face, 2) here is what I think we should do, 3) here is why I think this, 4) here is what and why we should watch, and 5) now, talk to me!"

Note the potential effect of training in Fig. 7 (other 'short-cuts' are possible but not shown). Training can help eliminate much of the cognitive processing required to determine what should be done. This allows effective alternatives to be rapidly defined and implemented.

Also, note the importance of observations. Observations provide clues to determine if implementation is producing the desired results. If it is not, the processes of identification and evaluation need to be repeated to help arrest the crisis. If clues indicate the crisis is being arrested, the process must be continued until the emergency is over. The process should not be stopped until adequate safety has been achieved.

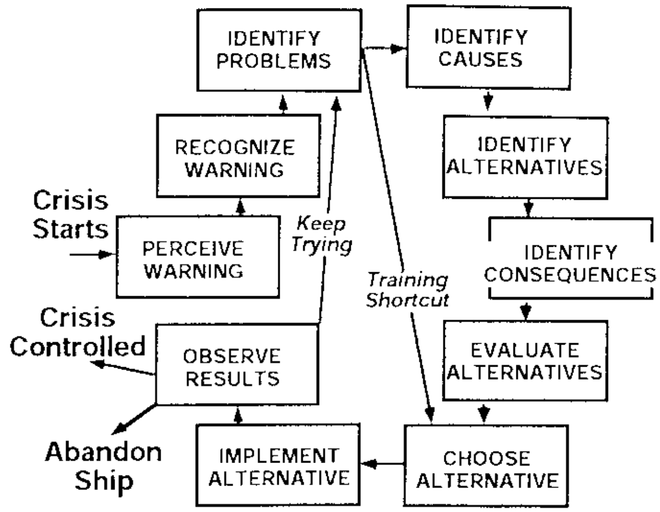

Figure 7: Primary steps involved in managing a crisis

CRISIS RECOGNITION

Perhaps no stage in a crisis is as important as the first stage: recognition or perception. This is typically where well kicks develop into full fledged blowouts (Sonneman, 1992). Because the crisis is just unfolding, if the situation can be quickly and correctly recognized, there will be more opportunity and time to bring it under control. However, there are often a variety of organizational constraints that delay this recognition including conflicts in incentives: production versus safety: "I will catch hell if I close the well in." Ambiguous information on the state of the well compounds this problem.

Three classes of cognitive factors seem to govern how and how well people perceive a crisis (Cook, Woods, 1994):

1) knowledge - background that can be accessed when solving problems,
2) attention dynamics - control and management of mental workload, maintenance of situation awareness, and avoidance of fixations,
3) strategy development - successful trade-off between conflicting goals, dealing with uncertainty and ambiguity, avoidance of organizational double binds, and development of good priorities and decisions.

Feltovich, et al., (1989) identified a number of factors or biases that tend to suppress quick and accurate recognition of a crisis. These include:

- treating a dynamic situation as static,
- assuming that some general principle accounts for all of the observations,
- seeing different entities as more similar than they are,
- treating multidimensional phenomena as uni-dimensional,
- treating continuous parameters as discrete (uni-valued),
- treating the whole as the sum of its parts,
- treating highly interconnected elements as separable.

Other factors can be added to this list (Bea, 1994; Bea, Roberts, 1997) including:

- failure to revise assessments based on new information,
- evaluation that the desired state or outcome is very likely when it is not likely (wishful thinking),
- over estimation of control over the developments and outcomes (supermen/women),
- over estimation of the predictability of the sequence of events, and

- 'garden path problems' in which strong 'signals' suggest plausible but incorrect answers; weaker signals that suggest plausible and correct answers are ignored or not detected.

Developing and maintaining an awareness of potentially hazardous situations involves a constant process of detecting anomalies; things that are not right or don't fit. This requires constant shifting of attention, a very limited resource, to modify a picture (mental model) of a system as a whole. Building and maintaining the picture of the system requires cognitive effort, which when it breaks down is called 'loosing the bubble' (Roberts, 1994). It is here that team work can provide additional information, attention capacity, and requisite variety (Weick, 1995a) in insights and potential solutions and enable the team to recognize the early warning signs of the developing crisis and quickly implement effective control strategies.

IMPROVING REAL-TIME CRISIS MANAGEMENT

Two fundamental approaches to improving crisis performance are: 1) providing people support, and 2) providing system support (Bellamy, 1994).

People Support

People support strategies include such things as selecting personnel well suited to address crises, and then training them so they possess the required skills and knowledge. Re-training is important to maintain skills and achieve vigilance. The cognitive skills developed for crisis management degrade rapidly if they are not maintained and used.

Crisis management teams should be developed that have the requisite variety to manage the crisis and have developed teamwork processes so the necessary awareness, skills and knowledge are mobilized when they are needed. Auditing, training, and re-training are needed to help maintain and hone skills, improve knowledge, and maintain readiness. Crisis management teams need to be trained in problem 'divide and conquer' strategies that preserve situational awareness through organization of strategic and tactical commands and utilization of 'expert task performance' (specialists) teams. Crisis management teams need to be provided with practical and adaptable strategies and plans that can serve as useful 'templates' in helping manage each unique crisis. These templates help reduce the amount and intensity of cognitive processing that is required to manage the crisis. Such a template could include:

a) throughout, question, anticipate, and take initiatives;
b) avoid radical responses, be moderate in seeking gains;
c) capitalize on the opportunities offered by the crisis;
d) look for anything that may add flexibility and slow escalation;
e) avoid making irreversible commitments;
d) do not forget the post-crisis period (recovery, rescue); and
e) keep all communications channels open.

System Support

Improved system support includes factors such as improved maintenance of the necessary critical equipment and procedures so they are workable and available as the crisis unfolds. Data systems and communications systems are needed to provide and maintain accurate, relevant, and timely information in 'chunks' that can be recognized, evaluated, and managed. Adequate safe haven and life saving measures need to be provided to allow crisis management teams to face and manage the crisis, and if necessary, escape. Hardware and structure systems need to be provided to slow the escalation of the crisis, and re-stabilize the system. Safety system automation needs to be provided for the tasks people are not well suited to perform in emergency situations.

One would think that improved system support would be highly developed by engineers. This does not seem to be the case. A few practitioners recognize its importance (Kleitz, 1991), but generally it has not been incorporated into general engineering practice or guidelines. Systems that are intentionally designed to be stabilizing (when pushed to their limits, they tend to become more stable) and robust (damage and defect tolerant) are not usual. Some provisions have been made to develop systems that slow the progression of some crises. Fire deluge systems, heat insulation on critical structural elements and fire walls, and blast pressure relief panels are examples of some of the provisions. Our work indicates that system robustness is achieved through a combination of redundancy (alternative paths to carry the loads), ductility (ability to redistribute loads and deform without compromising safety), and excess capacity (to carry the redistributed loads). These guidelines also apply to the organizational or people components of systems.

Effective early warning systems and crisis information and communication systems have not received the attention they deserve in providing marine system support for crisis management. Systems need to be designed to clearly and calmly indicate when they are nearing the edges of safe performance. Once these edges are passed, multiple barriers need to be in place to slow further degradation and there should be warnings of the breaching of these barriers. More work in this area is definitely needed.

Table 1 - Crisis management personnel

Criteria	Competencies
• technical and professional qualifications • managerial & leadership qualifications • demonstrated abilities to command and control emergencies	• leadership • communications • delegating • team working • stress management • situation evaluation • planning • implementing
Attributes	
• task oriented • goal oriented • flexible • information seeking • sanctifying	• status leveling • self confidence • emotional control • self reliance • strength of personality

The Right Stuff

Selection and training of personnel are critically important in building effective crisis management teams. Selection and training of crisis management personnel are discussed by Flin and Slaven (1995) for offshore platforms. The 'right stuff' consists not only of leaders, but as well followers. Both leaders and followers must be team players. As the nature of the problem changes, leaders can become followers and vice versa.

Slaven identified selection criteria (Table 1) as: technical comprehension, intellectual capacity, perceptiveness, sociability, self-control, and stress tolerance. Psychological tests were developed to shed light on the capacity for logical thinking, stress- tolerance, perceptiveness, technological comprehension, the capacity for simultaneous performance, understanding instructions, self-assertiveness, responsibility, emotional stability / self-control, vigilance, accuracy, sociability, and tempo.

Flin and Slaven organized the selection criteria into three general categories: technical and professional qualifications, managerial and leadership qualifications, and demonstrated abilities to command and control emergencies. Based on research regarding a wide variety of types of emergencies, including those on offshore platforms, they identified eight key competencies (Table 1) and ten key attributes of 'the right stuff' (Flin, Slaven, 1996).

All research on crisis management indicates the importance of training. Training is intended to help reduce the amount of cognitive processing required. Training is intended to help prevent cognitive 'traps' that can develop during an emergency and develop key competencies needed in managing crises.

The how's of crisis management training are tricky. Training should not endanger the trainees. However, training should be realistic. Training in the field with the system of concern is the most desirable form of training as long as the training can be realistic and the danger to personnel and the system minimized.

Training in simulators is the next most desirable form. Simulators must develop realistic and physical mental images of an actual system in emergency situations. Danger to personnel must again be minimized. And, it is here that simulators have one of their major limitations: the trainees know that it is not likely that they will die in the simulations. The trainees also know that the most desirable reactions and actions in the simulation are those that will produce safety; thus, the trainees are relieved of realistic production versus safety goal identifications and resolutions. Another major challenge for simulator training is to capture the unfolding and interactive nature of unpredictable events and the organization - crew interactions so important in such events.

CONCLUSIONS

The primary purpose of this discussion has been to point out the importance of three approaches to reduce the incidence of platform drilling and workover blowouts. These are reactive, proactive, and real-time approaches. The reactive and proactive approaches have been used extensively by industry. The approach that needs more attention and further development is the real-time approach that has been identified here as 'crisis management.' In addition, it is obvious that even with the reactive and proactive approaches, not enough attention has been given to HOF. The HOF aspects of equipment design (ergonomic or people friendly design) and maintenance, emergency procedures, inherently safe design (robust systems), and providing sufficient and effective people and system support have been highlighted.

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Application and Implementation of Human and Organizational Factors into Management Systems to Reduce Human Error and Improve Offshore Platform Safety and Productivity

*** DRAFT #2.2***

Preface

It is often stated that 'human error' accounts for approximately 80% of marine casualties. Marine casualties such as *Piper Alpha*, *Ocean Ranger*, *Glomar Java Sea* and others have demonstrated that these problems are not as simple as 'operator error'. Each of these disasters were compounded by management related factors that influenced their operations and emergency preparedness. Upon review of both offshore casualties and casualties from other industries, although casualties occur in many different ways, most have similar 'signatures'. That is, most casualties are contributed to by breakdown of communication, incentives, emergency preparedness, selection of properly trained, experienced personnel and other contributing factors. However, one key element has been that the vast majority of causes of casualties are rooted in the management system of the organization (Bea and Moore, 1990; Libuser, 1994; Roberts, 1990).

Most all organizations have two distinct long-term operational goals: production and safety and in the long-term are both within the interest of the organization to stay viable. However, short term goals may not necessarily be compatible in light of limited resources and therefore conflicts may arise in balancing safety and production (Reason, 1990). This was the case with *Piper Alpha*, to continue production while performing maintenance on the production system (Moore and Bea, 1993). An effective safety management system is a key element to the success of an organization to balance both safety and production at all times.

There are three key elements that impact safety offshore: technology, the human operator, and the operational management. To ensure safety and production, these three elements must be properly managed. To manage these factors in unison requires a strong safety culture that incorporates these three core elements. Within the last 5 years, considerable effort has gone into developing standards for safety management.

API RP 75, the Safety and Environmental Management Program (SEMP) and the International Maritime Organization's (IMO) International Safety Management Code for self-propelled MODUs are making valuable strides in that direction. Nevertheless, there is a strong need to ensure that human and organizational factors (HOFs) are both explicitly and implicitly included in the development and implementation of offshore safety management systems.

Objective

The objective of this paper is to focus upon effective means by which to ensure proper consideration of HOFs in the development of a safety management systems for offshore oil and gas exploration and production. This will be described by demonstrating how standard management techniques can be applied to incorporate HOFs which are the most critical elements for proper implementation of a safety management system.

Background

The *Piper Alpha* disaster has led to significant changes in the way we address offshore safety. The Cullen Report laid forth 106 recommendations of how to enhance offshore safety with key elements related to safety cases. As a result, the U.S. Minerals Management Service (MMS) requested the National Academy of Sciences Marine Board to assist them in investigating alternative strategies for inspection and safety assessment of OCS platforms, with a view toward improving operational safety and inspection practices (National Research Council, 1990).

Considerable effort was made to select members of the working committee, known as the Committee on Alternatives for Inspection (CAI), who not only had both the requisite expertise in OCS operations and safety management, but would also bring a balanced viewpoint with respect to public interests in environmental protection and safety. CAI members reviewed the current OCS inspection program and practices, appraised other inspection practices for 'lessons-learned' including those of platforms in state waters as well as inspection practices in other industries, reviewed MMS databases and the OCS safety record, and developed evaluation criteria and alternative recommendations for consideration by the MMS.

The CAI developed inception recommendations focused upon key issues to characterize and measure potential for human failure such as hazardous events, near misses, inspection and repair, maintenance, location, platform age, etc. Another key element was a means by which to determine evidence of a lax attitude towards safety by managers, supervisors or operating personnel representing a lack of a 'safety culture' and risk awareness onboard.

The CAI stressed the importance of management's safety culture and suggested that MMS make this explicit in its safety management and inspection philosophy. The CAI cautioned against a 'compliance culture' in which some operators may perceive their responsibility and objective as simply 'to pass inspection'. The CAI emphasized its belief that mere compliance with requirements and regulations does not equal safety, and that practice and by law, operators bear the primary responsibility for safety.

Management System Design and Development

A management system represents an organizations explicit arrangements for planning, organizing, implementing, and controlling its work processes. The management system itself is an organized assemblage of interdependent activities used to manage the work processes. Managing and improving processes have been evolving since humans began perfecting their crafts and passing them down from generation to generation. As organizations formed, and processes became more complex, higher levels of risk were introduced and other elements such as standards and regulations, word of mouth, on the job training and apprenticeship were not enough to achieve desired results (e.g. in terms of quality, safety, environment and business). Organizations had to begin documenting and controlling their activities to achieve multiple objectives, ensure reliably, fulfill customer needs, protect employees, public, the environment, and even increase profitability.

The ANSI/ISO/ASQC A8402-1994 Quality Management and Quality Assurance vocabulary states that a process is a set of interrelated resources and activities which transform inputs into outputs. Inputs can be transformed into desired outputs both "linearly", and "systematically". The linear or one dimensional approach, focuses on each process beginning at point "A" and ending at point "B". The systems or multi-dimensional approach focuses on the process, related processes (up and down stream), and factors that influence or can influence the process. There are few guidelines or consensus standards published on how to design, develop, implement and control a management system. There are numerous publications on what should be included in a management system such as the elements outlined in various management system related regulations and performance standards (e.g. API RP 75, ISO 9000, etc.). There are also numerous publications that provide guidelines on controlling processes, mapping processes, analyzing process hazards, total process management, system re-engineering and system communication within an organization.

Where does the management system development process begin? How do we integrate human factors into the system? What changes will be required? Will the management system effect the way the organization operates? How do we ensure we haven't left out elements important to our organization? To what level of detail must the documentation be developed? What elements are needed to ensure that the system meets the requirements and delivers the desired results? The answers to these and many more questions do not appear to be readily available or are still evolving. Before designing a management system it is important that the systems components are understood. Figure 1 represents a hierarchy of management system components discussed by the working group. At the apex, are the values and beliefs that shape the culture and character of both individuals and an organization (ref. Edward Wenk Jr. working group support paper "Safety, Corporate Culture and Corporate Character"). Individual values and beliefs (e.g. morality) play an integral part on the decisions and actions of individuals and individuals working as groups in organizations (Moore and Bea, 1993).

Individuals do not necessarily make the same value judgments when working as groups than they would individually.

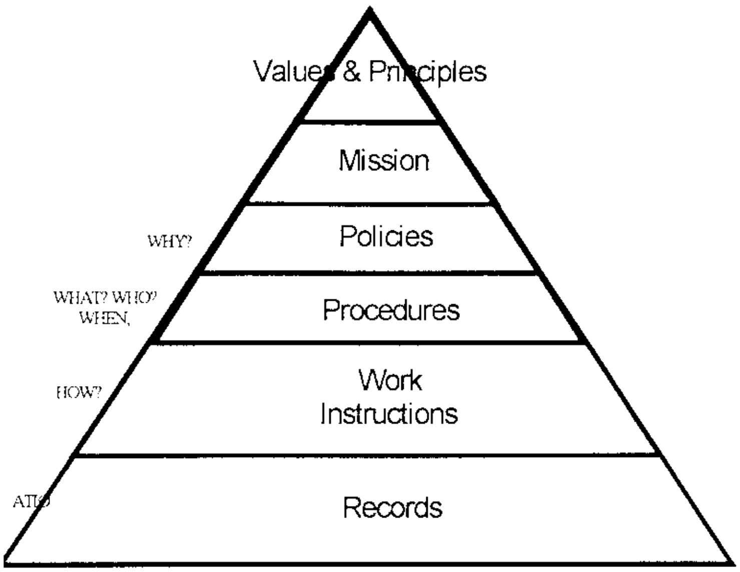

Figure 1 - Components of a Management System

At times, 'group think' are in conflict with the values and beliefs of individuals. Values and beliefs of an organization can overtake the individual's ability to influence the organizational value and belief system. An example of this is the military. The military works on breaking down a person's individuality to make them part of a fighting unit. Under these circumstances, this is arguably a good system to maintain discipline and develop a well organized fighting unit. On the other hand, a military recruit also has the value and belief system that he/she grew up with and that is maintained by the individual. At times, these values and beliefs may come into conflict (e.g. killing during a wartime situation) where individual beliefs are sacrificed to a degree. It is important to establish what is desirable and undesirable and ensure that undesirable elements are prevented from undermining (either internally or externally) the organizations fundamental values and principles.

Organizations establish mission statements based upon the business they are in, the customers they serve, the safety and environmental standards they wish to establish and how they wish to be known. For many organizations, the mission is to increase revenues and profits and to ensure it is done safely. The mission should be defined as clearly as possible to ensure the mission represents the overall intentions and direction of the organization.

Policies are those documents that represent what is needed to complete the overall mission. Policies should answer why each process is needed.

Procedures are those documents developed to communicate the approach to meeting the requirements outlined in the policy documents. Procedures communicate to the stake holders what, where and when activities are done and by whom.

Work instructions, where required, are developed to communicate how activities are carried out related to the specific procedures. Work instructions may also be further refined into task instructions (e.g. a work instruction would describe the activities to inspect, test and maintain rotating equipment and what the acceptance / rejection criteria is. A task instruction would provide the tasks necessary to change the oil on a specific type of compressor).

Records are those documents that verify conformance or non-conformance to the requirements. Records are used to measure performance of activities carried out so that adjustments can be made, if necessary, to meet the requirements.

The volume of documentation required is subject to the complexity of operations, number of equipment and engineered systems, the knowledge and experience of the employees, and the level of performance (e.g. quality, safety and environmental) that is appropriate.

The mission statement is normally brief and concise, understood by all employees and easy to remember. The policies are typically brief, coherent and clearly establish what needs to be accomplished to meet the requirements. Procedures provide details on the approach to the work and management responsibilities. Work instructions are activity and or tasked based and usually require a higher level of detail to communicate how specific work is to be performed. If records are meticulously kept, the volume of information collected over time can be quite substantial. Hence, electronic forms of document and records control are now commonly used for information management.

Generic Work Process

The key element for the development of effective implementation of policies, procedures and work instructions described above is the proper mapping of each work process. Figure 2 is a diagram illustrating a generic work process we wish to manage. The inputs required to begin the process are identified, as well as the desired outputs. Activities and resources used to plan, organize, implement and control the process as well as who manages, performs and verifies the work are also documented to ensure that the requirements are met.

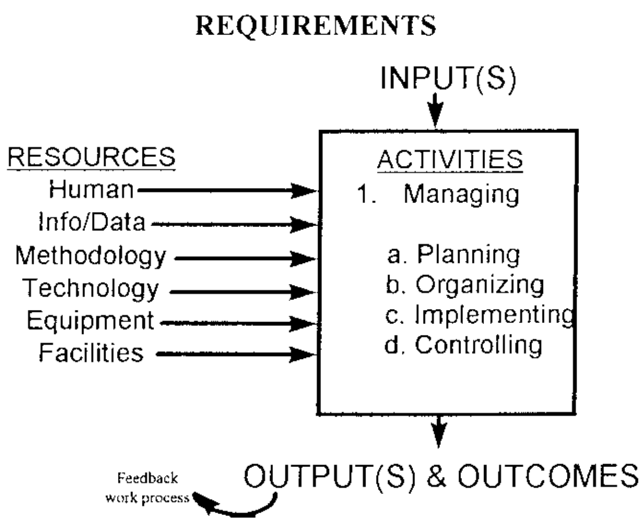

Figure 2 - Generic Work Process

Core elements of a Safety Management System (SMS)

A comprehensive listing of the elements of a SMS was developed during the Workshop and are included in Table 1. The primary source of these elements are API RP 75 Safety and Environmental Management Program (SEMP) and the International Maritime Organization's International Safety Management Code (ISM Code). The use of both the SEMP and ISM Code reflect the considerable effort and expertise to ensure all core elements of a safety management system are in place. In addition, SEMP and the ISM Code cover both fixed structures and MODUs.

Table 1 - Elements of SMS

• *Safety and environmental policy statement*	• *Documentation*
• *Company responsibility and authority*	• *Auditing*
• *Designated persons*	• *Hazards analysis/risk assessment*
• *Responsibility and authority*	• *Management of change*
• *Resources and personnel*	• *Training*
• *Operations plan*	• *Pre-startup review*
• *Emergency preparedness*	• *Ensuring control of contractors*
• *Reports of non-conformities, incidents and accidents*	• *Safety and environmental information*
• *Proper maintenance and inspection*	• *Continuous improvement*

Safety and Environmental Protection Policy

The safety and environmental protection policy is to be a clear and concise statement of the SMS's goals and a general outline as to strategies to attain these goals. This outline should include the company's philosophies regarding health and safety in the work place and environmental protection policies. It is also important to ensure that these concepts are consistent with the company's operating policies and procedures.

To ensure commitment from top-level management, the policy statement should be signed by the company's executive officer (or equivalent senior management personnel). There should also be a means by which senior management personnel can review and update the SMS as necessary. It is also important to ensure that all employees are made aware and have a clear understanding of the company's safety management policies.

Company Responsibility and Authority

It is imperative that each and every employee involved in the operations aspects of the platform have a clear understanding as to their safety management responsibilities. The level of competence, responsibilities, and authority of each job should be clearly defined. It is also the responsibility of top-level management to ensure that personnel assigned to each job are properly trained and qualified for the duties to be performed.

Designated Person(s) for Access Between Platform and Top-Level Management

A key element of operational safety is communication. To ensure that top-level management is aware of operational factors that affect safety management, designated individuals in the organization should be the direct interface between management and operating crews. The responsibilities of those personnel are to ensure that the policies and procedures of the SMS are properly implemented. It is also those individual's responsibility to resolve non-conformities, carry out internal safety audits, and have direct access to top-level management personnel to ensure expedient resolution of non-conformities to the SMS.

Responsibility and Authority

The individual or individuals responsible of ensuring SMS policies are effectively and efficiently conducted on a day-to-day basis should be properly defined. For example, for MODUs underway, may be the master's or their designee(s) responsibility to ensure that each individual aboard the MODU is aware of the policies and procedures of the SMS and performs his or her duties in compliance with the SMS. On the other hand, while the MODU is on station the responsibility may shift to the tool pusher or their designee(s) with different risks and operations to be concerned with than that of the MODU when underway.

Companies are encouraged to develop specific guidelines and strategies regarding how to promote, encourage, train, and monitor platform personnel in the policies of the SMS. In addition, the company should also encourage the master / management and crew members / employees to participate in the development of the safety management system. This can greatly enhance the performance of platform crews. Another important issue is to ensure that the responsibilities for managing, performing and verifying the work is clearly specified and that all stake holders are aware of their authority to ensure safety and pollution prevention.

Resources and Personnel

Moore and Bea (1993) point out that proper resources be applied to safety management as well as the best personnel to implement it. To ensure this it is important that platform crew are well trained, experienced, knowledgeable, and physically and mentally fit for the duties their jobs entail.

Each member of the crew should be familiar with the specific duties of their job. It is the responsibility of the company to determine the most effective methods by which to familiarize the crew with the SMS (shoreside and in-service training, videos, written material, etc.). Crew members should be familiar with other relevant rules and regulations (local and international) that relate to crew safety and environmental protection (e.g. guidelines on safe working routines).

Managers need to be knowledgeable and experienced in making decisions concerning safe operations of their platform. Not only is it important that these personnel be cognizant (know where problems exist) of problems, but also competent (know how to solve the problems). These individuals should have a good working idea of the constraints and limitations of a platform's operations and crew. It could be to the advantage of the company to have individuals who have substantial sailing experience assist in making safety related suggestions, recommendations, and decisions in the day-to-day operations of the platform.

A variety of training exists in the form of classroom skills training, through role playing to enhance communication skills, simulations for team development and virtual reality. The more complicated the company's platform operations, the greater necessity for proper resources to be put towards training.

Development of Plans for Offshore Operations

It is the responsibility of the platform operator to develop safety plans for the platform during all of its operating modes (e.g. during drilling, workovers, production, etc.). Instructions should be issued for key operations to ensure that the operations are consistent with the SMS philosophies. The instructions should be simple and unambiguous.

Emergency Preparedness

It is imperative that each platform have written procedural guidelines on how to handle emergency situations required by national and international regulations as applicable. Crew members should have training and a good working knowledge of how to handle emergency situations.

Both the platform and shoreside emergency plans should be consistent and properly integrated to ensure prevention or mitigation in the event of an accident. Communication of critical information between the platform and shore based personnel should be properly maintained. The emergency plan should include allocation of duties and responsibilities aboard the platform in crisis situations, method of communication, procedures for notifying the company and relevant regulatory authorities, etc.

Reports and Analysis of Non-Conformities, Casualties, and Hazardous Occurrences

It is the responsibility of all offshore personnel to report any accidents, hazardous occurrences (near misses), non-conformities with the SMS, and suggest modifications for improvement to the SMS. There should be established written procedures and instructions on how this information should be disseminated throughout the company. Currently, there is no formal industry wide information system that documents hazardous occurrences. Historically, accident reports have been written with an emphasis on establishing blame instead of trying to gain better insight into how to prevent complex interactions of accident causing scenarios (Moore, 1991; Reason, 1990).

To improve any SMS, an effective and efficient system of reporting non-conformities must be established. Non-conformities with the SMS need to be brought to the attention of the company and the platform operators and should be eradicated in an expedient manner. In addition, the master of the platform should play an integral part in providing suggestions for modifications and improvements to the safety management system. The platform crew has the best understanding of the detailed day-to-day safety issues aboard the platform. It is important that the company use this valuable information to the best of its ability.

Maintenance of Platform and Equipment

The responsibility of each company is to provide each platform with adequate reference material to allow critical maintenance of both the platform and its equipment. Proactive maintenance of the platform and equipment can lead to longer platform life, lower long term maintenance costs, and a higher level of safety.

Each platform should have sufficient maintenance manuals that are easy to access, use, and understand. These instructions should describe the procedures by which to properly maintain all platform systems in accordance with industry accepted practice. In addition, it is imperative that all safety related systems are kept in proper working order.

The platform and company should have an effective system by which records are kept on testing, inspections, and periodic maintenance of all critical operating systems. This information should include the date and depth of inspection, actions taken, results, corrective actions, and dates of the next periodic and extensive inspections.

Documentation of Compliance with Safety Management Concepts

A Safety Management Manual should be developed and be simple to understand by any person in the organization. The Safety Management Manual should also be consistent with relevant references and interconnections between other related marine life safety and environmental policies. The document should be easily accessible to any and all members of the organization associated with safety management. The company should ensure that all new and updated material relevant to the SMS is distributed to all affected parties in the organization. Any revisions should be easily identified as a revision to outdated policies or procedures.

Auditing

One of the most important aspects of any SMS is to have a means to verify, review, and evaluate the effectiveness and efficiency through periodic auditing. Audit plans should be established to capture all of the important aspects of the SMS for each platform in the company's fleet. It has been recommended that the plans include (ISF, 1993): (1) specific areas to be included in the audit, (2) qualifications of personnel performing the audits, and (3) procedures by which the audit findings, conclusions, and recommendations are reported in the organization. It should be the responsibility of management to review accident and hazardous occurrences (near misses), non-conformities, audit findings, and recommendations following both internal (company) and external (coastal state - e.g. USCG or MMS) inspections.

Hazard Analysis / Risk Assessment

Hazard analysis and risk assessment are integral parts of the operation plan and emergency preparedness described above. Some of the major risk assessment techniques are preliminary hazard analyses, hazard and operability studies (HazOps), failure modes and effects analyses (FMEAs), fault tree analyses and event tree analyses.

In any case, there are two approaches to incorporate into risk assessment methodologies: *qualitative* and *quantitative*. Both of these approaches have particular advantages. Qualitative modeling forms the basis from which to address the problem through design, operational maintenance, operational procedures, and regulation. Quantitative methods provide a means from which the effectiveness of procedures and regulations can be evaluated. One approach is not a substitute but a supplement to the other.

The objective of a risk assessment is not to produce numbers; it is to produce insights that can assist in improving the platform safety. Any quantitative assessments should be used as a decision support tool for qualitative judgments and not a replacement for the sound judgment and common sense approach of the FSA methodology.

Various innovative risk assessment tools have been developed for the industry. These risk assessment tools have been developed to capture particular elements of human factors, safety management issues, and other 'intangible' factors that are not readily captured in other formalized risk assessment techniques. This section provides short descriptions of some of these techniques that have been developed and deemed useful for identifying, assessing and managing risk for the offshore oil and gas industry. Such techniques will be used in the future as a means by which to capture HOF factors that are not captured through traditional risk assessment means.

FLAIM can best be described as a quantitative indexing methodology in which selected key factors relevant to fire safety, life safety and safety management are identified, assessed and assigned numerical (weighted) values (Gale, *et al.*, 1995). Risk contributing factors are thereby indexed and ranked using a weighting system algorithm, keyed to relative (comparative) risk, to yield a set of risk indices specific to particular fire and life safety issues.

Key topside risk factors, identified on the basis of scenario analysis, expert opinion, and historical records, are selected and evaluated by the user together with provided or planned-for risk reduction measures. Life safety is assessed independently from fire safety using risk factors specific to each, but accounting for their close interdependence. The adequacy of risk reduction measures and overall platform safety management can be assessed and provisions for risk mitigating and safety management can be evaluated. A second generation of FLAIM (FLAIM II) is currently under development.

A risk assessment program called Tripod was developed to highlight key underlying and latent casualty causing factors (Hudson, et al., 1991; Groeneweg, 1994). As described by Reason (1990), latent factors are those factors with adverse consequences that may lie dormant in a system and will only become evident if combined with other factors and/or an initiating factor activates it. The intent of Tripod is to identify latent factor contributors to casualties in a system. These indicators include hardware, design, maintenance, procedures, error enforcing conditions, housekeeping, incompatible goals, organization, communication, training and defenses. These factors generally lead to unsafe acts or trigger events that create an accident scenario. An instrument was developed called a Failure State Profile that measures the extent of how problematic the underlying indicators may be for a particular system.

In 1986, the International Loss Control Institute, a subsidiary of Det norske Veritas, developed the International Safety Rating System (ISRS). The ISRS has been widely used in the nuclear power and offshore industries to describe casualties from a human and job factor perspective. Similar to both TRIPOD and FLAIM, the ISRS is using a quasi-quantitative/qualitative approach to determine underlying human error and management factors contributing to casualties.

Management of Change

Change is specific to all three core elements that are to be managed: technology, operational personnel, and management (API, 1993). This includes changes in process and mechanical design, effects upon upstream and downstream facilities, necessary revisions of procedures, work practices and personnel training programs. Changes in personnel onboard the platform, particularly contractors, personnel rotations, shift work or tour rotations necessitate ensuring that safety is maintained during these changeovers. 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.

Training

Training applies to personnel with direct or indirect safety responsibilities both onboard and shore side. This applies to ensuring personnel onboard and shore side are properly familiarized with their job, qualified, experienced and knowledgeable of their responsibility. This includes initial and periodic training as required. For example, required periodic training may be necessary for personnel to learn operations of new technologies or unfamiliar operating conditions. Familiarization training for contractor personnel is absolutely necessary and operators should properly determine the minimum familiarization training required.

Pre-Startup Review

For new and modified facilities, it is important to ensure all equipment and machinery are in accordance with design specifications, personnel are properly familiarized with their responsibilities, normal operating and emergency procedures are in place and hazard analyses have been performed to ensure adequate operation and emergency planning.

Contractors

The company should ensure that all contractors have safety and environmental protection that are consistent with the organization's policies. Contractors should have proper documentation of their injury and illness reports. Experience Modification Rates for Workers Compensation Insurance for the last three years should be readily available. Contractors should also have available an outline of familiarization training in safety and environmental protection, an outline of required safety programs for the contracting company and a description of safety programs and refresher training program that is required for employment.

Safety and Environmental Information

Both shore side and platform personnel should have available any valuable information that can assist them in ensuring platform safety. This includes seminars, safety bulletins, safety meetings, written and multi-media material that can further enhance personnel's ability to ensure safety.

Continuous Improvement (explicit)

The primary objective of any safety management system is to strive for continuous improvement. This should be the commitment of management and line personnel. Errors can be defined as controllable, inherent and non-controllable. The objectives of the SMS should be to reduce controllable and inherent errors to the lowest possible degree.

Organizational Research Findings on Safety Management

Considerable research in the area of safety management has identified five factors common to ensuring safety across many industries (Libuser, 1994; Libuser and Roberts, in prep.). All but one of these factors is reflected above to be critical elements of SMSs in various forms.

1. Process auditing: An established system for ongoing checks designed to spot expected as well as unexpected safety problems. Safety drills are included in this category as is equipment testing. Follow ups on problems revealed in prior audits are a critical part of this.
2. Reward system: The reward system is the payoff an individual or organization receives for behaving in one way or another. Organizational theory points out that organizational reward systems have powerful influences on the behavior of individuals in them. Similarly, inter organizational reward systems also influence behavior in organizations. In the SMS requirements discussed throughout, this is the only item that is not explicitly provided, since it is at the discretion of the organization to provide personnel with appropriate awards. However, it is interesting to note the influence it has on ensuring safety.
3. Degradation of quality and/or inferior quality: This refers to the essential quality of the system as compared to a referent generally regarded as the standard for quality.
4. Perception of risk: There are two elements of risk perception: (1) whether or not there is knowledge that risk exists and (2) if there is knowledge that risk exists, the extent to which it is acknowledged appropriately and/or minimized. Part 2 is a logical outgrowth of part 1.
5. Command and control: Roberts (1989, 1992b) outlines command and control as separate factors, but we combine them here and list sub-factors of the broader construct. The command and control elements are:
    - *migrating decision making* (the person with the most expertise makes the decision who is not necessarily a higher ranking manager);
    - *redundancy* in people and technology (i.e. sufficient backup systems exist);
    - *senior managers who see the 'big picture'* (i.e. they don't micro-manage);
    - *formal rules and procedures* (a definite existence of hierarchy but not necessarily an over burdening bureaucracy); and
    - *sufficient training.*

Incorporating HOFs into an Offshore SMS

Above we have described the core key elements of a safety management system and SEMP. Now the question is: *How do we take a safety management system and ensure that HOFs are properly taken into account in the core elements of a SMS?*

This requires five steps:

1. define the human error inventory to provide a means to identify critical error types to be managed;
2. identify opportunities to address HOF both explicitly and implicitly within a SMS;
3. assess the HOF management opportunities to determine if they significantly impact safety;
4. apply HOF selected enhancement alternatives; and
5. measure the impacts of the SMS effectiveness and performance.

These factors can be addressed within the generic work processes for a management system that has been described.

Human error inventory

As shown in Table 2, a human error inventory was developed at the Workshop that reflected the primary causes of casualties based upon the experiences of individuals in the group. In the development of this inventory, three types of errors were considered: (1) individual human errors [H], (2) errors by groups of individuals or teams [G] and (3) errors by management [M]. A number of human error inventories specific to the maritime and offshore industry have been developed that could also be used for investigation of casualty causes (Moore and Bea, 1993; Pate-Cornell and Bea, 1990; Bea, 1994; National Research Council, 1978, Det norske Veritas, 1995, Anglo Eastern, 1997).

Table 2 - Human error inventory

• *Communication (H,G,M)*	• *Fatigue (H)*
• *Job security (H,G,M)*	• *Inattention (H)*
• *Job design (H,G,M)*	• *Human system interface (H)*
• *Competence (H,G,M)*	• *Personality variations(H, G)*
• *Stress (H,M)*	• *Motivation (H,G,M)*
• *Situational awareness (H,G,M)*	• *Industry culture (H,G,M)*
• *Experience (H,G,M)*	• *Cultural differences (H,G,M)*
• *Management of change (H,G,M)*	• *Incentives (H,G,M)*
• *Violations (H,G,M)*	• *Values and beliefs (H,G,M)*

To address these factors, there are implicit and explicit management alternatives to enhance safety. For example, communication is a critical matter that all organizations face. These communication factors include communication between shifts, between supervisor and operator (verification), operator to operator (cross functional), within and between groups, upper management to workers, inter-organizational (e.g. contractors) and the medium means of communication.

For example, a means to explicitly impact communication problems are to provide better radio systems, sound mitigated areas in critical locations to let workers plan and organize work. These are explicit items that directly impact individual's ability to communicate.

On the other hand, implicit management alternatives are those that impact human errors indirectly. For example, providing an incentives for workers onboard a platform for a reduction in loss time injuries while ensuring that all incidents and accidents are reported. That is, you would like to have an incentive structure that promotes safety and allows crews to report incidents without concern that it will affect their job security or their ability to receive their incentives. This would indirectly impact communication onboard. Crew members would be more willing to report minor incidents and other safety concerns to superiors and superiors would be more willing to communicate these issues to shore side personnel.

In many cases, if possible, hazard analysis or risk assessment techniques should be applied to determine whether, the impact of human and organizational factor management opportunities would be beneficial. This would include preliminary hazard analyses, qualitative risk analysis, personnel questionnaires and/or any other means to evaluate or measure whether the proposed management alternatives are worth the cost investment.

The next step would be to apply those alternatives that have been selected. This would include planning organizing, implementing, controlling and performing these initiatives. The last and very critical element is to measure the impact of the effectiveness and performance of the alternatives selected. This can be a very difficult thing to do. One of the most critical means to determine the impacts are to look at the reduction in injuries, fatalities, incidents and accidents. However, significant reductions in these areas may take considerable time and are not easily measurable over the short term. Therefore, when possible, it is beneficial to identify 'easily' definable indicators that can be measured through time that will assist in measuring and evaluating the effectiveness of the SMS.

Incorporating HOFs into an Offshore SMS: An Example

A key element of a SMS as defined above is the reporting of incidents and accidents. Historically, most accident investigations have focused on the technical aspects to the failure and what the person did wrong that affected the technical system. However, the requirements of accident investigations should be directed at the root causes of accidents to determine how an organization could address systemic human and organizational errors if they exist. The following is an example of how to incorporate HOFs within a SMS's non-conformity, incident and accident framework using the generic work process described above.

Figure 3 is an example of application of the generic work process to, incident and accident reporting. First, the general inputs are the people, positions, parts, information and any other relevant information that are relevant to the accident. Collecting the information of an accident can be a very time critical and time consuming job. People tend to forget specific details of incidents and accidents they were involved in after a relatively short time, hence the importance of defining the requirements for the incident investigation process, ensuring the approach for conducting incident investigations meet the requirements and are recorded.

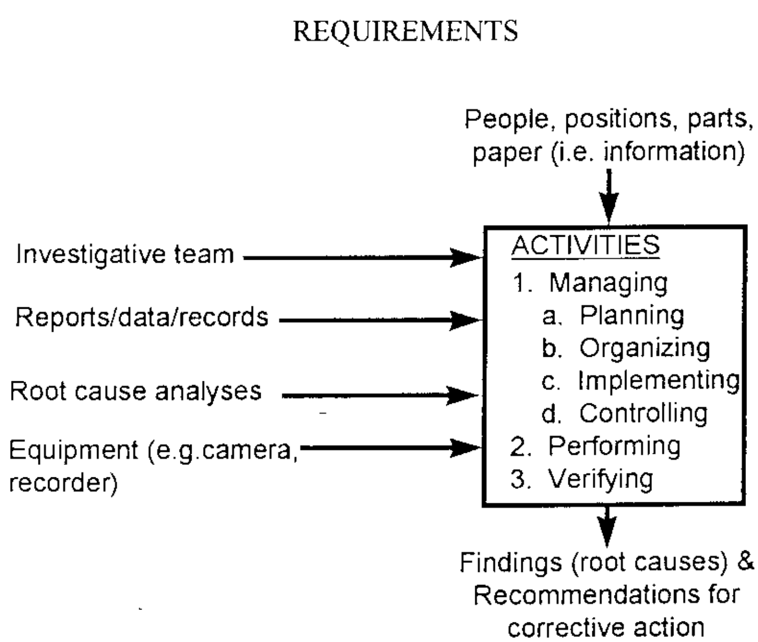

Figure 3 - Application of Generic Work Process to Incident Investigations

In this case, the resources required for the incident or accident investigation discussed by the working group are: the investigative team (human), reports, data and records (info/data), root cause analysis techniques (methodology) and relevant equipment e.g. cameras, audio and visual recorders). The following items were identified as key considerations when developing policies, procedures and work instructions for the incident investigation process.

Investigative Team

The critical elements identified for the investigative team are: The team must be technologically competent in the system in which they are evaluating. In cases where the company may not have the in-house expertise (e.g. small companies that out-source most of their maintenance and operation) may need to look elsewhere to acquire the proper knowledge of the system being investigated. The team should have good communication skills to facilitate asking the right questions and be able to communicate to management to ensure they convey the correct message and acquire needed information and resources.

The team must be competent in investigative techniques and human factors issues. These techniques include how to question individuals in a 'non-blame' manner that will encourage individuals to share their experiences even though it may show they were responsible in some way for the accident. There are means to ask compound questions of people that help to bring out root causes to accidents that may otherwise not be possible by other lines of questioning. Also, when severe injury or fatality occurred, the investigative team needs to be sensitive to those being questioned if the victims were close associates since they may be traumatized by the incident and need to be handled in a certain manner to get the relevant information.

The team must also have the 'requisite variety' of personnel to provide a well balanced insight into the incident. This may require individuals from all facets of operation and management of the operation, cross industry representatives to provide expertise on how other industry deals with similar problems. For example, an investigative team for a gas process system incident may include a human factors expertise, risk assessment, an offshore installation manager, a manager of the downstream pipeline operation and a maintenance contractor. The team should also look to have a variety of personalities that enhance each other during the investigation process. You do not want too many of one type of individual such as too stoic or too aggressive.

The selected team must also be motivated and be provided with proper incentives to ensure an unbiased investigation. They must have an interest in solving the problem and not just arriving at solutions to direct blame or trivialize systemic human or organizational problems. The team must also be independent and credible. In order to ensure that all or most parties involved will believe in a balanced solution, the team must have absolute credibility and respect within the industry and organization. The team must be independent to prevent against biased assessments and conclusions.

The team should apply stress management techniques when appropriate. At times, particularly after catastrophic casualties, there is significant pressure from management, workers and society to act swiftly to arrive at expedient conclusions leading to solutions that may not be effective and cost efficient over time. The team needs to be able to disassociate itself from these pressures to arrive at the appropriate solutions.

Reports, Data and Records

To properly evaluate an accident or incident, it is necessary to provide all relevant reports, data and records that will facilitate and provide clarity to the investigation. The following items were discussed as key information that should be included:

- Personnel training records;
- Personnel records (e.g. drug and alcohol testing, psychological evaluations);

- Occupational health information;
- Near miss & casualty information (platform specific, equipment specific, company specific, industry specific and/or application specific);
- Previous inspection reports (audits, non-conformities and corrective action reports);
- Platform and relevant system design (i.e. design of system that led to incident or accident);
- Specific procedures applicable to the incident that occurred;
- Hazard analyses that have been performed on the system; and
- Technical, human and organizational changes trends and histories.

Analysis of Root Causes

The team must be familiar with those tools that are used to evaluate the root causes of casualties. A number of techniques that are available and used to evaluate accidents and determine the events that occurred and their relevant causes were discussed such as:

- Event/incident tree
- Event/causal factor chart (ECFC)
- 'Why' tree analysis
- Tap Root
- Root Cause Tree (good on HFE, fatigue, inattention, stress)
- Management oversight and risk tree and
- TRIPOD that addresses design, hardware, procedures, error enforcing conditions, housekeeping, training, incompatible goals, communication, organization, maintenance management and defenses of a system (Groweneweg, 1994).

These or any other useful technique can be applied to the investigation process. However, it is important that as many team members as possible (all if possible) have expertise in these techniques.

Proper Equipment

Providing the team with the proper equipment necessary to perform the investigation was also discussed. This includes items such as cameras, tape recorders, video recorders and relevant measurement instruments. Having these instruments at the disposal of the team can greatly impact the investigation, conclusions and recommendations. In addition, in the event of a lawsuit, the information could provide valuable evidence to financially protect individuals and organization.

Investigation Case Study Summary

The application of this generic work process to incident and accident investigations and taking both explicit and implicit account of HOFs was described. It is interesting to note that HOFs needed to be determined and their impact upon the casualty, but also the impact of HOFs on the investigation process itself. In performing an incident or accident investigation, it is important to incorporate all of these relevant factors as they apply.

Incorporating Sub-Contractors into a SMS: A Case Study in Success

Beginning in 1993, Shell Offshore Inc. developed and presented a series of workshops to core vessel contractors to introduce the principles of *Bridge Resource Management - Human Factors* (BRM-HF) and to explore how best to make the concept a practical reality for the offshore service vessel fleet. As a result of these initial efforts, Shell Offshore, Inc. and Tidewater Marine, Inc. initiated a dialog to minimize incidents of unsafe behaviors/unsafe actions that have historically led to personnel injuries, resulting in a joint effort to establish the concept of BRM-HF as the cornerstone for the development of a safe, effective, efficient vessel management system. The principle of BRM-BF is coordination and practical application of all of skills and resources available to the vessels' crew to achieve and maintain Situational Awareness.

An increasingly demanding marine environment requires that vessel officers and crew possess additional skills that are not routinely addressed in traditional maritime training and education. Combined, these skills form the practical concept of BRM-HF, and require the ability to:

- identify and recognize behavioral traits;
- process the increasing flow of information and data received from shore side, as well as that generated aboard;
- understand and operate increasingly complex control, propulsion, monitoring and communications systems;
- avoid complacency in conduct of routine tasks critical to the efficiency of vessel and safety of crew;
- cope with additional business pressures and meet more stringent schedules;
- deal with changing skill and experience levels, differing work ethic and multicultural work force; and
- meet and achieve heightened expectations for safe operations by customers, regulatory agencies and the public.

To effectively meet the increasing demands placed on their officers, Tidewater Marine, Inc., with assistance and support from Shell Offshore Inc., has embarked upon a series of Vessel Officer Seminars to enhance the professional development and managerial skills of their officers. The seminars focus on human error, the primary cause of mishaps (near-misses, errors, incidents/accidents, etc.) and the contributing, or underlying causes resulting in flawed decision-making. The USCG has determined that over 96% of the maritime casualties experienced over the last decade can be attributed to human error. Clearly the elimination or reduction of human error will yield the greatest safety dividends. The Vessel Officer Seminars incorporates the principles and philosophy of BRM-HF to establish a foundation for the proactive management of operations. The seminars utilize the skills of Situational Awareness that have proven successful in anticipating and mitigating errors before they develop into near-misses or accidents.

The seminars introduce a number of concepts and skills that directly impact the Masters' ability to safely and effectively complete their assignments while safeguarding their crews, cargo, vessels, and the natural environment. Shell Offshore Inc. and Tidewater Marine, Inc. recognize that *human factors* (HF) play an integral part in the causation or avoidance of human errors. Because of its importance, the seminars address topics and issues that relate directly to HF, which includes:

- *Situational Awareness* (SA): the accurate perception of what is going on with the individual, the crew, the vessel, and the working environment, both now and in the near future. Maintaining SA is critical, as the perception by officers and crew members greatly impacts how aware they are of conditions around them and as a result how they respond/perform in a given situation. SA can differentiate human error from excellence in marine operations.
- Team Development builds on the principle that a vessel's crew, performing as a team, is much more effective than individual effort. Shell Offshore Inc. and Tidewater Marine, Inc. believe that teams, specifically vessel crews, will work together more effectively and therefore more safely. As team members, the crew becomes

more aware of individual or team limitations, preventing unsafe work practices and identifying training opportunities, thereby, enhancing the efficiency and safety of the entire crew's performance.

- Stress Management recognizes that stress can degrade human performance and reduce SA that, in turn, increases the risk of human error. The vessel Master and crew who can handle stress effectively are less likely to make mistakes and are more likely to be aware of the mistakes of others.
- Fatigue Management focuses on scheduling watches in relation to vessel activities and work loads. Work demands may cause officers and crew members to attempt to perform beyond their physical capabilities based on length and quality of rest or the number of rest periods available to the crew. By educating crew members on the exposure resulting from fatigue and by creating opportunities to better schedule rest periods and duty schedules, fatigue related errors can be mitigated.
- Good Communications Skills are critical to establishing and maintaining a high level of SA. Crews that communicate effectively make fewer mistakes, identify and resolve problems faster, and are more likely to recognize and prevent errors, all of which facilitate enhanced SA at the group level. Good communication skills ensure that the message and its meaning are transmitted and understood accurately.
- Good Decision Making Skills are critical because of immediacy and ramifications. In operations, there is often little time to consider decisions, and available time must be shared with other operating tasks. Necessary information may not be available or may be limited, and alternatives may not be fully recognized.
- Interpersonal Skills are critical to achieving a safety conscious, effective work group. People needs and expectations change with experience, time and circumstance. Masters must become skilled at managing people, developing an awareness of different personalities and their appropriate motivators, and be aware of the dynamics of command and leadership.
- Continuous Improvement is critical to the process of learning and improving. It should be used as a means to identify and mitigate an immediate risk, to incorporate new information acquired to create and to maintain a knowledge base to minimize opportunities for recurring errors.

This effort is innovative in its philosophy of developing individual and team skills and the criticality of a discipline of awareness at the operations level in order to achieve pro-active safe working behaviors, as opposed to focusing on incident-driven responses. BRM-HF is superior to traditional safety methods and practices in its development of the core skills of the individual vessel officers and crew. This foresight has direct impact on the approach to task analysis, how officers direct their crew members and the ability to recognize and deal with potential influences on safe, successful outcomes.

Achievement

Critical to the development of the principles of BRM-HF is the skill and discipline of Situational Awareness. SA is established by effectively processing all of the influences, positive and negative, that challenge vessel officers in the course of performing their duties and achieving objectives. The development of a discipline of SA requires cultural change and it is here that SA stands apart from a "conventional" incident based program. It is a proactive and methodical discipline that employs risk identification and risk management concepts to prevent or mitigate incidents or accidents. It reinforces the concept of loss control by recognizing and addressing the critical elements of risk that determine the success of an organization's safety efforts.

Shell Offshore Inc. and Tidewater Marine, Inc. have established BRM-HF as a foundation for the development of the discipline of Situational Awareness. Tidewater has accomplished the institution of the discipline through traditional means of instruction and reinforcement, as well as by initiating seminars, Safety Teams, assignment of Safety Captains and development and issuance of their *Safety Operations System* (SOS):

- Development of a framework of SA relationships that makes sense to the organization. The discipline draws from the experiences and expertise of the individuals within the organization. When it is demonstrated that the discipline can make a significant difference and that it is not " another program" being overlaid on the organization, resistance is diminished and a learning/improving environment can be established.
- Senior management's leadership and commitment to reinforce and encourage correct utilization of the discipline and to recognize and understand why decisions have been made.
- Identify education and skills needed to facilitate a behavioral, and ultimately, a cultural change in safety and operational effectiveness.
- Development of reliable performance data to allow valid measurements, assessments, learnings and improvements to be made. An organization can only be sure of its accomplishments, or of its shortcomings, if they're demonstrable and valid.

The BRM-HF workshop was developed as a vehicle for comprehensive and meaningful change to a behavior based process; i.e., "cultural change" for effectively managing the complex, high risk operations found in the offshore service vessel industry. The principles of BRM-HF and Situational Awareness can be utilized in any business or organizational mode. The elements of SA, as they are presented here, deal with a marine operational setting but they are applicable to any facet of the offshore industry. The goal in mind is to facilitate an organization's ability to change from a safety objective of "accident avoidance" to the development of a culture of "safety assurance".

Summary

To reduce human error and improve offshore platform safety and productivity, integration of human and organizational factors into existing risk management programs is essential.

Applying human factors to processes unique to offshore exploration and production and marine environments is a new challenge for both offshore owners and regulators. To be effective, human factors need to be integrated into formal risk management systems as opposed to developing individual practices and procedures that address human factor issues. The basic difference is that individual practices and procedures are developed to simply comply with established human factors requirements. They often are missing administrative controls required to ensure effective implementation, are missing or do not link with key elements that should include human factor considerations and or do not take into account the actual human dynamics of the organization. An effective management system provides site specific policies, procedures, and work instruction documents necessary to ensure human factors play a key role in process safety, meeting SEMP requirements, and business results. In addition, management systems provides the framework needed to integrate and optimize human factor elements necessary to reduce incidents related to human failure(s).

To improve performance, managing human factors must become a part of the way offshore facilities are operated. Management systems define how decisions are made that either directly or indirectly effect humans, who make those decisions and by what criteria. Management systems provides the ideal means to gather information needed to understand human factors site specifically, have the information analyzed, and adjust operations accordingly.

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SAFETY, CORPORATE CULTURE AND CORPORATE CHARACTER

BY

Edward Wenk, Jr.

--Abstract--

To help understand organizational as well as human factors in causing accidents, some interlocking internal elements of corporate culture are examined to identify which qualities of an authority structure promote safety and which undermine it. Special emphasis is placed on the role of "organizational character," the matter of internal integrity.

--The Notion of Organizational Error--

Media headlines snap readers to attention when announcing disasters, especially those involving human error in operating 20th century technology. Brought to mind are the *Titanic*, the wreck of the *Exxon Valdez*, the Bhopal chemical catastrophe, Chernobyl's nuclear accident, explosion of the *Challenger* space craft, the crashes of TWA flight 800, United flight 585, and long ago, the *Corvair* automobile. All these events raised critical questions about safety and accident prevention. As in over 80 percent of such disasters, cause was attributed to those human perpetrators directly designing or operating the wayward equipment, beset with ignorance, error, blunder, folly or even mischief. That flaws in host organizations could set the contextual stage for casualties was wigwagged decades ago but ignored until recently [1,2,3]. Now, we are trying to extract lessons about organizational factors--macro-ergonomics--from recent accidents, and from systematic research to facilitate safety of complex technological megasystems [4,5,6]. In both operational and regulatory regimes, more attention has been focused on enhancing a "safety culture" in all system organizations, but the scope has often been limited to better trained operating personnel and teamwork. In what follows, the corporate culture is probed, and a new element introduced of "Corporate Character".

--Pathologies in Organizational Behavior--

People readily grasp human factors causing accidents with risky technologies; most have had close shaves with automobiles. Understanding how organizational cultures influence safety is more complex. The commission investigating the *Exxon Valdez* made the case that this was an accident waiting to happen because of management protocols [7]. Choices were made to design the largest possible ship with the thinnest hull plating, lease compartmentation, single instead of double hull except in way of the engine room, no redundancy in power or steering. The ship's master with a history of alcohol abuse was retained. The ship was operated with the smallest permissible crew despite periodic exhaustion from sleep deprivation when loading and unloading under pressure to minimize turnaround time.

Events of a totally different nature also deserve analysis because they reveal other pernicious weaknesses in organizational cultures that have less obvious but nevertheless powerful implications for safety. We spotlight the role of trust, truth and integrity.

We are reminded of this breach all too often. Government captured headlines for its misdeeds with Watergate, dissembling on the Vietnam war and on the Iran-Contra episode, for exaggerated effectiveness of smart bombs in the Iraqi war, support of the School of the Americas to train agents in torture and mayhem, a cover-up of the Navy's Tailhook scandal and of deliberate exposure of citizens to radioactive fallout. The Legislative Branch added its share of offenses with the recent criminal conviction of Dan Rostenkowski, and questionable ethics of the 104th Congress that allowed vested interests to draft legislation for their direct benefit and collaterally failed to limit campaign contributions.

Industry, however, readily matches government in betraying the public trust. Failures of Savings and Loan institutions were largely due to fraud. Wall Street's geniuses Milken and Boesky were indicted for criminal insider trading. Most major brokerage houses and insurance companies have been charged with cheating. Tobacco and asbestos companies denied that their products threatened human health while they hid contrary evidence developed from their own studies. Exxon has been charged with negotiating under-the-table kickbacks from plaintiffs harmed by the Alaskan oil spill as the price for settling out of court. Archer Daniels Midland was fined $100 million for price fixing. The *New York Times* adds to this noxious list daily.

--All Technologies have Unintended Consequences--

These two universes of government and industry are oddly linked by another set of ethical dilemmas triggered by technology. All technologies spin unintended consequences. These impose risks on some sector of the population, somewhere, now or at some time in the future [8]. Such side effects are more intense, far reaching, swiftly injected, affect more innocent bystanders and are more ecologically or socially irreversible than in the past. A nagging problem then surfaces that the private sector catering the hard building blocks of technology faces a highly competitive global market. Accident preventative measures are neglected because mitigating externalities adds to their costs.

The public must thus seek protection of life, health, property, social and economic fairness through public policy. Only by government's involvement can property rights and human rights be balanced. This is the rationale for the U.S. Coast Guard, and globally the IMO, to safeguard maritime safety, and for analogous public institutions.

--Conflict and Healthy Tension—

That public/private association, however, is torn with conflict. Regulated industry fights all imposed constraints, and tries to block measures that would enhance safety of ships and of navigation. A long history of tradeoffs of safety for profit continues. Indeed, commercial shipping firms have adopted an array of techniques to avoid responsibility--single ship corporations, flagging with countries having feeble safety requirements, deferred maintenance through successive sales. This condition in the maritime industry can generate tense dilemmas for engineers, naval architects, lawyers and accountants who seek to fulfill parochial, corporate interests that often violate codes of professional conduct to protect the public interest. As employees, however, they are coerced to assume the values of their employer or risk punishment as whistle blowers [9].

The same tension appears in all private functions regulated for the public interest--safety of food, pharmaceuticals, chemicals, water supply, hazardous waste, work-place dangers, other modes of transportation, banking, radio transmissions, security of information services, and environmental quality. In its public tactics, industry often treats government as the enemy rather than as a legitimate and essential partner, and it plays out that antipathy by funding political causes thought to be more congenial to a business philosophy of *laissez faire*. Their anti-government scenario is reinforced by other ideologically congenial groups to undermine government's role to balance who wins and who loses. Unfortunately, the revelations of lying by government add to public dismay and distrust, to believing everything they hear or nothing. Neither extreme is healthy for democracy.

Accidents often expose these lapses of ethical standards by management that range from irresponsible negligence to willful deceit. The corporate culture that bonds people at all levels within an institution to a common set of values all too often violates standards of society as a whole. What goes awry in the secret life inside?

--Describing Corporate Cultures--

Organizations, public and private, are like people. Individuals are readily distinguished by their appearance, voice, age, resume of accomplishments, reputation as to character and net worth, by their fingerprints and social security number. Less visible and requiring more time to discover are their personality traits--values of integrity, compassion, and sense of justice, their common sense and sense of humor, emotional stability under stress, their understanding of the social contract, political ideology and spiritual life.

Corporations also have public persona and private behavioral patterns. Deliberately publicized are logos, mottos, slogans and stock exchange symbol, growth, agility in responding to transient market preferences, distinction in quality or price of product or service, ingenuity, sales volumes, reputation as to quality of output, prospects for the future.

Far less apparent is their secret life. Staff eventually learn that score, although mapping may take a while. They read the obligatory mission statement, learn the structures of authority, its symbols, equity in fringe and retirement benefits, golden parachutes and handcuffs. They check out the system of rewards and punishments, ladders of upward mobility. They calibrate management's imperatives of efficiency and definition of excellence, capacity to manage risk and to manage crisis, commitment to social responsibility, vision of the future, openness to innovation or resistance to change, tolerance for dissent, strategy and tactics to meet competition. Staff are taught techniques of internal communication, public relations, dress code, acceptable levels of socializing with peers and collegiate mentoring. They know the politics and biases among organizational leaders, and how much decisions are driven by economics and law to win the Wall Street beauty contest while living at the edge of or beyond the tax code, criminal laws, and limits of legal liability. They perceive whether employees and clientele are treated with respect and dignity as humans or only as profit centers and as controllable system components.

Although not detailed here, the internal culture of government agencies ad on not-for-profit organizations is remarkably similar.

--Corporate Character, Trust, and Safety--

Buried deep in that complex culture is the factor of integrity, a specific code of ethics based on the honoring of truth and trust [10]. This is *Corporate Character*.

The corporate culture and corporate character clearly matters to insiders, but it also matters to outsiders because internal cultures have external consequences. Conspicuous examples lie in tradeoffs of safety for cost or for deadlines. The practice of safety is not simply a set of protocols using the latest in technology or in the art of human relations. It is a state of mind, of individuals having their hands on the hardware, and of corporate executives isolated on the top floors.

A sincere commitment to safety is a necessary condition for its attainment, but it is not sufficient. Elements of corporate character having the greatest potential to enhance safety arise from social responsibility made operational by a sensitive regard for integrity.

It often takes an accident to agitate a complex system and expose the internal culture and the strengths of organizational ethics, or violations that shape individual error. The Valujet crash provides a recent case where the accident whose cause is still unresolved illuminated major safety-related weaknesses within the organization that resulted in a temporary shutdown by the FAA. The *Seattle Times* recently ran five articles by an investigative reported on crashes of Boeing 737's [11]. Details were made public of longstanding recommendations of the National Transportation Safety Board that had been shelved by the FAA in a dual position of airline promoter and regulator. The articles highlight Boeing's delay in responsibility to make changes derived from suspicions of defects in steering controls because of concerns over liability and reputation. They refused an interview prior to publication. Two days after publication, the FAA acted and Boeing discovered some shattering evidence of their own of faults in steering machinery. That the three organizations have vastly different attitudes related to safety culture is obvious.

Unfortunately, after alarm bells ring with a technology-related disaster, public relations are substituted for problem solving, often seasoned with deceit.

Although difficult to confirm in most accidents cause records are protected by privilege or by impetuous shredding, the internal culture is tutored from the highest level of management. Watergate is a government example. The expose in "On a Clear Day You Can See General Motors" illustrated the industrial counterpart [12].

--Steps to Strengthen Corporate Character--

These ethical predicaments were anticipated in principles and canons published by the National Society of Professional Engineers and the American Society of Mechanical Engineers, and in publications of this author [13]. Here is a summary:

*****Hold paramount the safety, health and welfare of the public.

*****Uphold the law, beginning with the Constitution.

*****Be honest; serve the public, customers, clientele and staff with fidelity.

*****Be vigilant of malfeasance and corruption; do not punish dissent and legitimate whistle blowing

*****Recall that all technologies have unintended consequences, many harmful; so make a practice of looking ahead to anticipate and prevent loss in human life, health, property, intended function or the environment.

*****In daily operation, demonstrate from the highest levels of internal management truth, openness and equity in benefits when making tradeoffs.

*****Counter one-way communication and loss of personal relationships by the growing reliance on electronic communications.

The power of such philosophy is confirmed in case studies. Researchers at the University of California [13] explained why accident rates are conspicuously low in certain high risk environments, in particular aircraft operating from carriers and submarines.

Answers lie in a deliberately nurtured atmosphere of trust, horizontally and vertically. Among other factors, senior personnel have "been there" and "done that", so that they are not simply hired guns trained in tax law or signs and symbols of business administration, pressured by shareholders to turn a quick profit while reducing risk of corporate liability.

There are other examples where integrity paid off in public safety and esteem. Admission of oversight in checking the strength of structural steel used in the Cities Service skyscraper required swallowing pride and even hazard of lawsuit to protect public safety. Companies have pulled products from the shelves when there was suspicion of tampering.

It would be interesting if organizations chose to post mission statements for staff with principles such as listed above, along with usual admonitions to wear hard hats.

--Technological Delivery Systems are Organisms, not Mechanisms--

Most management decisions regarding goals, capital formation, product design, organizational structure, allocation of resources, recruitment of talent, and marketing are based on criteria of efficiency. The problem is that technological delivery systems behave more as organisms than mechanisms and thus are subject to uncertainties, diversity and ambiguities of human behavior, the blurring of cause and effect, change from dialectic interactions with other organizations, and response to an intense environment of global economics, media attention and public policy [14].

A rigid doctrine of efficiency may suffice in the short run to do things right, but ultimate success, even survival, depends on doing the right thing, integrating a broad range of social-psychological factors. These have been examined in a flood of treatises dealing with the pursuit of excellence, but surprisingly few emphasize that the most crucial ingredient of any human enterprise is trust and its revelation in many forms.

There is a related problem arising from the new complexity of technological megasystems. The number and diversity of interlocking organizations that must be synchronized for a particular function have increased. Each participant has its own narrow goals and cultural attributes. For mutual understanding, all must speak the same language. But in the face of increasing diversity, successful collaboration depends on mutual trust in each other and in the information exchanged.

--Summary--

Tragic as are technology-related disasters, we can learn from failure. Especially, we confirm that the practice and achievement of safety depends on a safety culture, and that is activated by more than technical virtuosity. Paramount is a corporate commitment to integrity and open, two-way communications by all members of the team and inspired from the top. Technology is driven by economic market forces, and steered by public policy, but the majestic issues in both private and public institutions are starkly ethical and beyond the teaching in economics and law.

At the highest level of abstraction, technology, democracy, public policy, and private enterprise are linked to and by moral vision. The national union succeeds only in the presence of truth and of trust. In the long run, the same things is true of all enterprises.

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ACCIDENT AND NEAR-MISS ASSESSMENTS AND REPORTING

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INTRODUCTION

The author's experience with the major marine accident databases and accident investigating and reporting protocols that underpin these databases indicates that generally they do not adequately capture the important human and organizational factors that underlie the majority of these accidents. In the course of seven years of research on this topic, the author has not been able to locate and access one fully functional near-miss and incident reporting and database system. This is due to a variety of reasons that are firmly rooted in the history, culture, and organization of the industry, its regulatory agencies, and the societies in which the systems of offshore platform activities exist. This is not unique to the marine industries. Other industries (e.g. commercial aviation, nuclear power, chemical refining, insurance, medicine, finance) have recognized many of these same problems. Most of these industries are taking significant steps to improve the situation.

This attention to accidents, near-misses, and incidents is clearly warranted. Studies have indicated that generally there are about 100+ incidents (oop's), 10 to 100 near-misses (that was close), to every accident. The incidents and near-misses can give 'early warnings' of potential degradation in the safety of the system. The incidents and near-misses, if well understood and communicated provide important clues as to how the system operators are able to rescue their systems, returning them to a safe state, and to potential degradation in the inherent safety characteristics of the system.

INCIDENT AND NEAR-MISS INFORMATION SYSTEM

The author's research indicates that different approaches, protocols, and information systems need to be developed to properly understand and utilize this important information. In particular, the near-miss databases need to be call-in or write-in systems that encourage operator participation and that are designed to protect the information and sources of the information. The Aviation Safety Reporting System (ASRS) provides some good experience on how to establish, maintain, and utilize such an early-warning system (Connell, 1996).

The ASRS possesses 'elegant simplicity.' The developers and users of this system recognize that it is not perfect, but it has proven to be very useful in providing early warnings of potential system degradation (Connell, 1996). Even at the present time, efforts are underway to further expand and improve the ASRS (e.g. to include ground and maintenance operations). Studies are being conducted on a 'world wide web version of this system that would permit integration of information from the international commercial aviation community.

All of the ASRS operations are conducted *outside* the FAA and in a 'secure facility.' Much attention is paid to avoiding conflicts of interest between the regulatory agency/ies and the sources of the information. Even more attention is paid to protecting the information sources. The ASRS is Federally funded.

When information is initially submitted to the ASRS, a structure and protocol is provided for the source of the information. Initially, the information source is identified. If a 'scan' of the incoming reports indicates that a 'call-back' is necessary to develop further information, the source is contacted. The scan and the call-backs are conducted by a small team of very experienced pilots (generally retired, well trained, and highly motivated). The number of call-backs is dependent on the availability of personnel and funding for hiring that personnel. The call-backs are intended to develop a more complete understanding of the incident or near-miss. Once the information has been verified and completed, the source identification is destroyed. 'Cry wolf' (false) reports have not proven to be a problem in the ASRS.

The information is then encoded into a database. All information introduced to the database is anonymous. If the information indicates some potentially important emerging trends, the information is distributed to all of the concerned sectors of the aviation community. Users can contact the administrators of the ASRS and have special searches and studies performed. The database can be made available to researchers that are conducting studies to improve air safety. Given sufficient Federal funding, the ASRS administrators are able to conduct research with information from the database. All of this information is distributed freely to those that 'have a need to know.' Only in the case where there are clearly legal violations are the violations reported in any formal way, still preserving the anonymity of the sources of the information.

The system is obviously successful. There are demands to expand its scope. There are demands to improve its protocols. The primary demands come from those that use the system on a daily basis and have daily responsibilities for the safety and integrity of air safety. A few devoted and highly qualified people make this remarkable system work, it is really not 'high tech.' The system is spelled 'integrity.'

There have been some efforts by the marine community to develop incident and near-miss information systems. In some cases, early indications are that the system can be useful. Our experience with several of these systems indicates that they likely can not be successful in the long-run. Reporting, verification, archiving, and analysis protocols are seriously flawed.

This system provides a good starting point for development of an Offshore Platform Operations Reporting and Information System (OPORIS). The need for elegant simplicity, experienced verifiers (it takes one to know one and understand one), protection of the sources and information from legal and employment repercussions, and an active reporting system that possesses integrity are key aspects of such a system. A simple (not dumb) OPORIS system needs to be developed, detailed, tested, and implemented.

Those that act safety in the face of pressures for production ('on-time', 'on-budget', and 'happy customers') need to recognized in positive ways so that compromises in the safety of the system are avoided by the people responsible for the safety of these systems. Our experience clearly indicates that the primary goals should be 'safety' and the 'quality6 of the system and its processes.' Integrity and trust should be built, earned, and recognized. Productivity, profitability, and the other goals of organizations need to get in line behind the goals that can help ensure the viability and longevity of offshore platform operations.

ACCIDENT INFORMATION SYSTEM

The author's research indicates that there is also a need for an industry wide accident information system. Here, I will call it the Accident Assessment and Reporting System (AARS). However, this system needs to be designed from the ground-up taking full advantage of private industry, Classification Society, insurance, U. S. Coast Guard, U. S. Minerals Management Service and other regulatory and industry accident information systems (Schmidt, 1996). Patch jobs based on existing systems should not be encouraged. We have seen some very good starts at good accident

6 Quality results from the combination of serviceability (suitability for intended purposes), compatibility (meets economic, schedule, and environmental constraints), durability (free from unanticipated maintenance), and safety (freedom from undue exposure and harm to people and the environment of which they are a part). Refer to SSC Report 378 for additional background on this crucial point.

information systems. But, also, we have not encountered one system that is really working or entirely workable.

When the accident occurs and must be reported and investigated, a wide variety of complex issues spring up. Most of these issues represent reactionary responses to the event. I have heard it as "kill the victim." I have personally experienced some of this killing and it is no fun. There are some remarkable ways to kill the victim that include exiling, shaming, persecuting, threatening, making believe that the accident never happened (covering it up), placing blame where it does not belong, terminating career development and promotions, and of course, monetary 'restrictions.' Given these kinds of reactions, it is little wonder that the lessons of accidents are not rapidly understood and 'sensible' measures put in place to manage the lessons learned to help prevent future accidents. Our work clearly indicates that many major accidents are happening over and over again, and in almost the same way. We need to learn how to break this chain.

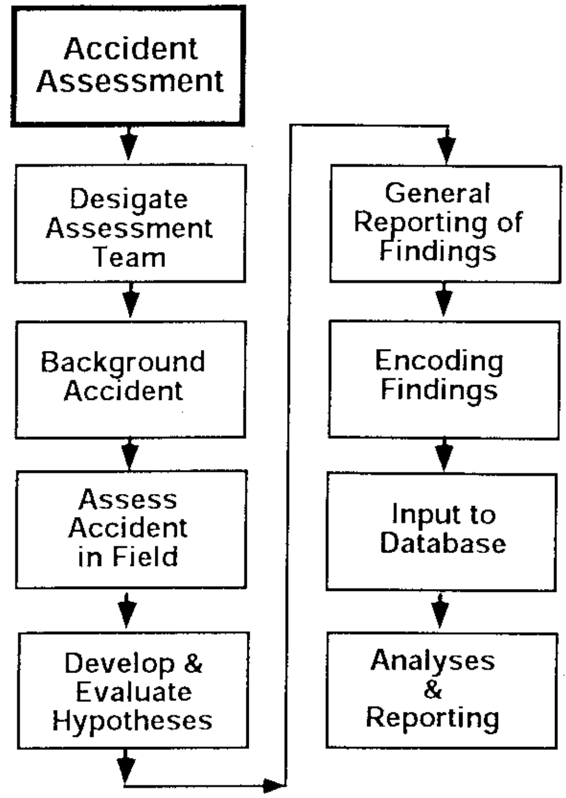

Figure 1 - Accident / incident / near-miss assessment system

The tendencies to 'find the root cause,' call lawyers and police, review the contract clauses, place blame, and other similar reactions are very counterproductive to truly understanding situations that caused failure or failures of the system. Given the litigious nature of the U. S. society, it is important that this nature be recognized and measures put in place not to encourage unnecessary or unwarranted legal action. We are spending too much time in unproductive legal action, maneuvering, and avoidance. The accident information system needs to recognize these challenges at the outset. Formal protocols need to be developed to help guide the DAAR team and process to avoid as many of these pitfalls and traps as is possible.

The accident information system needs to again focus on the life-cycle phases of an offshore platform, and major compromises in the quality attributes of an offshore platform. The accident information system that our research indicates needs to be fleshed-out, detailed, tested, revised, and then implemented is outlined in Figure 1. We have tried to take the best practices and experiences from other accident information systems (Kayten, 1993; Itts, et al., 1995; Miller, 1979; Maurino, et al., 1995). At this stage of our work, no claims can be made for the completeness or the utility of this system.

The system is triggered with the recognition of the need for an 'accident (incident) assessment' (not investigation please) (Figure 1). An accident assessment team is assembled. The team members would represent experienced, trained, qualified, DAARs (Designated Accident Assessment Representatives) whose expertise and integrity are widely recognized. Ideally, the team members would include DAARs from the sectors that had primary responsibilities for the safety of the particular system or systems involved in the accident. It would be extremely important that the DAAR team have the 'requisite variety' to understand the causes and sequences of events that could lead to the accident. Deductive and inductive thinkers are needed on such a team.

A protocol needs to be established for qualification and requalification of DAARs and for selection of DAARs to form an assessment team. Strict confidentiality of the members and organization of the team needs to be preserved in so far as possible and necessary. If a DAAR receives 'excessive' pressures that could sway or cloud their judgment and analysis, then he should be able to be relieved and a replacement DAAR appointed.

The next step in the process is to gather all available pertinent information on the accident and the life-cycle of the marine system. This information can be obtained from data and background on previous similar accidents involving similar systems. This information can be obtained from the MSRIS (there may have been early warnings). This information should address three categories of events and factors:

1) **initiating** events and factors that may have triggered the accident sequence,
2) **propagating** events and factors that may have allowed the accident sequence to escalate and result in the accident, and
3) **contributing** events and factors that may have encouraged the initiating and propagating events.

The information developed in the three foregoing categories needs to address seven categories of factors:

1) the **personnel** (operating team) directly involved in the accident,
2) the **organizations** that may have had influences on the accident events and factors,
3) the associated **procedures** and 'software' used at the time of the accident (formal, informal),
4) the associated **hardware** (equipment),
5) **structure** (physical life and equipment support),
6) the associated **environments** (external, internal, social), and
7) the **interfaces** between the preceding five categories of factors.

This is no trivial undertaking, and it needs to be done as thoroughly as possible.

The information needs to address the life-cycle characteristics and history of the system including:

1) **design,**
2) **construction,**
3) **operation,** and
4) **maintenance**.

The information that is gathered at this stage is intended to lead to a number of plausible scenarios for the accident, starting with its incubation and ending with the final event in the accident sequence. An objective is to progressively gather more information until one scenario can be designated as 'most probable' (Miller, 1979). The reasons for this designation need to be clearly documented and the reasons for the lower probabilities of the other scenarios need to be clearly documented. The intent is to avoid premature conclusions and a rush to the wrong judgment and scenario. The intent is to develop as complete as possible a most probable picture of why and how the accident happened and unfolded. It is realistic to recognize that the complete understanding may not be possible. It is realistic to recognize that 'violations' may have taken place. These violations need to be carefully defined and the reasons for the possible violations understood. The objective is to understand as much as possible about the most probable scenario so that valid and beneficial learning can take place. The worst case is to come up with the wrong scenario, attempt to fix the wrong things, and divert scarce resources from attention to the real problems or challenges to quality, including safety.

The next step is to go the 'field' where the accident happened. This step needs to be reached as soon as is possible so that valuable 'clues' and factors are not lost, obliterated, or modified. The 'site' or locale of the accident needs to be preserved as well as possible. On site during or after audio, photographic, and / or video evidence can be very important. All documentation possible needs to be preserved. This is why flight data and ground operations recorders have proven to be so important for the safety of commercial aviation (more improvements are presently being made to these systems to increase their scope and fidelity). The field could involve an office (design), construction yard (manufacture), operating site, maintenance facility, or decommissioning facility or a combination of these. Everything possible needs to be done to alleviate defensive and evasive postures on the part of all involved in this step. The objective of the assessment needs to be continually stressed: to understand how to make the system or systems like it safer in the future for those that are responsible for its operation to operate. This is really a tough one to create and is a primary talent and sensitivity required in the DAAR team.

A protocol or procedure needs to be developed to help guide the DAAR team activities during the field assessment phase. This protocol needs to address how things should or might be done, the factors and structuring that needs to be developed, and very important how information is recorded and reported (Stoklosa, 1983; Maurino, et al., 1995). The confidentiality of the proceedings needs to be maintained as much as possible. Leaks should not be tolerated. Credibility and trust takes a life time to create and an instant to destroy.

Again, the DAAR team may need to gather additional information from databases, interviews (confidential and non-confidential), qualified consultants and experts, and may need to have additional DAARs added to the team to develop the necessary requisite variety. Testing and simulations may need to be done.

The next stage is the assessment phase. It is here that scenarios are constructed and documented. It is here that evidence is assembled and evaluated in the attempt to identify the most probable scenario, or scenarios. It is here that the majority of the documentation is developed. At this stage, it may be desirable to bring in a 'fresh' DAAR to help verify and validate the process. This is intended to help avoid 'group think' problems and identify any significant 'biases' that may be diverting the team from the most probable scenario/s. Again, more information may be necessary to help the DAAR team identify the most probable scenario/s.

Perhaps, the most important step in this phase is the development of suggestions to help improve the safety of the system. The suggestions need to be prioritized, effective, detailed as much as possible, justified, and practical. Nothing will destroy the system quicker than a scatter gun approach to the suggestions, ineffective measures, insufficient detailing (to enable understanding what can be done), and unjustified - impractical 'pie-in-the-sky' suggestions. Protocols need to be developed for the conduct of this stage.

The next stage is the formal and general reporting phase. This is the formal report that will be distributed to the concerned industrial, classification, and regulatory groups. Concerned parties are those that have daily and continuing responsibilities for the safety of marine systems. Unnecessary exposures of information from the assessment should be avoided whenever possible, and the DAAR team needs to understand the importance of unnecessarily polarized and inflammatory media exposure. Given today's society in the U. S., some exposure probably cannot be avoided in some instances. And, it is impossible to avoid media distortions. This is a significant hazard that needs to be carefully managed for the good of the AARS. Organizational protocols need to be developed to prevent unnecessary and unwarranted legal entanglements (Lauber, 1989; Bruggink, 1985). Congressional and or legal privileged information systems need to be developed. There are several precedents for such systems (kConnell, 1996; Kayten, 1993).

The next stage is the encoding phase. This phase is intended to develop the information that will be eventually incorporated into an AARS database. This is intended to be a computer based system that will archive the most meaningful information, insights, suggestions, and other events and factors that influence the basic objectives of AARS. This is not an easy task. Much of the 'richness' of the information developed by the DAAR team can be lost if this is not done correctly. This is precisely one of the major problems of existing marine and non-marine databases. Some very experienced and thoughtful study is needed to establish the system (hardware, software, procedures, personnel, organizations, and environments) to capture all of the richness from the information that has been developed. This will probably be an evolutionary process (as most of the rest of this system should be). It should be regarded as a 'live' system that needs continual maintenance and adaptations to evolving needs and problems.

The information developed during the encoding phase is input to an archiving relational database system that should contain information on the results of the assessments and the background developed to arrive at these assessments. The information input to the system should be verified.

The last phase of the process is the information analysis and reporting phase. Correlation studies of information in the database should be conducted to detect emerging safety problems. If the information analysts detects an emerging safety problem that high widespread implications, then an alert is output to the system users. The objective of this phase is to understand the available information so that early warnings are developed so that corrective action can be taken before additional accidents are developed.

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FURTHER DEVELOPMENTS OF STANDARDS, SPECIFICATIONS, AND GUIDELINES RELATED TO HUMAN AND ORGANIZATIONAL FACTORS (HOF) TO REDUCE HUMAN ERROR IN OFFSHORE FACILITIES OPERATIONS

Prepared after the discussion in Work Group "E" at The "International Workshop on Human Factors in Offshore Operations", New Orleans, LA., Dec. 1996.

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ABSTRACT

Over the past few years the offshore industry has become increasingly aware of the number of offshore accidents caused by human error. One way to improve this safety record is to concentrate on the source of these errors, i.e., the individuals who design, operate, and manage the offshore facilities. Much is known about how and why individuals behave in a work setting. This data, called human and organizational factors (HOF), is used by a special engineering discipline [i.e. Human Factors Engineering (HFE)]to assist in the design of the work place, select and train personnel, prepare user friendly job manuals and procedures, and establish effective management practices and polices.

This paper, was prepared with the extensive inputs from the co-authors and individuals present in the Working Group "E" of the 1996 International Workshop on Human Factors in Offshore Operations. It describes the current use and effectiveness of HOF specifications, standards, and/or guidelines in the design, operation, and management of offshore facilities and offers potential areas for improvement. It identifies the current role of each of seven key player groups (i.e. government agencies, industry associations, professional associations, classification societies, offshore companies, insurance companies/clubs, and academic institutions) involved in the preparation, encouragement, or enforcement of HOF specifications, standards, and guidelines in the offshore industry. The paper also offers suggested changes in these roles to increase the future effectiveness of HOF in the prevention of human induced errors on offshore facilities.

1.0 INTRODUCTION

Safety and protection of personnel, facilities and the environment is a major concern for the majority of the companies working in the offshore oil and gas industry worldwide. Yet, accidents continue to happen, and companies continue to strive to improve their safety records. One study of accidents on offshore facilities in the U.S. found that 80% of these incidences were caused by human errors, and 80% of those occurred during operations. Another study, this one by the Health and Safety Executive (HSE) in the UK, found that of approximately 1,000 inadvertent hydrocarbon releases in the UK sector of the North Sea since 1992, human error was a strong contributory factor in 60% of these releases. It would appear therefore, that human error is a major contributor to accidents in the offshore oil and gas industry on a global basis.

Over the past fifty years or more, a significant amount of research has been conducted on what shapes and influences human behavior in a work environment. By taking this knowledge, and applying it to the design, operation, and management of offshore facilities, a total work environment can be created that will maximize the worker's capabilities, and minimize his/her limitations. The ultimate outcome is a safer and more efficient employee. This can translate to higher employee morale, greater company profits, an enhanced corporate image with a public concerned over environmental issues, and potentially less scrutiny from regulatory agencies.

The application of this human behavior knowledge [called Human and Organizational Factors (HOF)] to the reduction of human error on the job has spawned a specialized engineering discipline called Human Factors Engineering (HFE). HOF has been successfully applied to other industries and applications (e.g. mining, nuclear power, aerospace, meat packing, military, and light manufacturing) for the past five decades in the U.S., and overseas. However, the systematic application of HOF in the design and operation of offshore oil and gas platforms, supply boats, workover rigs, and general support systems and equipment, has been limited at best. The reasons for the limited use of HOF in the offshore industry appears to be based on several factors, including:

1. The lack of knowledge in the industry at all levels of what HFE is, and the benefits in increased employee safety and productivity that can accrue as a result of incorporating HOF in the design and operation of offshore facilities,

2. The lack of trained HFE professionals with experience in the offshore industry to promote the utilization of HOF in that arena, and

3. The limited use of the pertinent and technically sound HOF standards, specifications or guidelines that are now available for the design, operation and management of offshore facilities.

With interest in reducing human error induced offshore incidences increasing around the world, the question of what future role, if any, should HOF based standards, specifications, and guidelines play is appropriate. To answer this question it is necessary to define what is meant by the terms "standard", "specification", and "guideline", define what HOF is, and then describe what the current state of use of HOF standards, specifications, and guidelines is within the offshore industry.

2.0 DEFINITION OF TERMS FOR HOF STANDARDS, SPECIFICATIONS, AND GUIDELINES

The below listed definitions have been established for the purpose of this paper to provide a baseline for discussion only. These definitions may or may not be universally accepted by the offshore industry or international design community.

1. Standard - A specific design requirement, expressed as a number, or some other human performance criteria, which is verifiable through a qualitative or quantitative measurement technique. Examples of current standards appropriate for use by the offshore industry include the American Society of Testing and Materials (ASTM) "Standard Practice for Human Engineering Design for Marine System, Equipment and Facilities" (ASTM F1166) and the American Petroleum Institute's (API) design standard for cranes (API 2C). When used, HOF standards normally are included as a part of a facility wide design specification, and generally become a contractual obligation on the part of the facility designer, owner, and/or operator in the design of an offshore facility.

2. Specifications - Statements that define, or describe which HOF activities must be completed, which HOF standards must be used, or, how the equipment or system must be built to accommodate the human operator/maintainer. The primary specifications (also called regulations) for the U.S. offshore industry are the United States Code of Federal Regulations (CFR's). These regulations govern the design of all types of vessels and structures and range from a general performance goal, i.e. "lifeboats shall be located so as to be readily accessible for use in an emergency", to the prescriptive, i.e. "A label in 3" high red characters shall be placed on each hazard warning sign".

   Specifications may also be used to identify one or more specific design standards that must be used in the design and construction of a vessel or platform for which the specification is written, e.g. "the vessel shall be designed to accommodate the 5th to 95th percentile male as defined in ASTM 1166".

   Specifications (or regulations) can also be non-prescriptive with statements that set goals or establish general requirements. As an example, one of the United States Mineral Management Service's (MMS) federal regulations governing offshore operations states," The lessee shall not create conditions that will pose unreasonable risk to public health, life, property, aquatic life, wildlife, recreation, navigation, commercial fishing, or other uses of the oceans". Non-prescriptive regulations for offshore safety are also used by the British government for North Sea operations.

   Specifications are prepared and imposed by organizations empowered with the authority to mandate their use by companies in the offshore industry. However, they are also prepared and imposed by individual companies or the design contractor (or even the owner/operator's own engineering staff) who completes the detailed design and/or construction of a new facility. As an example, at least two major oil production companies have develop company and project specific design specifications that must be followed by design contractors hired by the oil companies to do the detail design of new offshore platforms in the Gulf of Mexico (GOM).

3. Guidelines - Guidelines are the same as standards or specifications as far as content is concerned but they are only "suggestions" on what should be done in the HOF area, or how the design should look, and carry no contractual obligation to be completed or used in the design or operation of an offshore facility. Examples of current offshore industry HOF guidelines are the several covering the design of work place consoles and panels, platform labeling, and general control/display design requirements prepared by a major offshore exploration and production (E&P) company in the GOM. These guidelines were issued to selected hardware vendors during the recent design and construction of several offshore platforms.

3.0 WHAT IS HOF?

One of the acknowledged obstacles in utilizing HOF in the offshore industry is the lack of universal agreement among users or suppliers of HOF expertise as to what constitutes HOF, and who does or should provide this expertise for the design, operation, and management of offshore facilities. Thus, not only must the individuals interested in, or assigned to, the utilization of HOF in offshore facilities integrate this new profession with the standard design and operation of these facilities, they must also learn how to combine HOF with the established safety programs and requirements already in place.

As an example, the American Petroleum Institute's (API) RP75, "Recommended Practices for Development of a Safety and Environmental Program for Outer Continental Shelf (OCS) Operations and Facilities", provides minimum guidance for process or mechanical design information and no specific guidance related to HOF. API RP14J, "Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities" references HFE (e.g. section 3.4.4) and recommends the use of ASTM F1166. However, there are no directions on how the ASTM standard is to be used in an analysis, or in the actual design process. Finally, API RP14C, "Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms" provides only minimal guidance concerning HOF issues.

The traditional safety professional at the headquarters level, or assigned to a specific platform or facility, may be considered by some to represent the HFE discipline. Yet, when carefully reviewed it becomes evident that the training, experience and responsibilities of the traditional safety specialist is not the same as that for a person who specializes in the application of HOF to the design, operation, and management of an offshore facility.

Therefore, for the purposes of this paper HOF is considered to include any element of human behavior (social, psychological, physiological) which controls or regulates how well, or how poorly, an employee performs his/her assigned duties while working on an offshore facility (e.g. platform, drilling or workover rig, supply boat, terminal). Within this broad description there are at least eight sub-elements of HOF, all of which can shape human behavior and influence how safely and efficiently a human behaves and performs in a work setting. Lack of attention to any of these eight sub-elements in the design, operation, or management of an offshore facility will increase the chance that a human error will be made on these facilities. Examples of the sub-elements are:

1. Management Systems - Management rules, regulations, work schedules, employee reward systems, and even management's decision on the type and quality of the equipment given to

the employees to work with can influence how safely and efficiently an employee behaves and performs on the job.

2. Workplace Design (sometimes called ergonomics) - Design of the hardware or software which the employee is given to work with must match the behavioral and physical capabilities and limitations of that employee as an operator and/or maintainer. Workplace design is not only concerned about the physical design and arrangement of the work site from a worker visual and physical access perspective, but also how that design and arrangement dictates the communications and personnel interactions required among the workers to safely and efficiently perform within the work site.

3. Personnel Selection - Identifying the special human physical and behavioral characteristics, and the skill levels and experience base, necessary to perform a particular task, or tasks, then selecting individuals with those characteristics to perform those tasks, can make the selected person a safer and more efficient worker.

4. Environmental Control - Allowing the physical environment (i.e. temperature, noise, illumination, vibration, etc.) to exceed known limits can cause, or enhance the likelihood of, environmentally induced human error to occur on an offshore facility.

5. Interpersonal Relationships - Individuals working offshore seldom operate in a vacuum. They give and take direction from others, both on a peer basis as well as a supervisor/employee basis. Persons, capable of working as a part of a team regardless of their organizational rank, management authority, or physical location (i.e. onshore office vs. offshore facility), placed in an environment that promotes teamwork, make for a safer and more efficient employee. The techniques for identifying and/or training these individuals to be team players is an important sub-element of the HFE profession.

6. Training - Training programs must be developed or modified to prepare a person to perform a specific task, or tasks, to a pre-determined and measurable level of performance. However, training must not be considered as the ultimate solution to human error reduction, nor should it be expected to overcome poor facility design.

7. Job Aids - Significant knowledge is now available on how to prepare job aids (e.g. operational or maintenance manuals, procedures, hazard warnings, or any other written material) to enhance their use by a worker to assist him/her in performing the job. This knowledge should now be applied to the preparation of job aids, whether printed or electronically presented, for offshore use.

8 Fitness For Duty - Each day an employee brings to the job site psychological and physical burdens or blessings which can affect the way he/she behaves and performs on the job. If these inputs are severe enough the employee can become a safety threat to himself and/or his/her fellow workers. Devising and using screening devices on a regular basis to prevent the affected employee from working on those days he/she is not suited to do so would make every employee safer on the job.

Therefore, within the context of this paper, i.e. what role, if any, should HOF standards, specifications, and guidelines play in future design and operations of offshore facilities to reduce human error, the standards, etc. to be considered should encompass one or more of the above eight sub-elements of HOF described above.

4.0 CURRENT STATUS OF HOF STANDARDS, SPECIFICATIONS, AND GUIDELINES IN THE OFFSHORE INDUSTRY

There appears to be two general approaches currently in practice to integrate HOF based requirements into the overall offshore E&P business. One, typified by that practiced by the government of the United Kingdom (UK), sets general regulatory goals designed to promote the health and safety of company employees which employers are required to meet. For the UK offshore industry specifically there is a regulatory requirement that each operator submit a "safety case" for each installation demonstrating that:

1. There is a safety management system in place,
2. All relevant hazards have been identified,
3. The risks from these hazards have been reduced as low as reasonably practical (ALARP).

How the companies achieve these requirements is ultimately up to them. However, the federal regulatory agency responsible for safety in the offshore industry, i.e., the Health and Safety Executive (HSE), provides general guidance to the operators as to the issues that HSE would expect to be addressed in a particular safety case. One of those issues is the role of HOF, both as a possible cause of, or contributor to, some of the hazards that could occur on a platform, and also as one of the preventive or mitigating measures to address those hazards.

Deciding exactly what shall be included in each safety case is a matter of discussion and negotiation between the company and HSE. However, there is an incentive for companies to comply with the HSE requests in most cases since HSE does have the authority to delay approval of the safety cases. More importantly, an interim report published in 1995 by the Health and Safety Commission in the UK estimated that average individual risk had been reduced by about 70% through the safety case regime.

With the emphasis on general guidelines rather than prescriptive design standards or specifications, the UK approach only minimally requires operator adherence to published detailed federal HOF design standards or specifications in the design or operation of their offshore facilities. With this approach, the emphasis is on good management practices, training, and procedures for human error reduction, rather than on mandating the use of prescriptive design standards.

The second basic approach, followed in the U.S., currently relies on offshore companies adhering to detailed design rules contained in federal regulations (i.e. CFR's) which must be met before the installation can be licensed or approved to operate.

Historically, the U.S. offshore domain has been divided between two federal agencies, the U.S. Coast Guard (USCG) and the Mineral Management Service (MMS). Through a Memorandum of Understanding (MOU) signed between the two agencies in August of 1989 each has their areas of responsibility for regulating the design and operation of offshore facilities. The USCG's interests lie mainly with ensuring offshore facility structural integrity and stability, fire protection, workplace safety, lifesaving equipment, living quarters, navigation and communication equipment, and helicopter deck installations and refueling facilities.

MMS, on the other hand, primarily establishes requirements and verifies compliance, with those requirements, for systems and equipment for drilling, completion, production, well control, and workover on offshore facilities. However, neither agency has instituted any requirement for an integrated HOF program, as defined above, within their area of jurisdiction, and with the exception of some limited training, personnel qualification and very minimal design requirements, neither has established even individual HOF requirements within the eight sub-elements of HOF described earlier in this paper.

As an example, in Title 33 and 46 of the CFR's, there are a few prescriptive requirements related to labeling, signs, and platform design, and a very few requirements covering training regulations. In 30 CFR, Chapter II, Subpart O, training requirements are listed for specific activities such as well-completion and well-workover control. Finally, the USCG's Navigation and Vessel Inspection Circular (NVIC), No. 4-89 specifically addresses the issue of HFE with a special section devoted to labeling. However, its recommendations are not mandatory.

Although compliance with the CFR rules is still in effect in the U.S. there has been, over the past five years, a shift toward a new way of achieving safety and health objectives in the U.S. offshore industry. In 1991, MMS notified the industry that it was considering making each installation owner institute a Safety And Environmental Management Program (SEMP). As implied by its title, SEMP was a management plan to insure that company attention was given to safety and environmental protection.

The offshore industry responded to this announcement by requesting that it be allowed to develop an industry wide voluntary compliance program to the MMS announcement under the auspices of the American Petroleum Institute (API). In 1993, API published both API RP75 and API RP14J which defines what the companies should do to comply with the SEMP requirements. In response to this action, MMS pledged a two-year moratorium on any further regulatory activity related to SEMP while it monitored the voluntary adoption of RP75 by offshore operators. It is of interest that the SEMP does not specifically require an offshore owner or operator to consider or address any of the eight HOF sub-elements listed above (with the possible exception of management participation). Nevertheless, it should be recognized that the SEMP concept is a step forward toward greater recognition of the planning and analysis necessary for offshore safety and could serve as the mechanism by which a more formal HOF program requirement could be introduced to the offshore industry.

In summary then the source of HOF standards, specifications, and guidelines for use in the offshore industry (particularly within the U.S.) comes from five principal sources:

1. Federal agencies [e.g. USCG, MMS, HSE] via selected CFR's and/or non-prescriptive regulations,

2. Industry Associations (e.g. API) via the minimal references to HOF in the RP75 and RP14J documents, and in a few cases, inclusion of limited HOF requirements contained in

specifications covering individual pieces of equipment's, (e.g. cranes),or for construction, fabrication, maintenance, etc.

3. Professional Associations [e.g. American Society of Testing And Materials (ASTM)] via its two standard practices (ASTM F1166 and F1337) covering human engineering design standards and program requirements respectively, for marine equipment and facilities,

4. Classification Societies [e.g. American Bureau of Shipping (ABS)] via some general rules for design of MODU's and offshore supply boats and,

5. Individual company prepared HOF standards, specifications, or guidelines [e.g. labeling guidelines for deepwater platforms prepared by one GOM E&P company].

There are some prescriptive HOF type federal regulations, governing the design and operation of offshore structures in the U.S. However, most are generally stated making them too vague to be enforced, sometimes in conflict with accepted HOF design standards (e.g. ASTM F1166), and/or do not cover the design areas where many of the human induced offshore accidents appear to originate. Therefore, the current HOF type federal regulations, specifications, standards, or guidelines existing today have only minimal impact on the inclusion of HOF elements in the design, operation or management of the majority of offshore facilities under U.S. jurisdiction.

Industry association HOF based requirements usually appear as a small part of a larger technical specification for a particular piece of offshore equipment, e.g. cranes, or for a specific area of an offshore facility, e.g. the control room. There are relatively few of these and in the context of the total design requirements for an offshore facility, they play a minor role. Further, where they do exist they sometimes appear not to be prepared by HOF specialists and sometimes are in disagreement with the more accepted HOF design standards.

The ASTM human engineering design standard (i.e. ASTM F1166) and the HFE program requirements standard (ASTM F1337) are HOF design standards prepared specifically for the marine world. The design standard (i.e. ASTM F1166) covers only two of the eight HOF sub-elements (i.e. workplace design and environmental control) but they are important elements in the design of offshore facilities, and the standard is a good HOF design reference. It is now beginning to be used by the USCG in the design of their own vessels, and has served so far as the primary HOF design criteria base for at least five deepwater production and drilling platforms in the GOM and Canada. However, in terms of having a general influence on the design of offshore facilities the ASTM design standard is not used, nor is it even known of, by the vast majority of the offshore industry, either in the U.S. or overseas.

At least two major American oil and gas exploration and production companies have prepared in-house HOF based standards, specifications and guidelines for use on both general facilities worldwide, and for specific offshore platforms. In one instance several of these guidelines, although created for a particular platform project, have now been extended to cover all future platforms designed by this company. The creation of such specifications however is obviously not widespread.

In summary, the role that HOF based standards, specifications and guidelines can play in reducing human error on offshore facilities has never been more evident, as supported by the success of HOF in other industries, (i.e. aerospace, aircraft, manufacturing, mining, military equipment, and power generation), and the few offshore companies who have adopted an aggressive HOF program for the design and operation of their offshore facilities. Yet, there currently is minimal overall movement industry wide to embrace even the most basic HOF concepts, practices, standards, specifications, or even guidelines, into the life cycle design and operation of offshore facilities.

5.0 SHOULD HOF STANDARDS, SPECIFICATIONS, AND GUIDELINES BE USED AS A METHOD OF REDUCING HUMAN ERROR IN OFFSHORE OPERATIONS?

The short answer to this question is yes. Decades of research data on human performance capabilities and limitations have been collected and published in the form of HOF standards, specifications, and guidelines for other industries and applications. The majority of these are concentrated in the design arena but some exist for the other sub-elements of HOF. Many of these are appropriate to the offshore industry and could be applied immediately. Other HOF standards, etc. unique to the offshore world may be required. However, whether or not the needed HOF standards, specifications, or guidelines currently exist, such standards could be a key part of any program directed at reducing human errors on offshore facilities.

It is important to note here that the application of HOF standards, guidelines or specifications should not be directed only toward new construction. HOF can be fruitfully applied to the reduction of human error in the operation and management of existing offshore facilities as well.

6.0 WHAT FORM SHOULD THE FUTURE HOF STANDARDS, SPECIFICATIONS, AND GUIDELINES TAKE?

It is recognized that not all eight HOF sub-elements lend themselves equally well to either the prescriptive or general goals approach. HOF requirements for such sub-elements as hardware design, job aid preparation, and control of the working environment lend themselves well to being described in prescriptive standards. However, elements such as management practices, training or personnel selection would be much more difficult to definitively define in a prescriptive manner. Therefore, it would appear that when future HOF standards, specifications or guidelines are deemed necessary, and are prepared, that some be of a prescriptive nature (i.e. in a format similar to the ASTM design standard), while others provide non-prescriptive performance goals.

7.0 SHOULD THERE BE A PRIORITY IN USING OR CREATING NEW STANDARDS, SPECIFICATIONS, OR GUIDELINES?

Although all eight of the HOF sub-elements can contribute to a safer and more efficient working employee, experience has indicated that not all contribute equally toward that goal. Consequently, it would appear that a maximum return on any future HOF activities could be obtained if efforts on covering the eight HOF sub-elements were prioritized.

As an example, the USCG's approach to achieving total fire protection on maritime vessels is to emphasize a minimum level of passive fire protection on all types of vessels, along with some form of active (i.e. human involvement) protection for a "total systems" approached. In the revised draft of the USCG's NVIC 6-80, it is noted that "to increase reliability, structural fire protection (SFP) is designed to be passive in nature and thus eliminate the need for personnel action to make SFP effective. This eliminates, to the maximum extent possible, the possibility of human error affecting the performance of the SFP system. The result is that SFP is assumed to be extremely reliable."

In like manner, designing out the chance for human errors to occur throughout the offshore facility provides a passive protection against that error. This reduces the need to rely on more active efforts on the part of the operator via more operator training, following written operating procedures or observing and adhering to posted warnings to protect against human error. Useful experience in applying existing HFE based design standards to the design and construction of a limited number of offshore facilities in the GOM and elsewhere has been acquired over the past eight years by a handful of major E&P companies. This experience has shown the positive benefits of including HOF based design standards in the design and operation of offshore structures. Further, there are existing HOF design standards, such as the ASTM HFE standard for marine equipment and systems, that can be used now on design projects worldwide. Therefore, application of HOF design standards to the design and construction of new, or upgraded, offshore facilities would appear to be a high priority HOF sub-element. Fortunately, this sub-element is one where there is good, practical experience, and existing HOF standards, from which the offshore industry can take immediate advantage.

Based on experience with the application of HOF in the design and operation of offshore facilities, other high priority HOF sub-elements which should have early involvement include management decisions and policies, and training, particularly in the handling of emergency situations.

8.0 SHOULD THE HOF REQUIREMENTS BE IN THE FORM OF VOLUNTARY STANDARDS, ETC. OR SHOULD THEY BE MANDATORY?

Based on the UK's current approach of creating general safety goals via the minimum regulatory requirement of the submittal of case studies by the offshore operators, a mandatory requirement to address all eight sub-elements of HOF in every future case study submittal may face resistance by that portion of the offshore industry. Similarly, based on the U.S. offshore industry's response to the SEMP proposal from the MMS, it is apparent that the U.S. offshore industry would also have a similar aversion to the imposition of new, federally mandated, HOF requirements in their operations.

Further, the current political climate, such as now exists in both the UK and the U.S., favors the position that since the offshore operators "own" their facilities, it is they, not the federal government, which must be ultimately responsible for the safety of their employees and facilities. Based on the above, it would appear that any effort to increase the role of HOF in offshore facility design and operation would best be achieved, at least initially, through a voluntarily initiated and incorporated effort by the offshore industry. with support, education, and encouragement from their federal partners.

The difficulty with a voluntary approach however, is that so far, left to their own, the vast majority of the offshore companies to date have not placed any focused effort on the use of HOF standards, specifications, or guidelines in the design and operation of their offshore facilities unless forced to by a regulatory agency of some form. This may be due to lack of knowledge about HOF, a concern over what is perceived to be yet another costly and time consuming burden imposed on them by others without a demonstrated cost benefit, a belief that they are doing all that is necessary now, or a deliberate choice to exclude HOF from their design efforts. Whatever the reason(s), the fact remains that the majority of the offshore industry is not currently voluntarily adopting HOF as a part of their design and operation team.

Nevertheless, in spite of the omission of a formal HOF effort to date in the offshore industry, the imposition of federally mandated requirements to include such a program does not seem to be politically palatable or technically viable at this time. However, with this initial respite from federal imposition of HOF regulations, etc. it behooves the offshore industry to begin now to collectively initiate an HOF program that will preempt the need for any federal HOF intervention for offshore safety in the future as well. Therefore, it is suggested that some form of cooperative HOF effort between the companies who constitute the "offshore industry" and government agencies who oversee and/or regulate those companies be enacted. Some countries, such as the UK and Canada already have such a cooperative effort in place. Consequently, their future HOF efforts could be directed at enlarging the HOF areas of concern in the safety case process. In contrast, the U.S. offshore industry may have a larger effort facing them since utilization of HOF, in any form or for any of the eight sub-elements, is still in its infancy.

It is also suggested that whatever HOF requirements or efforts come from the new partnership between government and industry, maximum use be made, wherever possible, of existing programs (e.g. case study submittals, SEMP) as the HOF completion and monitoring mechanism and not create yet another new separate initiative. However, where existing programs are not in place new initiatives may be required.

9.0 WHAT ROLE SHOULD EACH OF THE HOF PARTICIPANTS TAKE TO PREPARE, ENFORCE, AND/OR ENCOURAGE THE USE OF HOF STANDARDS GUIDELINES AND/OR SPECIFICATIONS FOR THE DESIGN AND OPERATION OF OFFSHORE FACILITIES?

The very question leads to the premise that each of the following listed organizations does have a role in one or more of four areas, i.e. 1) preparation of selected HOF design standards, guidelines, or specifications, 2) education of the offshore industry to HOF and it value, 3) encouragement of offshore companies to use HOF , and 4) development and use of performance monitoring mechanisms to measure the cost and effectiveness of using HOF in the design, construction, operation, and management of offshore structures. An expanded description of these roles is provided below.

Since the offshore oil and gas industry is global in nature it is not reasonable to propose a HOF program that would be equally acceptable to all companies and countries. What is provided here is one approach, obviously more appropriate to the U.S. offshore industry. However, it is hoped that by providing one model for implementing HOF in the offshore industry it will spark interest and discussion that could eventually lead to use of HOF, not only in the U.S. offshore industry, but in other parts of the world as well.

9.1 FEDERAL AGENCIES

Before identifying the suggested roles of the federal agencies who should be involved in the HOF arena it is first necessary to identify those federal agencies who are now involved. In the UK it is principally the HSE. Their, the cost of complying with the safety case regulations, i.e. producing a safety case, is typically around one-half million pounds per case, giving an overall cost to the offshore industry in the UK of 100-150 million pounds for safety case submittals.

However, in spite of these costs, there appears to be sufficient support by both industry and government for continued use of the case study approach. Therefore, it is assumed that offshore safety in the UK will continue to be the responsibility of the HSE and it would be they who would institute any additional HOF activities.

In Canada, the National Energy Board currently has a leading role in ensuring safety in the Canadian offshore industry and it would be assumed that they would continue to fulfill that role in the future, including the addition of any further HOF efforts deemed necessary for the Canadian offshore industry.

In the U.S. both the USCG and MMS have shown recent interest in the HOF area, and both should expand that role in their respective fields of responsibility and influence in the offshore industry. However, to achieve this expanded roll will require an increase in both agencies interest in, knowledge of, and commitment to, HOF over that which has been shown in the past.

It has been suggested by some that for the U.S. either the USCG or MMS become the "lead agency" for HOF in the offshore industry. However, after discussions with industry representatives it would appear that at this time it is in the best interest of any U.S. HOF program that each agency institute a HOF effort within their own organization,. It is also suggested however that their be a stronger inter-agency HOF cooperative effort than has been exhibited in the past.

Preparation of HOF Standards and Guidelines

To assist the integration of HOF into the U.S. offshore industry it is suggested that both MMS and USCG cooperatively sponsor a joint government/industry project to prepare a series of HOF standards acceptable to the industry that could be used in the design and operation of offshore facilities. Precedence for such a government/industry cooperative effort toward reduction of human errors within the maritime industry already exists between the USCG and several shipping industry associations. That same approach could work with the offshore industry. As for the preparation of HOF standards directed specifically at the offshore industry, precedence already exists their as well with at least two of the major U.S. GOM oil and gas E&P companies having prepared HOF design standards/guidelines for their in-house use on future offshore structure design projects.

Suggested topics for these HOF standards/guidelines include:

Design

1. General Control And Display Requirements
2. Control Panel And Console Requirements
3. Workspace Design Requirements
4. Alarm Requirements

5. Project Labeling Requirements

6. Maintainability Design Requirements

7. Computer Interface Requirements (i.e. DCS Systems)

Job Aids

1. Operator and Maintenance Manual Preparation Requirements

2. Procedure Writing Requirements

3. Hazard Warning Preparation Requirements

Training

1. Training Guides For Selected Offshore Occupations

2. Behaviorally Based Safety Program Training Guides

Personnel Selection

1. Job Aid Preparation Requirements (Manuals, Guidelines, etc.)

The existence of these, or other, HOF standards would allow offshore companies to design and operate their facilities from a common base, and to select those standards that they felt were applicable to their specific each new facility design program.

Establish Minimum HOF Requirements For New Offshore Facilities

As a second HOF effort, it is suggested that MMS and USCG, in cooperation with the offshore industry, develop a list of minimum HOF activities that should be included in the design, operation, and management of new offshore facilities and operations. These activities could be similar in concept and format to that established in the SEMP. It is suggested that the API give serious consideration to the addition of these HOF requirements as added SEMP requirements in the next revision of RP75 and/or RP 14J. It is also recommended that at a minimum the HOF activities address the following elements of a HOF program:

1 That HOF be addressed in each design effort on all new offshore oil and gas facilities.

2. That each owner of a proposed new offshore facility develop a HOF plan as a part of their risk management program for that facility. This plan should be as inclusive and appropriately detailed as necessary to fit the facility's size, location and complexity. The Plan should cover:

a. A description of the HOF tasks (selected from the eight HOF sub-elements described above or other sources such as ASTM F1337-91) that will be completed during the lifecycle of the facility.

b. Which HOF design standard(s)/guideline(s) will be used (i.e. ASTM, selected sections of the joint government/industry HOF standards discussed above, existing industry association specifications, classification society guidelines, or other documents).

c. How will HOF activities will be performed (i.e. in-house personnel or contractor support).

d The training, experience and qualifications of personnel conducting HOF activities.

e. When HOF tasks will be performed in relation to the overall design, fabrication, and operation schedule.

f. Identification and level of management responsibility for managing HOF related activities.

g. How the company proposes to integrate the HOF requirements into daily design activities, and

h. A description of specific HOF processes such as process hazards analysis studies, quantitative risk assessments, task analysis, etc., to be completed during the lifecycle of the facility.

The HOF plan should be developed at the very early stage of any new offshore facility design.

Some companies may elect to develop a generic HOF plan which could be modified to fit elements unique to each facility. Other companies may elect to prepare individual facility HOF plans as required to meet specific requirements.

Sponsor Industry HOF Training

Thirdly, it is suggested that MMS and USCG, in cooperation with the offshore industry, educate the offshore community in both the benefits of incorporating HOF into the daily Company operations, as well as specific instructions on how to incorporate HOF into the Companies design, operation, and management activities.

Develop Measures of Safety Performance

Finally, the government agencies should develop a method for measuring how effective including HOF into company operations is in reducing the rate, type, and severity of human errors on offshore structures. It is understood that this effort can only be accomplished after the offshore industry has had an opportunity to develop and use HOF standards/guidelines in the design and operation of future offshore structures. This task is listed here to ensure its inclusion in the total HOF plan being proposed. However, a simple but important first step in the evaluation effort can be commenced now with the inclusion of the eight HOF sub-elements in offshore accident investigations. Further, the HOF investigative effort should be conducted either by individuals academically trained and experienced in the HOF discipline, or by accident investigation specialists provided special HOF training and tools. It is imperative that an accurate baseline first be established as to the actual frequency and root cause of human errors occurring in the offshore industry. With that base the industry can then observe any improvements brought about by the inclusion of HOF in future operations.

Some form of baseline HOF effort for all offshore design and operations efforts would even the playing field for all companies in the business. Currently many of the major E&P companies in the North Sea and GOM have extensive safety programs, and hopefully will expand those efforts to include all eight sub-elements of HOF as yet another tool to use to enhance employee safety and efficiency. However, for smaller independent companies which may tend not to emphasize safety to the same degree, an industry wide and accepted baseline HOF program for all new facilities could reduce the rate and severity of human errors on those structures.

Encouragement

Here would be a new role for the federal agencies. The agencies could do several things to encourage the use of HOF by the offshore industry. The agencies could develop a way of providing recognition to those companies who utilize HOF in their operations.

The agencies could also reduce their surveillance and inspection efforts for those companies who demonstrate a commitment to HOF in the design and operation of their offshore facilities.

The encouragement effort should be a significant part of the federal agencies HOF program.

9.2 INDUSTRY ASSOCIATIONS

Preparation of HOF Standards And Guidelines

Industry associations (e.g. API, IADC, IPWA, OOC, AWS) typically produce design and other standards for a variety of applications to include design of individual pieces of equipment, construction, fabrication, inspection, testing, etc. Some of these contain HOF based requirements. As an example, the API standard for offshore cranes (API 2C) contains a series of sections, (e.g. 6,7,9,10, and 11), which possess HOF type design requirements. An example of incorporation of HOF in construction standards are the fact sheets produced by the American Welding Society (AWS) related to ergonomics concerns in the welding environment which should be addressed at each construction site.

Because of the above activity, there is a need for the Industry Associations to sponsor the research and development of HOF based guidelines, standards, and/or specifications unique to their industries which do not currently reside in the existing HOF community. These guidelines, standards, and/or specifications can be in the form of a stand alone documents or in the form of an appendix or commentary section for existing documents.
For revision of current standards and introduction of new standards there is a need for the Industry Associations to utilize excepted HOF industry accepted practice. The Industry Associations could

enhance the value of their standards if the requirements were based on the HOF standards produced by the joint federal agencies/ industry task forces described above or input from HFE professionals and/or existing HOF standards.

Finally, Industry Associations could take the lead in representing the offshore industry in the preparation of the federal government/industry HOF standards described above, as was done by API with the SEMP program.

Education

Industry Associations should sponsor HOF educational classes for their members in the offshore industry, explaining what HOF is, and how it could be applied to the design and operation of offshore facilities.

Finally, Industry Associations could serve as the industry's contact point in working with the federal agencies to develop the scope and content of the HOF Plan described earlier in the Federal Agency section. This would allow the offshore industry a major voice in determining the minimum HOF effort that should be expended on any new offshore facility design and construction program.

Enforcement

The current use of industry association design standards occurs primarily through their reference in another regulatory agency standard or specification which is enforced by that agency, not the industry association. Therefore, the industry associations would be no more involved in enforcement of their new HOF standards or requirements than they are for the standards that they now publish.

Encouragement

The Industry Associations could be helpful in providing encouragement to their memberships to establish HOF in-house programs. The Associations could collect and distribute HOF success stories that could be disseminated among their members, and they could provide recognition of HOF programs in their membership publications..

9.3 PROFESSIONAL ASSOCIATIONS

Preparation of HOF Standards And Guidelines

The ASTM human engineering design standard for marine facilities has received its first revision since its original issue in 1988 and is now issued as F1166-95a. ASTM has also published a companion HFE standard entitled, "Standard Practice for Human Engineering Program Requirements for Ships and Marine Systems, Equipment, and Facilities" (ASTM F1337-91) which defines the various HOF program activities that could be completed during the design, construction, and operation of an offshore facility. Used together, the two ASTM documents could provide a good basis for the HOF design standards prepared by the joint government/industry teams described above.

Other professional associations (e.g. IEEE, ANSI, SPE, CCPS)) currently produce a limited number of HOF based design standards in their area of specific interest, e.g. lighting, control room design, and noise control. These are acceptable for offshore use but would not be needed if the joint government/industry design standards described above were created. If they are retained however, an effort must be made to ensure that these design requirements agree with those contained within the proposed HOF design standards produced by the federal government/industry teams, or at least with current HOF design standards such as the ASTM F1166.

Education

Professional associations could provide education to their members on the HOF requirements issued by them, and how to apply these in the design and construction of offshore facilities. The Associations could also distribute HOF training materials and assist the federal agencies HOF education efforts by soliciting association members to attend the federal agency training programs.

Enforcement

As with the Industry Association standards, those published by the professional associations most often appear as a referenced requirement in a regulatory specification, or in an equipment specific purchase specification prepared by the company or design contractor designing the offshore facility. As a result, the association is not involved in enforcement of its standards. Therefore, it is envisioned that the ASTM, or any other trade association which would produce future HOF based standards for offshore application, would not be involved in the enforcement of those standards as well.

Encouragement

Professional Associations could encourage their members to utilize HOF in their daily design activities in the same manner as described above for Industry Associations.

9.4 CLASSIFICATION SOCIETIES

Preparation of HOF Standards And Guidelines

Classification societies, such as ABS, DNV, Lloyd's, etc. can offer an expedient way of introducing HOF design standards into those elements of the offshore industry (e.g. MODU's and support ships) where the societies currently establishes rules for the design and construction of these facilities. Currently, these rules are mainly performance based HOF requirements which are open to interpretation as to what must be furnished in the design of a MODU or ship. In order for a classification society to serve as a source of HOF design and operational requirements they must first quantify in some manner their existing HOF based rules, and then prepare new rules, standards, or guidelines such that these can be used to influence the design and operation of offshore structures. These new HOF design standards could be prepared by facility type (i.e. MODU, jack-up drilling rig, supply boat), by space within a facility (e.g. machinery room, generator room, etc.), or by area of HOF (hardware design, labeling, environmental control, etc.). However, these HOF requirements must be in compliance with those produced by the government/industry task force described above, or at least with current and accepted HOF design standards (e.g. ASTM F1166, or W. Woodson's "Human Factors Design Handbook).

Perhaps even better, the new rules written by the classification societies could simply reference the design standards prepared by the government/industry task force.

In either case, the Classification Societies can, and should, begin now to develop, publish, and distribute their new design rules with HOF design standards included based on what is now available in the HOF design standard literature.

Education

The Societies could provide training to their clients on how to prepare the HOF plans mentioned above, how to use the ASTM and other HOF design standards, how to conduct hazard analysis studies, and how to establish a formal HOF program within the company management. They could also conduct educational programs on how to perform the companies own HOF drawing review programs before drawings are submitted to a Society for approval.

The Societies should also be completing their own in-house training with their engineers, designers, and surveyors covering the integration of HOF into the design of offshore facilities, and what to look for in terms of HOF design and operational deficiencies when an offshore facility survey is made.

Enforcement

The classification societies would be expected to enforce the new HOF based rules and standards just as they now enforce their other design requirements.

Encouragement

The classification societies are in a good position to both require and educate their clients to use HOF in the design and operation of their offshore facilities. Further, unlike most of the other parties discussed above, the Classification Societies could offer financial incentives to their clients who integrate HOF into the design, construction, and operation of their offshore facilities.

9.5 OFFSHORE COMPANIES

Preparation of HOF Standards And Guidelines

As noted before, there currently are no industry consensus standards mandating or even encouraging the use of HOF based standards covering hardware or software design, personnel selection, training, environmental control or other HOF elements for offshore facilities. However, there is no reason why individual company's cannot begin to create their own to incorporate HOF elements into their facilities design and operations without waiting for industry consensus standards to be developed. As an example, one major GOM E&P company has maintained a major HOF program since 1990 covering both design and operation of all of their new deepwater facilities. As a part of their effort, they have written and applied four HOF based design standards/guidelines, covering stairs and ladders; labeling; controls and displays; and workplace design, to all of their new deepwater platforms. These standards and specifications are applied by the company's in-house designers as well as contract design agencies, and in a few cases, by suppliers of their purchased hardware.

Several other major E & P Companies in the U.S., Europe and Canada have also initiated their own HOF programs. The early returns from these first efforts indicate that HOF is economically viable, can lower training costs, increase employee production, reduce costs associated with human loss due to accidents, reduce manpower requirements and in some cases offset initial up-front investment cost. However, these results come from a tiny fraction of the total companies working in the offshore industry. Therefore, the vast majority of individual companies in the offshore business need to be more pro-active in applying HOF into their offshore facilities design and implementing HOF in their operations and maintenance activities. Preparation and use of in-house HOF design standards can be done now, and can pay benefits now.

If companies do not want to create their own HOF design standards they can utilize those standards that already exist such as the ASTM F1166-95a standard or W. Woodson's "Human Factors Design Handbook".

Beyond the standards there are many HOF tasks that can be done with no standard or specification driving them.. HAZOPS, risk assessment studies, HOF audits of vendor supplied hardware, and layouts of control rooms, medical spaces, and quarters buildings are all examples of HOF activities that have been recently completed on offshore facilities and none were done because of any regulatory requirement. Clearly, it has been demonstrated that an individual company can successfully take the lead in utilizing existing HOF concepts and methodologies on their own without a HOF standard, guideline, or regulatory requirement driving that effort.
There are other activities that industry can do to promote HOF in the design and operation of offshore structures including:

1. Support HOF workshops and training programs conducted by the government or trade and professional associations as described above.

2. Request and participate in special sessions on HOF at major industry meetings (e.g. OTC).

3. Work with the government in developing the safety performance measures described above.

4. Share HOF experiences with others in the industry such as was done at the 1996 International Workshop on Human Factors in The Offshore Industry.

9.6 INSURANCE COMPANIES/CLUBS

To date insurance companies or clubs have not been a participant in the offshore HOF arena. However, since the industry desires to reduce its losses, and since much of those losses come from human error, it would appear that the insurance industry would be a strong advocate for HOF in the design and operation of offshore facilities. Therefore, it is strongly suggested that the insurance industry become a major advocate for, and participant in, the incorporation of HOF in the design, construction, operation, and management of future offshore facilities. It is also suggested that the insurance industry investigate the feasibility of establishing insurance rates based on the degree of HOF involvement a company has in the design, construction, and operation of their future offshore structures.

9.7 ACADEMIC INSTITUTIONS

As with insurance companies, academic institutions have to this point not been a major player in the incorporation of HOF in the design and operation of offshore structures. With the increase in interest in the HOF arena there will be a need for academically educated and trained HOF specialists to work with, and for, offshore companies. Because of the current shortage of HOF educated persons with marine experience it is suggested that academic institutions which currently have HOF undergraduate and graduate programs, and who have an already existing tie to the offshore industry, establish classes which provide training for application of HOF to the design and operation of offshore facilities. These classes could be offered as:

1. Applied HOF classes given to engineering students outside of the HFE profession.

2. Extension classes for both HOF specialists or general engineering students.

3. Special classes given to individuals majoring in HOF

The academic institutions could also conduct research specific to the application of HOF to the offshore industry. Conducted either as a part of their graduate students thesis programs, or as stand alone research projects funded by government agencies or the industry or professional associations, the research projects should be directed at creating data or information specific to the application of HOF to the offshore industry. Some specific R&D projects that could be of real value to the offshore industry include:

1. Development of methods to measure the cost effectiveness of incorporating HOF into the design, construction, and operation of offshore structures.

2. Creation of a HOF glossary to standardize HOF terminology .

3. Investigation of standards, guidelines, and best practices developed by other industries that have successfully integrated HOF into their operations, and which could be used by the offshore industry.

4. Establishment of torque production capabilities of offshore workers such that valve operators can be sized and oriented to allow use by the full range of potential offshore employees (male and female) during the full lift cycle of the platform.

5. Establishment of the anthropometric dimensions of the offshore worker.

6. Creation of HOF design standards or guidelines specific to the offshore industry.

Finally, the academic institutions could provide a technology transfer service whereby successful HOF programs are reviewed and described for dissemination to the total offshore industry.

10.0 WHAT SHOULD BE DONE BY HOF SPECIALISTS TO PROMOTE THE USE OF HOF SPECIFICATIONS, REGULATIONS AND/OR STANDARDS IN THE DESIGN AND OPERATION OF OFFSHORE FACILITIES?

There are several actions which those in the HOF profession can do to encourage the use of future HOF regulations and standards in the offshore industry. First, be willing to participate in the writing of new, or reviewing of existing, HOF design and operational regulations and standards for all offshore applications to ensure that they are technically sound and enforceable.

Second, make it known within your commercial organization, your offshore consulting clients, your federal agency, that the application of HOF to the design and operation of offshore facilities can reduce accidents caused by human error. Without some form of HOF standards and guidelines it is impossible to achieve a consistent, level application of HOF criteria to the design and operation of any offshore facility.

Lastly, but most important, the HOF Professional needs to provide the technical resources for:

1. Developing the HOF Standards, Specifications, and Guidelines previously discussed.

2. Assisting industry in applying HOF Standards, etc. to the design and operation of offshore facilities.

3. Establishing tools, such as HOF checklists, which can be used by industry personnel to ensure that HOF is considered and properly applied

4. Measuring compliance with HOF Standards.

11.0 WHAT QUALIFICATIONS SHOULD ONE POSSESS TO PREPARE, APPLY, OR ENFORCE HOF SPECIFICATIONS, STANDARDS, or GUIDELINES?

No amount of HOF based regulations or standards will meet every offshore design or operation application. Converting or adapting a published regulation or standard to a specific design or operational requirement for a specific offshore structure will not be unusual. But better it be a HOF professional, working with the other engineering disciplines involved, that makes that transition from the standard to the specific application than someone without a HOF background.

It has been suggested by some in the offshore community that facility engineers and/or operations personnel, provided with some form of HOF training and tools, could possess the necessary qualifications to make the majority of the HOF inputs needed in the design and operation of offshore facilities. Thus, HOF specialists would need only to be called upon for those infrequent occasions when a "special" HOF need arose. The experience of other industries (as well as the few major offshore facility design projects in the GOM where HOF has been an integral part of the design team), shows this not to be the case. HFE is as unique an engineering discipline as are any of the other "traditional" engineering fields (e.g. civil, electrical, mechanical, etc.). There are now many universities and colleges that offer the full range of academic HFE degrees (i.e. bachelors, masters, doctors), through their engineering schools. These HFE academic educations require detailed technical preparation which is as arduous and extensive as the other engineering fields. The HFE degree however, possesses a uniqueness not shared by any other engineering discipline, i.e. the years spent studying how and why human beings behave as they do (physically, psychologically and socially), and how that behavior can be positively impacted to make the human a safer and more efficient performer on the job. Further, decades of research by HOF specialists on human beings has yielded the HOF profession its own set of methodologies, procedures and design standards and handbooks, which are as legitimate and useful as those possessed by the other engineering disciplines. HFE is not just "common sense", selecting the correct number from a table, or relying on a HFE checklist to ensure that the human has been given the proper attention in a man-machine system. Nor can the HOF expertise and the HFE "mindset", which is especially important when trade-offs must be made between HOF requirements and the other engineering needs, be adequately acquired by individuals (even if they are trained in another engineering discipline) who are given only a few days, weeks, or even months of HFE instruction and handed a set of HFE "tools". This is not an indictment of the other engineering disciplines or operations personnel. It is rather a realization of how significantly different HFE is from the other disciplines. Therefore, It is no more logical to expect a facility design engineer or operator to successfully fulfill the HFE role during the design and operation of an offshore structure than it would be for the HFE specialists to also perform the structural design on that structure.

In the same manner educational or experiential training as a ship officer, federal agency marine inspector, naval architect, offshore platform operator, or other marine related training provides an excellent background for those who are formally trained in HOF, but that background in and of itself, does not prepare a person to be a HOF specialist.

As more emphasis is placed on the reduction of human error on offshore facilities, preparation of, and adherence to, HOF standards and guidelines for the design and operation of these facilities will hopefully increase. Because of the long standing low attention given in the past to HOF in the design and operation of offshore facilities, there are currently few HOF professionals with direct experience in the design and operation of offshore facilities. However, this will change once the demand for HOF expertise support increases. In the mean time, for those companies looking to acquire in-house or outside HOF assistance to prepare new, or comply with existing, HOF standards and guidelines, the following qualifications should be sought:

1. An academic degree in the HFE profession (e.g. organizational, industrial, or social psychology, human factors engineering, ergonomics, human physiology, medicine, industrial engineering)

2. Experience in applying HOF to the design and operation of industrial facilities

3. Experience in preparing, complying with, or enforcing HOF regulations in an industrial setting

In order to gain credibility and acceptance within the offshore industry minimal specific educational and experience requirements for the aforementioned qualifications should be established. The current requirements for professional certification in the HOF profession as established by the Board for Certification of Professional Ergonomists could serve as a springboard for establishing other minimum qualification requirements for HOF employment in the offshore industry.

12.0 SUMMARY

Reducing human error, and its subsequent consequences of personnel injuries and fatalities, and equipment and/or environmental damage, can be achieved by the offshore industry via inclusion of HOF in the design, operation, and management of offshore facilities. As a part of the overall engineering profession, HOF is largely unknown in the design and operation of offshore platforms, rigs, supply boats, etc. Some reasons for the current exclusion of HOF in the offshore industry include:

1. Few HOF specifications, standards, or guidelines that are based on human performance data have been prepared for, and used by, the offshore industry,

2. HOF standards, specifications or guidelines that do exist are often vague in nature and open to too much interpretation as to what will satisfy the standard or specification,

3. Many companies in the industry see no incentives now (either positive or negative) that would compel them to use HOF standards and specifications in the design and operation of their offshore facilities,

4. There is a general lack of knowledge of what HOF is, what a HOF specialist does, and the benefits that can be derived by the offshore industry from using HOF in its operation, and

5. There is a misconception among some firms that have heard about HOF that applying the standards and guidelines to their facility designs and operations will significantly increase their costs, or delay new construction schedules although actual experience indicates otherwise. As one example, on a large offshore platform design and construction project initiated and completed in the early 1990's the extensive three-year HOF effort was not responsible for a single delay in any schedule date. Further, the total HOF cost was approximately .08% of the design and construction expenses, and only .03% of the total project costs.

To reduce human induced errors in the offshore industry requires a coordinated effort by government, industry and professional associations, classification societies, individual companies and insurance organizations within the offshore domain. The program described above for those agencies, companies, associations, academic institutions, insurance companies, and individuals who make up the offshore industry can be a start. One fact appears to be indisputable: human errors cause, or contribute to, more accidents and incidences in the offshore oil and gas industry worldwide than any other single factor. Consequently, the offshore industry must concentrate on the source of those accidents, (i.e. humans who design, construct, operate and manage the offshore facilities). At the 1996 International Conference on Human Factors in The Offshore Industry a group of individuals representing many of the players in the offshore industry met to discuss the issue of human error in the offshore industry, and what role, if any, should HOF standards, guidelines, and specifications play in reducing those errors. The consensus of that group's findings was:

1. There is a need for greater emphasis on HOF in the offshore industry.

2. There is a need to educate the offshore industry on HOF, and the role it can and has already played in reducing offshore accidents.

3. There is a need for the development and use of HOF technical standards and guidelines within the eight sub-elements of HOF described earlier within the offshore industry, and

4. Inclusion of HOF in the design and operation of offshore facilities should be voluntarily initiated, promoted, and adopted by the industry.

The paper presented above provides one framework to accomplish the groups findings.

MINERALS MANAGEMENT SERVICE (MMS) PERSPECTIVE ON USING HUMAN AND ORGANIZATIONAL FACTORS TO REDUCE HUMAN ERROR IN OFFSHORE FACILITIES AND OPERATIONS

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ABSTRACT

The author discusses standards for human and organizational factors and whether further development of these standards can lead to improvements in the safety of offshore oil and gas operations. More specifically, the author addresses the current role of MMS in research, regulatory, and nonregulatory activities. The author also addresses potential further roles of Government, and specifically of MMS, in developing and implementing standards that address human and organizational factors. The author advocates the integration of standards for human and organizational factors with standards addressing other aspects of safety and protection of the environment and stresses the need to develop good indicators of performance to enable Government and industry to gauge the level of safety and environmental protection being achieved.

INTRODUCTION

Government, industry, and the public all have a goal of safe offshore operations and protection of the environment. It is generally accepted that further improvements in areas of human and organizational factors can help reach that goal. If there is a need to debate whether there is a role for human and organizational factors, that debate will be left to others in this conference. This paper will address the role of further development of standards, specifications, or guidelines related to human and organizational factors in obtaining those improvements.

In discussing the need for further development of standards, specifications, or guidelines, the paper will address several interrelated questions:

1. Is there a need for mandatory standards or specifications or voluntary guidelines?

2. Who should enforce any mandatory standards or specifications?

3. What should the role of Government, individual companies, trade organizations, or other groups be in developing and monitoring standards, specifications, and guidelines?

4. How do we know if the requirements are working?

MMS'S BACKGROUND IN HUMAN AND ORGANIZATIONAL FACTORS

Although MMS, industry groups, standards-setting organizations, and contractors all have a role in offshore safety, it is the lessee that is primarily responsible for offshore safety. Whether a provision is directed at equipment or human and organizational factors, MMS regulations are based on the understanding that it is the organization operating offshore (the lessee) and not MMS that is responsible for safety. The "performance standard" that begins many of the subparts of the MMS regulations embodies this responsibility of the lessee. For example, Subpart C of 30 CFR part 250 begins with the following:

> During the exploration, development, production, and transportation of oil and gas or sulphur, the lessee shall take measures to prevent unauthorized discharge of pollutants into the offshore waters. The lessee shall not create conditions that will pose unreasonable risk to public health, life, property, aquatic life, wildlife, recreation, navigation, commercial fishing, or other uses of the ocean.

MMS regulations are in place to provide oversight and to ensure that lessees provide for safety and environmental protection. One area directly related to human factors is training. In 1979, MMS began certifying and requiring that offshore workers take specific training courses for well control. MMS expanded this program in 1991 to also certify courses for production safety systems and well control for well-completion and well-workover operations. MMS continues to review these regulations attempting to find ways to best ensure that offshore workers are properly trained to safely perform their function.

Other than requirements for training, the details of the MMS operating regulations generally deal with the installation, maintenance, testing, repair, and operation of equipment. Although these regulations generally do not address human and organizational factors, there are provisions that address issues such as communications. For example, included in regulations addressing drilling and production safety are provisions dealing with the performance of the individual. This includes requirements for conducting safety meetings, drills, and supervising drilling operations.

The history of accidents and spills over the past 25 years shows that employees have been well trained, and lessees have been responsible for safety and environmental protection. While the safety and environmental record is good, some accidents continue to occur and MMS and industry have looked to the operating organization for further improvements. Many of the organizations operating offshore are developing programs to better integrate safety and environmental protection into management of operations. One means has been to develop and implement safety and environmental operating programs (SEMP). When properly implemented, a SEMP plan address all aspects of safety, including human and organizational factors. All interested parties continue to work together to identify the best role for Government and industry in defining and monitoring SEMP requirements. Although SEMP is different from human and organizational factors, when a company adopts SEMP, it recognizes that safety and environmental management must be an integral part of operations. Any company that accepts safety and environmental management as an integral part of operations must also be dealing with human and organizational factors.

DOES THE OFFSHORE INDUSTRY NEED STANDARDS, SPECIFICATIONS, OR GUIDELINES TO ADDRESS HUMAN AND ORGANIZATIONAL FACTORS?

Standards, specifications, or guidelines that address human and organizational factors can help to further the goal of operational safety and environmental protection. MMS has regulations addressing all phases of offshore operations from initial exploration to platform removal. These regulations incorporate over 60 standards, most of which were developed by groups representing the oil and gas industry or independent standards setting groups. For the most part, these requirements address equipment and procedures. In some cases, the requirements also address human or organizational factors. MMS has adopted these requirements because the regulations and the incorporated documents represent good and safe practices. They enable MMS to meet the mandate of ensuring safe and pollution free operations.

Even with the current regulations, safety remains the primary responsibility of the lessee. Since it is the lessee's organization and not MMS that must take primary responsibility, one area to look into for further safety and environmental improvements is in the lessee's organization and the offshore workers. New requirements might supplement or replace portions of current regulations. The new requirements might be voluntary or mandatory. Regardless of the exact nature or role of any new requirements, the offshore industry needs further standards, specifications, or guidelines addressing human and organizational factors.

Four areas provide an opportunity for improved safety and environmental protection through the development of new requirements. These four areas (discussed later in this paper) are:

- Establishing and Enforcing Company Policy and Practices,
- Training Requirements,
- Communications, and
- Man-Machine Interface.

The potential for new requirements does not have to be in new documents. Industry may be able to integrate all safety and environmental safeguards if standards writer(s) expand existing documents to properly address human and organizational factors.

WHAT FORM SHOULD REQUIREMENTS TAKE?

There is a role for both guidelines and enforceable regulations. The task in the coming years will be to determine when each is appropriate. In developing regulations, MMS prefers to specify a performance level that the lessee must meet. The biggest deterrent to using performance standards has been the difficulty in specifying and measuring a required level of performance. In many cases, most "safe" operators use similar design for various pieces of safety equipment. Specifying features of that design in lieu of specifying an actual level of performance minimizes the changes that companies will need to make. Operators who wish to consider an alternate design are able to suggest an alternate design for MMS to review. While this approach has worked for regulating equipment, it may not work for human and organizational factors. Companies do not generally use a standard communication system in the same way that they might generally use a safety device in a certain situation.

Developing performance standards rather than prescriptive regulations will be important for requirements addressing human and organizational factors. But just as it is more important, it will also be more difficult. MMS and industry can specify a performance level for an engineering function far more easily than for a human or organizational factor. Commitment to safety and having the knowledge to perform a function properly are important to safety, but we cannot measure them as easily as we can a safety device's ability to withstand pressure.

WHAT SHOULD MMS BE DOING?

MMS has traditionally established regulations based on an indicated need. The offshore oil and gas industry is responsible for safety and protection of the environment. It is appropriate that each company individually (with the support of industry groups) take appropriate actions to develop and implement company plans and industry standards. MMS will continue to monitor offshore safety and industry activity in all areas including those related to human and organizational factors.

If MMS needs to develop regulations to address human and organizational factors, no one wants those regulations to be prescriptive. If MMS could accurately monitor offshore safety, it would be possible to make all regulations less prescriptive. This is desirable for all regulations but especially for those addressing human and organizational factors. MMS and industry will both benefit if they can develop measures of safety. MMS and industry should work together to develop measures of performance.

The final thing that MMS needs to do is to be prepared to act. MMS does not regulate unless needed, but if needed, they must. MMS's delegated responsibility under the Outer Continental Shelf Lands Act mandates that they establish regulations necessary to ensure safe operations.

WHAT CAN OTHER ORGANIZATIONS DO TO HELP?

Many companies already have SEMP plans in place. Industry groups are working on standards to address human and organizational factors. The question remains: Are the plans and standards working? When MMS and industry know that safety is assured, MMS will be able to move significantly away from current prescriptive requirements and toward performance based requirements. Industry can work with MMS to develop measures of performance.

HOW CAN MMS ENCOURAGE OTHERS TO USE HUMAN AND ORGANIZATIONAL STANDARDS, SPECIFICATIONS, AND GUIDELINES?

As MMS monitors the activity of industry, they are also an advocate for the use of human and organizational standards, specifications, and guidelines. MMS can be a catalyst for the development of standards. MMS-sponsored workshops (such as this one) provide an opportunity for representatives of the various areas to come together and exchange ideas. For example, in November 1994, MMS held a workshop to discuss an advance notice of proposed rulemaking on training of offshore workers; and, in December 1995, MMS held a workshop to discuss testing of offshore workers and a proposed rule for training offshore workers.

MMS is also active in the area of research. MMS and industry jointly sponsored research addressing management of human error in operations of offshore facilities. MMS and industry are continuing the joint sponsorship with a project addressing tasks and responses associated with managing a "kick" during drilling operations, crane operations, and service vessel activities.

WHAT ARE THE KEY ELEMENTS OF REQUIREMENTS ADDRESSING HUMAN AND ORGANIZATIONAL FACTORS AND WHAT TYPE OF INDIVIDUAL SHOULD DEVELOP THESE REQUIREMENTS?

Causes of accidents do not always fall neatly into a category of equipment failure or human error. Neither will solutions fall neatly into a category of equipment solutions or human and organizational factors. The most important element of requirements for human and organizational factors is the need to have the requirements integrated into the overall operating structure as well as into the overall safety and environmental protection of the operation. Safety plans addressing equipment cannot ignore human and organizational factors, and safety plans addressing human and organizational factors cannot ignore equipment. This will be true for mandatory or voluntary guidelines regardless of who develops the requirements.

The format or "table of contents" of requirements for human or organizational factors will vary depending on which entity prepares the requirements and how it chooses to integrate human and organizational factors into other facets of its program. Several existing guidelines for SEMP type plans provide examples of how requirements can be organized. For example, API RP 75, "Recommended Practices for Development of a Safety and Environmental Program for Outer Continental Shelf Operations and Facilities," addresses areas that apply to human and organizational factors as well as various other areas. A document such as API RP 75 may provide a means of integrating human and organizational factors with other important safety and environmental concerns. API RP 75 addresses:

o Safety and Environmental Information

o Hazard Analyses

o Management of Change

o Operating Procedures

o Safe Work Practices

o Training

o Quality Assurance

o Mechanical Integrity

o Pre-startup Review

o Emergency Response and Control

o Investigation of Accidents

o Selection of Contractors

API RP 75 may provide the appropriate vehicle for adopting requirements that address human and organizational factors. However, regardless of the format used, the four areas previously discussed need to be addressed in any requirements.

Establishing and Enforcing Company Policy and Practices

Under normal circumstances, when a worker is faced with a safety rule, he or she will follow the rule and still get the job done. Under unusual circumstances, e.g., when following a safety rule may cause a delay and prevent the employee from meeting an operational goal, what will the employee do? Everyone hopes he or she will follow the safety rule. It is this situation where the employee must really believe that safety comes first. The employee must know that management wants him or her to accept the possibility of not meeting an operational goal rather than placing an employee or the environment in danger. Organizations can have SEMP plans. In doing so, they must let the employees know that safety really does come first and management means it. Requirements might be company by company or a combination of industry-wide standards and company standards.

Training Requirements

MMS training requirements are directed at ensuring that offshore workers are able to perform their function. Since first issuing training requirements, MMS has continued to search for ways to improve the requirements. MMS is currently reviewing its role in regulation of training with the aim of making training rules more performance oriented. Question remains as to what the performance measure should be, how MMS can measure it, and whether it should be MMS or some other party that is measuring whether training is adequate.

Communications

Communication is an integral part of offshore operations but one for which requirements are difficult to establish. An example of requirements addressing communications is the MMS regulation at §250.52(b) that addresses the potentially dangerous task of welding, burning, or hot tapping. MMS requires that the lessee prepare and follow a welding, burning, and hot tapping plan. This example combines engineering requirements with communication requirements. When reviewing the welding, burning, and hot tapping plan, MMS will ensure that proper engineering safeguards are in place. A requirement that the welding supervisor be familiar with the plan addresses the communications issue.

Man-Machine Interface

Some accidents are caused by human error and some by equipment failure. It is not always an easy call. For example, if a sensor is not checked properly and subsequently fails when needed, is it an equipment failure or a human error? The failure to check the sensor did not cause it to fail, but if it had been checked, it could have been replaced and ultimately served its intended purpose. It is sometimes good to concentrate on the human and organizational factors. But, the man-machine interface makes it clear that we need to look at safety as a whole and cannot always separate the equipment side from the human and organizational side. Traditionally, standards, specifications, and guidelines have tried to address this area, but much work remains.

Other Areas for Further Improvements

Other areas may also be appropriate depending on who develops the requirements. Economic issues that may be key to a program within a company may be inappropriate for a document developed by a Government agency.

The qualifications of the standards writer(s) need to match the content. Since integration of equipment requirements with human and organizational requirements may be the key to a good document, integration of these qualities in the writer(s) may be equally important. We should not have the document written by an organizational expert who lacks an understanding of the needs of the equipment any more than we should have the document written by an equipment expert who lacks an understanding of human and organizational factors.

HOW CAN MMS AND INDUSTRY BEGIN THE PROCESS?

MMS and industry are not starting a new process. Regulations already exist. Industry has established some standards and guidelines. Many companies use SEMP. Some companies have developed and implemented their SEMP plans. Others have developed a plan and will implement the plan over a period of time. While existing programs such as SEMP are not directed solely at human and organizational factors, they are nevertheless in place and provide an infrastructure for human and organizational factors. Infusing human and organizational factors into existing programs also increases the likelihood that the human and organizational factors will be properly integrated into other aspects of offshore operations.

If we accept that the next steps need to build on what is in place, then individual companies, industry groups, standards-setting groups, MMS, other Government agencies, and other interested groups each need to establish their role in developing, implementing, and enforcing human and organizational factors. MMS and other Government agencies need to work together to avoid duplication. At the same time, each agency needs to be sure that it is meeting its mandate.

SUMMARY AND CONCLUSIONS

All parties must be careful not to lose sight of the goal. Everyone is here working together to develop ways in which industry can make better use of standards, specifications, and guidelines for human and organizational factors. Everyone must remember that human and organizational factors are a means, maybe an important one, but still only a means. The use of human and organizational factors is not the ultimate goal. Safety and protection of the environment is the goal. In reaching that goal, the best path might be an integrated approach. An integrated approach needs to concurrently address hardware requirements and human and organizational requirements. Just as some accidents don't fall completely into a category of human error or equipment failure, some solutions may not fall neatly into hardware solution or human and organizational factor solution.

The final point is to reemphasize the need to develop performance measures. The measures must be definable and measurable. Industry generally does a good job of safety and environmental protection. Without Federal or industry standards, companies would follow their own procedures, and accidents would probably be rare events. Requirements for offshore operations, whether they are MMS regulations or industry standards, are intended to prevent rare events. Waiting for an accident and then correcting the cause is not acceptable. Performance measures need to assess safety before accidents occur. The performance standard must assess safety of operations. Measuring compliance with a standard is not enough.

HUMAN FACTORS CONSIDERATIONS IN ANOTHER HAZARDOUS INDUSTRY: MINING

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Introduction

A worker is injured and the event is called an accident. Many times the event is attributed to human performance, and in the past, blame was often placed upon the worker. Today, we know that humans have limitations and "accidents" are bound to happen when these limitations are exceeded, no matter how hard a worker tries to be safe.

The role of human performance as a causal factor in injuries has been documented in many studies *(Sanders and Peay, 1988)*. Mining is no exception. Detailed analysis of mining accidents has shown that approximately 73% of all underground mining injuries have human performance as a causal factor *(Sanders and Shaw, 1988)*. Human factors strives to define human performance capabilities and to design the workplace so that these capabilities are not exceeded.

Research to reduce human factor-related injuries has been conducted by the former U.S. Bureau of Mines (USBM) and the U.S. Department of Energy (DOE) Pittsburgh Research Center (Health and safety functions of the U.S. Bureau of Mines were transferred to the U.S. Department of Energy on April 4, 1996.) since 1970. This research has addressed equipment design, accommodation of a difficult environment, training technology, and unsafe (risk-taking) behavior. Human factors is but one part of a broad-based federal government research program whose objective is to improve miners' health and safety.

This research, as well as much effort by the mining industry, labor, and government regulatory agencies, has resulted in significant gains in health and safety. The mining industry suffered 382 fatalities and 21,327 lost time injuries in 1969. This was improved to 98 fatalities and 13,700 lost time injuries in 1995 (see figure 1). Since 1969, the fatality rate for coal mining operations has declined from 0.84 fatalities per 200,000 employee-hours to 0.21, and the lost time injury rate has declined from 8.4 injuries per 200,000 employee-hours to 6.0. Likewise, the fatality rate for *non*coal mining operations has declined from 0.33 fatalities per 200,000 employee-hours to 0.14, and the lost time injury rate has declined from 4.2 injuries per 200,000 employee-hours to 2.2.

Human factors research has examined many aspects of how the miner fits into his/her physical and social environment, and much has been learned. Human factors principles have permeated various standards, as well as the design of equipment and work practices. This paper examines the recent history of human factors research and considerations in the mining industry and highlights some of the major changes.

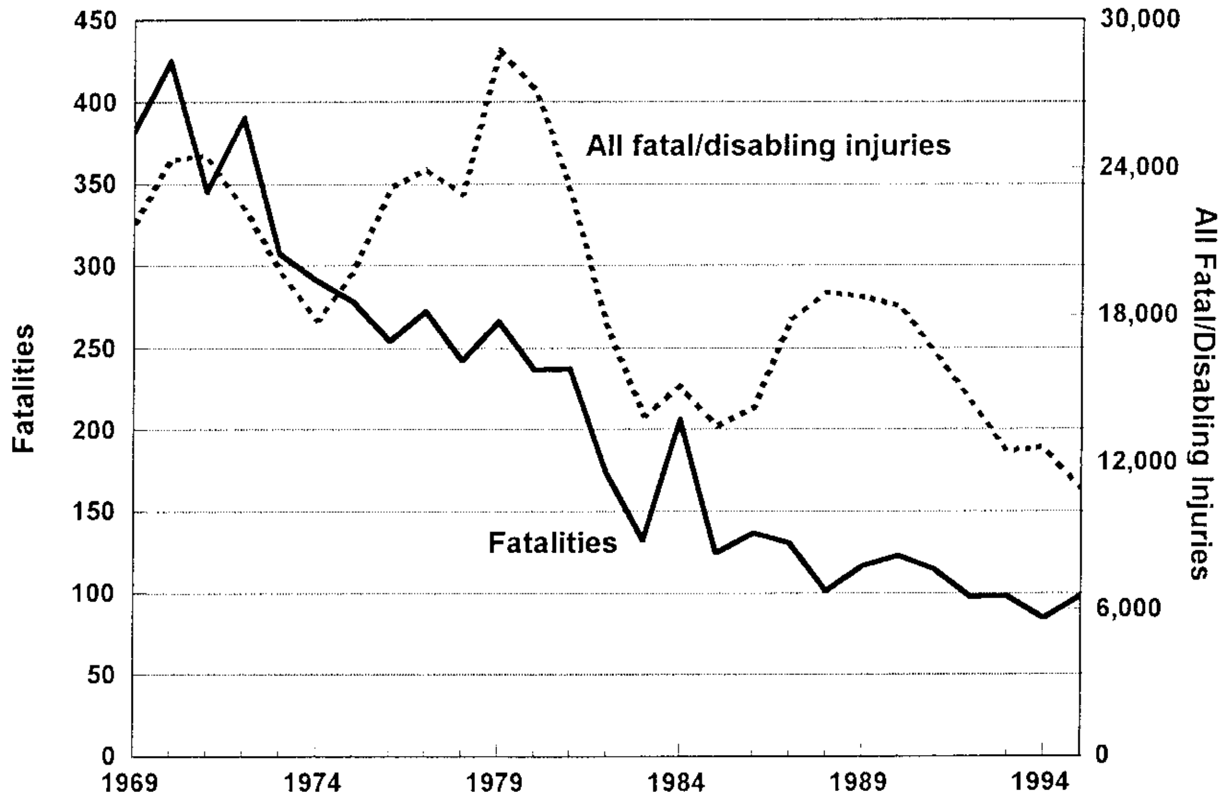

Figure 1. — Mining Fatalities and Lost Time Injuries

Human Factors and Mining

Unfortunately, the history of mining health and safety contains many stories of high injury rates and disasters. It was a number of mine disasters in 1968-69 that prompted the U.S. Congress to pass a sweeping health and safety act that imposed far-reaching regulation of coal mining and directed the USBM to undertake research to address a broad range of health and safety problems. Human factors became one of the major focuses of that program.

The mining industry is made up of enterprises that exploit widely varying mineral deposits. The physical form/shape of the deposit will often determine the characteristics of the workplace. For example, some coal mines are only 61 cm (24 inches) to 91 cm (36 inches) high. This illustrates one of the unique aspects of mining compared with other industrial settings.

The mining human factors research program began with a focus on underground bituminous coal mining and eventually expanded to investigate most other mining types. An initial study conducted for the USBM by the Naval Ammunition Depot, documented human factors problems in the underground bituminous coal mining industry *(Naval Ammunition Depot, 1971)* . This report identified research needs that formed the framework for future work in the following areas: (1) equipment design, (2) personal protective equipment, (3) illumination and vision, (4) communications, (5) personality and the mine social system, (6) noise and hearing, and (7) the mine operation (including training). Subsequent efforts examined surface coal, low-seam coal, and metal/nonmetal mining.

This early work found a mining industry that gave little attention to accommodating the miner. Equipment was often designed to meet the technical and engineering requirements of the intended task with little regard to operator comfort or ergonomic principles. For example, some vehicles were designed so that when the steering wheel was turned to the left, the car turned toward the right! The brake and accelerator pedals were often reversed from the stereotypical automobile layout. Training was usually on-the-job and unstructured. Materials handling was usually done manually with little attention given to the weight of the materials handled. Standard operating procedures were rare, if not totally absent.

How Important Is Human Factors?

Numerous studies had shown that human performance is a contributing factor in many accidents. However, the magnitude of this problem had never been established for mining until a study commissioned by the USBM *(Sanders and Shaw, 1988)*. Researchers collected details concerning 338 underground coal mining accidents and asked a panel of experts to quantify the causal factors in each accident. Figure 2 shows that approximately 73% of all accidents had human performance as a contributing factor. This study also served to highlight the fact that accidents rarely have a singular cause. The vast majority of accidents are the result of a string of events/conditions that interact to produce the undesirable event.

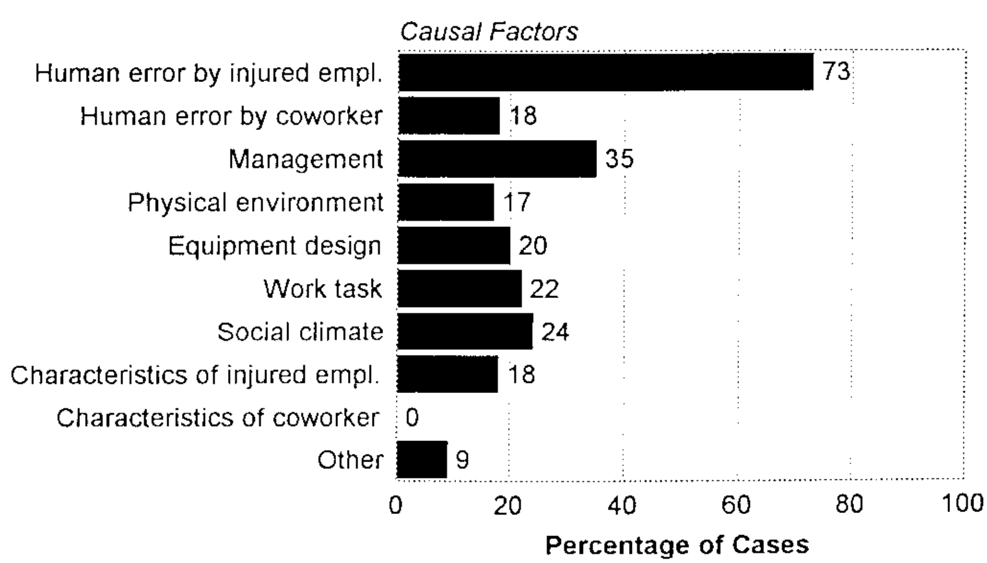

Figure 2. – Mining Accident Contributing Factors

The Impact of Human Factors in Mining

This workshop has identified Human and Organizational Factors (HOF) as encompassing person/machine design, personnel selection, environmental control, training requirements, job aides, and the role of the organization and management. Each of these issues will be addressed as it relates to progress made and lessons learned in the mining industry.

Person/Machine Design

Mining machines are built to accomplish demanding tasks, and it is often difficult to accommodate the needs of the operators. However, much progress has been realized. In underground mines, research has defined the operational requirements of canopy protection for those machines that operate in the most hazardous areas-- the point of extraction of product. It is in this newly created opening that the earth is least stable and unsupported, resulting in fall-of-rock injuries. Regulations now require that most of these machines be equipped with canopies, and hundreds of lives have been saved since their implementation. Similarly, in surface mines, regulations require that most mobile machines be equipped with rollover protection and seat belts.

Guidelines for control placement on major pieces of mining equipment have been developed, and the Society of Automotive Engineers *(Gilbert, 1990)* has accepted the work for review. No regulations specifically require standardized controls; however, ergonomic principles are routinely applied in the generation of related standards. Original equipment manufacturers (OEM's) are also independently incorporating such considerations and actively training their design engineers to do so.

An often overlooked equipment design issue is maintenance. In the past, mining machines were simple, rugged devices that were able to be maintained with little difficulty. However, as these machines grew in size and complexity, maintenance became more challenging. Maintenance activities account for over 30% of injuries in the mining industry. Guidelines have been published *(Conway and others, 1988)* that will result in machine designs that facilitate maintenance. Mining OEM's are voluntarily incorporating these principles in their new designs.

Personnel Selection

The mining work force is typically stable, with little turnover. Furthermore, personnel selection can be a difficult thing to do fairly. The approach taken was to define the capabilities of the population in typical mining tasks, then redesign the tasks (where possible) to accommodate the general population found in mining.

For example, approximately 40% of all injuries in underground coal mining are back injuries. Psychophysical and biomechanical research studies have defined safe limits of lift for stooped and kneeling postures. As a result of this work, many mines are now procuring their rock dust, which is used to prevent coal dust explosions in 42 pound bags rather than the standard of 60 pounds.

Environmental Control

Much of the mine environment is determined by the deposit being mined. Characteristics of the workplace, such as height, width, temperature, and humidity, are determined by the commodity being mined. Only in extreme situations is any attempt made to control temperature. In deep underground mines, rock temperatures can exceed 110^0 Fahrenheit. Three environmental variables, not typically considered as "human factors" in the mining community, have received much attention as significant research areas: illumination, respirable dust, and noise.

Miners typically rely on a helmet-mounted cap lamp for task illumination. However, the cap lamp beam is typically narrow and provides little peripheral illumination. This limited illumination can cause hazards to go unnoticed, especially in the congested extraction area of the mine. Research has established that .06 ft-lamberts are required to maintain photopic vision. Subsequent research produced illumination hardware that is explosion-proof and capable of surviving the harsh mining environment. Regulations have been in place that require this level of luminance in the extraction areas of coal mines. Other regulations address illumination in surface areas of underground mines and at surface mines.

Coal dust can contribute to explosions and pneumoconious (black lung). Silica dust can cause silicosis. Dust is a byproduct of breaking rock. Its adverse effects on health have been documented by the National Institute for Occupational Safety and Health and others. Exposure limits for coal dust (2 mg/m^3) and other contaminants have been set by regulation. Significant physical science research, outside of human factors, has developed dust controls for existing mining operations and continues to work on controls for future systems.

Mining requires large and powerful machines that typically produce high levels of noise. Currently an 8-hour exposure is limited to 90 dB. Control technology has been developed to enable most mining equipment to work within this limit. The use of hearing protectors has also been examined, and these devices are required when exposure limits are exceeded. Many mines have recently begun to operate on 12 hour shifts extending worker exposure.

Training Requirements

Training can be a powerful tool in bringing change to an industry. Research has addressed the required frequency of training, content, and better ways to train skilled adults.

Required skills may be viewed as both those needed in the worker's daily tasks and those required in nonroutine, emergency situations. USBM research has helped to determine the frequency that training is needed, developed some new training technology, and supported the promulgation of regulations requiring training for miners.

Federal regulations (30 CFR 48) require that underground mine operators provide 40 hours of new miner safety training and 8 hours of annual refresher training to all underground personnel. Unfortunately, several significant deficiencies have been identified concerning the methods and materials traditionally used to conduct mine safety training *(Adkins and others, 1976)*. Many of these are being overcome through the development of a new form of training known as interactive problem-solving stories based on authentic mine injury, fatality, or disaster reports and the problems and predicaments encountered in these real-life events.

The interactive problem-solving stories have been found to be very effective through field tests with 3,658 miners in 8 states. Compared with most previous forms of miner training, these exercises place greater emphasis on collaboration and active problem solving. Trainees must integrate their practical knowledge and experience with the mandatory safety and health content presented in miner training classes. To date, more than 500,000 copies of these exercises have been distributed by the Mine Safety and Health Administration's (MSHA) National Mine Health and Safety Academy, Beckley, WV. (MSHA's primary role is to see that mine safety and health regulations are being followed through inspections and enforcement activities. MSHA also distributes training materials and approves each mine operator's plans for conducting employee safety training. The Bureau of Mines' role has been to conduct research on mining health and safety problems and provide advice about how they can be solved.)

Job Aides

During the early 1990's, MSHA began to strongly encourage mine operators to conduct a job safety analysis (JSA) for each job performed at the mine site. JSA is a four-step operation: (1) select the job to be analyzed, (2) separate the job into its basic steps, (3) identify the hazards associated with each step, and (4) control each hazard. JSA's were promoted as a useful tool in task training, as well as a logical procedure for anticipating and eliminating hazards. Because changes in technology are common in mining, JSA's must be regularly updated. It is important to involve experienced workers in the JSA process because they are in the best position to thoroughly analyze jobs and identify all of the potential hazards. The National Mine Health and Safety Academy has prepared a series of On-The-Job Training Instruction Guides to cover most mining tasks. These guides can be used as a handy reference when starting to develop a JSA. An instruction guide and videotape demonstrating the JSA process are also available *(U.S. Dept. of Labor, 1990)*.

Organizational and Behavioral Strategies for Encouraging Self-Protective Employee Behavior
The effects of organizational structure and managerial practices on mine safety performance have been examined from a number of aspects *(Sanders and others, 1976; Fiedler and others, 1983; National Academy of Sciences, 1982; Gaertner and others, 1987; DeMichiei and others, 1982; and Peters, 1989)*. It is clear that the impact is large.

Perhaps one of the most significant findings is that there is a strong and direct correlation between safety and efficiency in mining *(National Academy of Sciences, 1982)*. That is, the safer a mine is, the more productive it is. The common thread is management practices. It had long been thought that safety came at the cost of productivity; this notion has been proven wrong. This understanding has given the mining industry a new incentive to implement appropriate management and safety practices, such as having top management overtly support safe work practices. Other important findings are various strategies to convince employees to avoid unsafe acts and/or adopt self-protective behaviors.

Techniques that have been used successfully at mining operations include: (1) incentives/feedback, (2) fear messages, and (3) employee participation.

Incentives have been found to be effective in improving employee compliance with safety rules in a rather large number of studies *(McAfee and Winn, 1989)*. However, there are some important limiting conditions to the types of settings in which this approach is effective *(Goodman, 1987)*. The use of safety incentives can arouse increased worker and company interest in job safety. However, incentive plans are no substitute for hazard control programs having well-established safety training, housekeeping, safety inspection, and reporting functions. Rather, the incentive approach is most effective when used to provide an added spur to an already well-designed hazard control program.

Fear messages are a commonly used strategy for encouraging self-protective behavior. Fear messages may emphasize threats to physical safety, emotional health, social functioning, financial well-being, or other risks. *Leventhal (1970)* argues that the most effective use of fear includes a threatening message followed by appropriate recommendations. Those who make use of fear messages hope that employees will perceive the recommended behavior as leading to a reduction of the threat and that they will begin following the recommended actions. Research shows that these messages often produce significant changes in attitudes and intentions to perform self-protective acts (or avoid unsafe acts) *(Sutton, 1982)*. However, only a small number of studies have shown that they have a long-term impact on behavior. All too often, training designed to increase employees' fear of a particular type of accident has, at best, only a short-term effect on behavior.

One should not rely solely on fear messages as a means of preventing employees from performing unsafe acts. It may be more advisable to use fear messages with new employees than those who have been employed for a time and have had a chance to form various unsafe work habits. It seems especially important that new employees fully appreciate the risks and severity of the potential consequences of following unsafe work practices. Once an unsafe habit has formed, it is difficult to break. Fear messages may be especially appropriate for employees at remote work sites because of the difficulty of monitoring employee compliance with safety rules via direct observation.

During the past decade, USBM researchers have videotaped a series of short interviews (10-15 minutes long) with miners who have either been victims or eyewitnesses to serious mining accidents, such as fires and roof collapses in underground coal mines. Along with each video, an instructor's guide was prepared containing questions that could be used to encourage discussion among trainees about why these tragedies happen and what needs to be done to ensure that similar disasters do not occur at their mine. These videos are available through the National Mine Health and Safety Academy *(Catalog of Training Products for the Mining Industry, 1996)*. They have been extremely well received by safety training professionals. Several thousand copies of these materials have been distributed.

There is virtually unanimous agreement among safety experts that employees should be frequently consulted for ideas about improving their safety and that they should be given a say in establishing new safety procedures and policies. A high level of employee participation in safety programs has the following positive effects: (1) more open and informal communication, (2) heightened employee awareness and interest in safety, (3) a perception that safety is an important management consideration, and (4) an expectation that management will be receptive to employees' inputs.

Two strategies for obtaining greater employee participation in safety issues at mining operations that appear to hold much promise are: (1) structured interviews, and (2) ergonomics committees. Structured interviews are a useful means of directly gathering information from employees about what motivates them to comply or fail to comply with safety rules and soliciting ideas about changes that would increase their willingness to comply. *Peters (1992)* conducted structured interviews with 297 underground coal miners to discover the reasons that people violate safety rules that lead to injuries and deaths from roof fall accidents. These miners made many valuable suggestions for redesigning equipment and work procedures so that the temptations to violate safety rules are eliminated or reduced. These recommendations are being communicated throughout the coal industry through publications and seminars. The number of deaths caused by roof collapses has been reduced from about 50 per year in the early 1980's to fewer than 10 in recent years.

Another form of employee participation that appears successful at mining companies is ergonomics committees. Ergonomics committees are usually composed of representatives of the various departments at a mining operation and include members of both labor and management. They meet regularly to generate new ideas for preventing accidents, then oversee their implementation and evaluation. American Electric Power, a large coal mining corporation began using this approach in the late 1980's to reduce the costs and incidence of back injuries among its underground coal miners. The program has been highly successful *(O'Green and others, 1992)*. Similar efforts are now underway at other mining companies.

Conclusion

Human factors, or for that matter any technology or practice, can be implemented via voluntary or regulatory means. Fines or other penalties can force quick adoption of work practices and technology. However, regulation can be a difficult tool to use for many reasons. An industry that is diverse can present so many variables that regulation is impractical. In some cases, regulations may conflict with one another, making compliance difficult or impractical. Political forces can also confound the regulatory process. In addition, multinational industries, such as mining and oil, may have no one to provide regulation.

Voluntary adoption of new technology or safety practices require that the end-users be aware of the knowledge or technology and then have an incentive to use it. Knowledge can be distributed in many ways: in trade journals, standards of consensus bodies, training, etc. The important thing is that the information is relevant to current needs. This requires that the safety performance of the industry be monitored to identify existing problems and emerging threats. Countermeasures can be then be developed to address specific items of concern. In some cases, this technique can be more certain and effective than regulatory action.

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A STRATEGY FOR MANAGEMENT OF HUMAN ERROR

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Abstract

This paper describes a strategy that originated in the commercial aviation industry to characterize and respond to human error. A systems approach to the application of the strategy consists of a number of specific interventions that are possible by management, the engineering staff and the offshore platform personnel.

Introduction

In the many process control industries such as petrochemical companies or in commercial aviation, human error challenges system safety and effectiveness. Beginning in the mid-1940s because of numerous aviation accidents and continuing until now, numerous investigators and federal and private agencies have spent considerable resources for human error research and problem resolution. The contribution of human error to system error has been quantified. The human error contribution to commercial airline accidents is 65 percent. It rises to 75 percent in business flying and for regional airline carriers; in general aviation accidents the figure is 95 percent. Air traffic control-related accidents show a rate greater than 95 percent.[2,3] Other industries and transportation systems also are thought to have high human error rates associated with system failures, faults, and accidents.[4,5] Human error is believed, but not measured, to be as much as 80-90 percent in petrochemical accidents and incidents.

Several different approaches are being employed to understand and predict human error, including development of human error databases, the use of human performance models, and systematic application of human factors analyses through control room design reviews[6,7,8,9,10]. An example of the oil industry concern for human error and human performance was notable in the January 1996 workshop, supported by the public and private sectors under the ageis of the National Academy of Science/National Research Council. Further, internationally known researches such as Jens Rasmussen[11,12], and others, have made notable contributions to our understanding of human error in the context of accident analysis. The methodology and decision processes seek to explain the course of events leading to an accident, allocates responsibility, and identifies system improvements to avoid similar events using data from risk analyses, specific simulator studies, and experiments.[13,14,15]

Given the wealth of human error research data, models, and methodology in the past decade, can we confidently approach the problem of the management of human error events? This paper examines a proposed set of strategies developed by the aviation community and proposed for the review of the oil industry.

Human Error

A few examples of the complexity of human error events illustrate the wide range of such errors, especially in complex sociotechnological systems.[16] These were typical problems of human error and the unanticipated consequences of technology, as seen in Figure I.

- Inappropriate responses to antagonistic environmental conditions, such as crowding and excessive clutter of information and personnel in institutional settings
- A change in the routine of work or the advent of a unique condition often predisposed error
- Corrective actions by management often were too narrow, so the fundamental error occurred again
- Cognitive errors of omission and commission precipitated by inadequate information and/or situational factors, such as stress, fatigue, or excessive workload
- Inadequacies or ambiguity in the design of a system or a device, procedures, or the institutional setting
- Inadequacies in the training of the person using the system or device; lack of systematic methods for mitigating an error once it occurred
- Lack of the "right" people at the "right" time.

Figure I. Human Error Causes

Human interaction interdependencies exist at all strategies of design, manufacturing, fabrication and assembly, and operation. Therefore, a strategy seems appropriate for the management of human error before it becomes a precursor event. The strategy is called "Intervention Strategy" by its developer, E. Wiener.[20] A distinction is made between interventions and error prevention methods. For example, application of traditional human factors principles, guidelines, and standards is an error prevention method. Interventions, on the other hand, are means to disallow or "manage" the error once it is made from seriously affecting system performance. This is why the management approach is called "intervention strategies."

Weiner proposes a set of guidelines for the design and evaluation of intervention strategy. He characterizes the guidelines as a template to which a design or operational proposal can be compared. For example, his first guideline in proposing an intervention strategy, one should ask *Is this intervention necessary? Is there a well-defined problem, or set of problems, that it can prevent or reduce?*

Weiner specifically identifies these guidelines as concepts directed toward the management of human error and the prevention of accidents and incidents. He does not discuss interventions designed to reduce injury or prevent death; for example, improvement in marking or increased cabin personnel training. He also excludes interventions aimed at executive management, such as scheduling. Figure II is a list of types of intervention strategies.

- Intervention through procedure
- Intervention through regulation
- Intervention through hardware
- Intervention through documentation
- Intervention through linguistic procedures
- Intervention through retrofit and design

Figure II. Intervention Strategies

The translation of these principles to analysis of precursor events requires a systems based approach. Answers to these questions and consideration of the system are the first step:

1. In proposing an intervention strategy, one should ask, "Is this intervention necessary? Is there a well-defined problem or set of problems that it can prevent or reduce?
2. Never implement an intervention or procedure that you feel the crews will not follow.
3. Politically inspired interventions should be resisted. Legislative bodies do not have the technical expertise to specify and evaluate safety interventions, and at the very least, their solutions may involve technically unfeasible deadlines.

4. Any intervention must be carefully examined to ensure that it does not interfere with other systems, diminish safety elsewhere, or create a problem for the crew or other personnel.

5. If the intervention strategy involves displays, the information should be easily interpretable.

6. Any design, hardware, or software should conform to accepted standards of human factors. The designer of the intervention strategy should be mindful of published design guidelines.

7. All interventions should be examined for any adverse effects on adjacent or interfacing systems.

8. Preferably the intervention strategy should be non-punitive. It should not place the personnel at an added risk of violation or other punitive action.

9. The intervention strategy should be economically feasible and otherwise acceptable to management (e.g., minimize contractual implications). It should likewise not impose a cost elsewhere in the overall system.

10. Whenever possible, the intervention strategy should be common to all models within the same company.

11. Examine each proposed intervention and ask if there is an easier, less invasive, or less costly way to accomplish the same thing.

12. Examine all paperwork associated with an intervention strategy. Does this paperwork actually aid the crew, or does it place unnecessary burdens on the crew? Can the responsibility be assigned elsewhere? If additional paperwork must be implemented, can its form be made more pilot-friendly? Can its design be improved?

13. The intervention strategy should be acceptable to operating personnel or other affected personnel.

14. Intervention strategies should not be at odds with other mandated items.

15. Above all, the intervention strategy should be effective. It must be demonstrated to achieve the safety gain for which it was designed.

Systems Approach

A first step is an information collection process having the following elements as seen in Figure 3:

- Collect first-hand reports of safety problems/incidents and related databases or analyses
- Extract and analyze safety-related data from reports
- Detect and identify trends and situations leading to actual or potential problems
- Develop and propose a draft Intervention Strategy

Figure III. Process

Next, a set of issues potentially related to the above Process allows a taxonomy matrix to be used.[14] Such issues are provided in Figure IV.

The "team" analysts is, by necessity, a multidisciplinary team of operating engineers and technicians, human factors specialists, systems engineers, and risk analysts. Experience has shown all too often that the development of a team approach rests on the understanding by the members to the methods and assumptions of each other. Interdisciplinary communication and dialogue grows out of awareness of different methods of research and respect for their underlying assumptions. The empirical, variable-centered approach of the psychologist must meld with the data-driven, analytical approach of the engineer.[14,18] All are needed to perform the human error analysis and application of the Intervention Strategy.

There is a relationship that is present intrinsically in the process between root causes and the potential for human error. Application of Intervention Strategies must be sensitive to this subtle relationship and precursor events can be a major indication of this relationship. Root causes may reside in the technical design of the process system, in the operations of the system, in management practices and policies, and in human actions at all stages of the process.

Rouse,[14] among others, notes that the adaptability of humans to the demands of complex systems is the norm. Intervention Strategy implicitly recognizes that the precipitating conditions, precursors, and ways in which humans adopt to the demands of the system. For this reason, the quantification of human error is constrained.

- Consensus regarding what prior human error methods, data, and analytical approaches can be used for this analysis
- Plan or system context for the analysis
- Crew variables
- Individual differences
- Organization variables, such as culture, management attitudes, and standard operating procedures
- Cognitive and gross task analyses data
- Validity concerns
- Explicit treatment of Performance Shaping Factors such as External, Stressor, and Internal PSFs
- System boundaries

Figure IV. System Issues

Conclusion

The problem of human error in critical processing systems is recognized, but not well understood; hence, this Workshop.

Among other considerations concerning human error countermeasures, there is the most important one of strategic planning. This must be followed by development and proof-testing of an industry strategy that deals with human error countermeasures. A management strategy is the first of several steps. Nevertheless, it should be a starting point by the individual off-shore oil managers.

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HUMAN FACTORS IN PROCESS SAFETY AND RISK MANAGEMENT: NEEDS FOR MODELS, TOOLS AND TECHNIQUES

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DECEMBER, 1996

ABSTRACT

This paper reviews the need to perform human factors studies for onshore and offshore processes. A general assessment is provided of the current state of development of the human factors discipline and the extent to which it is currently meeting the needs of the process industries.

Scant attention has been paid to human factors by the process industries and the reasons for this are discussed. Areas within human factors are identified where we believe more work is needed to facilitate the consideration of this subject by the process industries. We provide a new conceptual model that can be used as a framework for identifying important human factors considerations in processes and we advocate an approach that we recommend both to satisfy current regulatory requirements and to provide a reasonable assessment of human factors considerations for processes.

1. INTRODUCTION

Recent government regulations and industry recommended practices have focused interest in the process industries on human factors. Pertinent regulations and recommended practices are:

- The Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) standard, CFR 1910.119
- The Environmental Protection Administration's (EPA) Risk Management Plan (RMP) rule, 40 CFR Part 68
- The American Petroleum Institute's (API) Safety Environmental Management Program (SEMP), RP75

These regulations and recommended practices cover both onshore and offshore facilities. Covered facilities generally process, handle or store materials that pose risks of toxic releases, fires or explosions.

These regulations and recommended practices require human factors be considered as part of conducting a process hazards analysis (PHA) for covered facilities. However, no explanation is provided of what is meant by human factors. OSHA, EPA and the Minerals Management Service (MMS) have provided some clarifying comments but have not yet provided any definitive guidance on what should be done. This is because the regulations and recommended practices are performance-based and there is a lack of understanding in the process industries on what constitutes human factors or how the subject should be handled.

Historically, the field of human factors has developed in somewhat separate areas. First, the discipline of human factors engineering has evolved and its principles have been applied in several industries such as automobiles, but with the notable exception of the process industries. There are many texts on this subject and they are typified by the classic work of Sanders and McCormick (1). Second, a number of workers have focused on theoretical considerations of human error and the human cognition process. These are typified by such researchers as Rasmussen (2,3) and Reason (4). A third group of workers has focused on the formal consideration of human errors in risk analyses using human reliability analysis. Much of this work has been performed in the nuclear industry and is typified by the work of Swain (5). Kirwan has provided a more recent description of work in this field (6). A fourth perspective has been provided by Kletz who advocates a pragmatic engineer's view for considering human error in safety studies (7). More recently behavior-based approaches to improving safety have been advocated by such authors as Krause (8) and McSween (9). The Center for Chemical Process Safety has also published a book that attempts to summarize much of what is known about preventing human error in the process industries under the authorship of Embrey (10).

Given the amount of work that has been performed and published in the area of human factors it is pertinent to inquire why the subject has received such scant attention in the process industries. We believe there are various reasons:

- Lack of awareness. The process industries is heavily focused on hardware. Most process engineers see equipment when they think of a process and do not see the people who are an integral part of designing, building, operating or maintaining the equipment.

- Lack of understanding. To the uninitiated the field of human factors appears confusing and poorly structured with apparently no definitive analysis approach that can be followed. There is no conceptual model that process engineers can use as a frame of reference to understand how human factors applies to their processes. It is difficult for process engineers to know where to start, or, for that matter, when they are done.

- Lack of need. Most engineers in the process industries are unaware of the benefits that can be obtained by attention to human factors in their processes.

- Misunderstanding of human factors. Process engineers and managers may feel threatened at the prospect of a human factors study. They may feel their job performance or personality is to be evaluated. Managers may feel that their effectiveness will be judged.

- Fear of the effort involved. Few in the process industries relish the thought of more studies that must be performed in order to operate their processes. The work force is already stretched thin after re-engineering and downsizing and few people are available to handle this work.

- Fear of opening Pandora's box. Many companies in the process industries have performed PHAs over the past few years that have resulted in many recommendations for process improvements that companies are now often obligated to implement with their associated costs. There is a fear that human factors studies may have the same result.

- Lack of integration. Various approaches to treating human factors are available but little work has been done on their integration. Human error analysts, human factors specialists, and behavioral scientists usually work independently.

- Lack of approaches to remediation of some human factors issues. When problems are identified with displays and controls, corrective actions can usually be devised without difficulty. However, when organizational or socio-technical problems arise their solution is often less obvious.

- Lack of qualified analysts. There are few practitioners who combine the required knowledge of human factors engineering, human error analysis, process engineering, safety and risk analysis and who have the requisite personal skills to work with process engineers and operators to perform these studies. Few companies have such individuals on staff.

- Lack of motivation. Until the advent of process safety and risk management regulations in the early 1990's, there was no need to consider human factors.

Given these issues, we may inquire as to the prospects for human factors studies in the process industries. Companies certainly are now motivated by regulations to do something and there is a developing awareness that this is indeed an important topic. However, many companies are still trying to decide what to do.

2. HUMAN FACTORS NEEDS OF THE PROCESS INDUSTRIES

In order for human factors studies to become a way of life for the process industries we believe various tools and information are needed including:

- A better understanding of the benefits of human factors studies. This can best come from publicizing case studies where the benefits are apparent, especially with regard to the investment required

- A simple classification of the types of human factors studies that can be performed.

- A conceptual model that defines the scope of human factors for processes and that facilitates understanding of the role of human factors in the process industries

- A classification of human errors that is both theoretically sound and practical for use in identifying human errors

- A compilation of human factors design guidelines

- Specific guidance on how process engineers can perform simple but meaningful human factors and human error studies that meet regulatory requirements

Other actions will also be needed but if the above items are provided we believe significant progress will be possible in the adoption of human factors studies by the process industries. Each of these issues is now addressed in the remaining sections of this paper.

3. THE NEED FOR AND BENEFITS OF HUMAN FACTORS STUDIES

People are key components of processes. They are involved in process design, operation, maintenance, etc. No step in the process life cycle is without some human involvement. Based on human nature, human error is a given and will arise in all parts of the process life cycle. Also, processes are generally not well-protected from human errors since many safeguards are focused on equipment failure. Consequently, it is likely that human error will be an important contributor to risk for most processes. This is evidenced by the number of major accidents that have been attributed to this cause including such well-known accidents as Piper Alpha, Feyzin and Flixborough.

It is generally believed that 50 - 90% of industrial incidents can be attributed to human error. Consequently, if human errors are not considered in process safety and risk studies, then at most only about half the risk is likely to be analyzed and perhaps as little as 10%.

Most processes have been designed with little, if any, consideration given to human factors. Consequently, many obvious changes are often identified in human factors studies to improve the process. Frequently, these changes are inexpensive. In today's competitive world, this source of relatively low cost process improvements should not be ignored.

While regulatory considerations are causing a number of companies to focus attention on human factors in their processes, there is a variety of other reasons that justify their consideration. Improving the human factors design of a process can produce not only improvements in safety and health but also gains in quality, productivity and employee job satisfaction.

A few process companies have begun to perform human factors studies for their processes with positive results. As word spreads and other companies become familiar with the benefits of human factors studies then we will see more of this work performed. Thus there is a real need for these early studies to be well publicized.

4. TYPES OF HUMAN FACTORS STUDIES

The term human factors is now used with a variety of meanings. Historically, it has meant the study of the human-machine interface. More recently, it is being used in a broader sense. Ideally human factors considerations should be incorporated in the design of a process by the design engineers. However, at the present time this is rarely done in the process industries. The greatest present need is for tools that can be used to assess existing processes and develop recommendations for changes in their human factors design that will improve the process. We believe it is convenient to consider three types of studies that relate to human factors:

- Human error analysis
  - the systematic identification and evaluation of the possible errors that may be made by operators, maintenance engineers, technicians, and other personnel in the plant
- Human factors engineering
  - the analysis of the interface of people with the process and its impact on system operation
- Human reliability analysis
  - the assessment of the impact of humans on the reliability of process plants

For each of these general types of studies there are several specific technical approaches available.

For example, for human error analysis the following approaches can be used:

- Checklists
  - review of a facility to identify possible human errors using a prepared checklist. This may be accomplished during the performance of a PHA
- Task safety analysis
  - a formal analysis of actions performed by people to identify potential for problems
- Task error analysis
  - a formal analysis of the steps performed to accomplish a task and the identification and analysis of possible errors and their probabilities

For human factors engineering the following approaches can be used:

- Human factors engineering review
  - use of a prepared checklist to evaluate a proposed design or an existing facility
- Human factors engineering evaluation
  - detailed review of a proposed design or an on-site inspection and review of an existing facility by human factors specialists

Human reliability analysis usually involves task analysis plus quantification using event and fault trees. Various approaches are available (6, 10).

5. MODEL OF HUMAN FACTORS IN PROCESSES

Many process engineers are confused by human factors because textbooks on the subject rarely explain how topics such as displays and controls, workplace design, environmental conditions, etc. arise as important issues and result in the consideration of all relevant human factors issues. What is needed is a process model that allows the complete scope of human factors issues to be defined and understood.

Classically, human factors often deals with the man-machine interface (Figure 1). While this model captures many important human factors a more complete model is required to capture all those of importance in processes. We must fully analyze the person-process interface and its impact on system operation. Consequently, in order to model human factors in processes we must define completely the person-process interface. This requires that we define a person and a process in terms meaningful for performing human factors studies. Humans can be defined by their attributes (Figure 2 and Table 1). Processes or facilities may be defined by their components (Figure 3).

The issues that need to be explored in a human factors study of a process may then be identified by examining how humans with their attributes interact with facility components and their attributes. This provides both a framework for organizing human factors issues as well as a practical model for identifying and analyzing human factors issues.

The model of a facility shows that people in the facility interact with one another as well as with the facility hardware (equipment and computers) and software (written and unwritten procedures and rules as well as computer software). These interactions occur in the accomplishment of various jobs and tasks by the people. They may be operators, maintenance engineers, etc. The jobs and tasks are performed in a particular workplace and each workplace has an environment associated with it. This all occurs within the organizational structure set up to run the process. These components of the facility may interact with one another individually or in combination to accomplish the purpose of the process. A matrix model can be envisioned to represent these interactions of facility components (Figure 4). Only two dimensions have been shown in the figure but additional dimensions can easily be envisioned in order to capture higher-order interactions. While this model is capable of representing the entire operation of the facility we are interested in the human factors issues so we must focus on interactions of people with the rest of the facility components. Thus, in order to define the scope of the human factors issues that need to be considered we consider first two-way interactions of people in the process with other process components such as:

people with other people

people with equipment

people with computers

people with procedures

people with tasks

people with the workplace

people with the environment

people with the organization

Higher-order interactions may also be important. For example, multiple people working on one piece of equipment or a person working on a specific task in a particular environment.

All people involved with the process should be considered (Table 2). This procedure allows us to identify numerous human factors issues by investigating the match of the attributes of the people with the attributes of the process components.
This model is important for several reasons. It provides:

- a theoretical framework for organizing human factors issues

- the means to completely define all human factors issues for a process

- a way to prepare detailed checklists of questions on human factors issues for use in conducting human factors studies (see example in Table 3)

6. CLASSIFICATION OF HUMAN ERRORS

Human error classifications facilitate the identification and analysis of human errors. In order to classify human error it must first be defined. A human error is any human action that exceeds some limit of acceptability or performance for a process or system in which the human is a component. It is an out-of-tolerance action such as an operator closing the wrong valve. The limits of performance are defined by requirements for successful operation of the system or process.

Alternatively, by analogy with hardware reliability, the probability of human error can be defined as the likelihood that a human fails to provide a required system function when called upon to do so, within a required time period. For example, an operator may not stop a pump within the time period specified in the procedures when a specific alarm condition arises.

The identification of errors requires an understanding of the range of error types and their causes/mechanisms (Figure 5). A knowledge of error mechanisms and causes is needed in order to decide how errors can be prevented or minimized. It is impossible to predict every possible, potentially negative, human impact on a process since there are many ways in which people can interact with processes and an infinite variety of possible human responses. Human error studies are best seen as ways of locating vulnerabilities of processes to human errors or performance problems.

There are various ways of classifying human errors. The simplest is classification by mode or action:

- Omission error - action is not performed
- Commission error - action is performed incorrectly
- Extraneous act - non-required action is performed instead of or in addition to required act

There is a variety of commission errors that are possible (Table 4).

This classification does not address the <u>cause</u> or <u>mechanism</u> of the error. While human error studies often deal with modes, a consideration of mechanism can provide guidance on suitable corrective action. A mechanistic classification is possible by combining Rasmussen's skill, rule, and knowledge-based model with more recent phenomenological work on human error (Figure 6). These error mechanisms are defined below.

Slips - errors in skill-based actions (require virtually no conscious thought). The intention is correct but a failure occurs when carrying out the required action, e.g. operator fails to close valve due to spatial confusion with another valve.

Mistakes due to failure of expertise - errors in rule-based information processing. The intention is incorrect, e.g. operator assumes reactor is OK based on one temperature indication that proves faulty.

Mistakes due to lack of expertise - errors in knowledge-based information processing. (requires conscious thought). The intention is incorrect, e.g. the operator fails to diagnose causes of a severe process abnormality under time-pressure.

Violations - deliberate acts that are prohibited or different from those prescribed and carried out intentionally.

Sociotechnical errors - originate in biases or behavior patterns of people. They are often related to problem-solving, emergency and team situations, e.g. decreased willingness to take decisions in the face of an emergency.

Management and organizational errors - errors attributable to decisions and actions (or inactions) by managers. They depend on the culture of the organization, e.g. unwillingness to communicate required performance goals.

Sociotechnical and management/organizational errors have been recognized relatively recently. Undoubtedly, more work is needed to fully define them and to develop ways in which their potential can be identified.

These classifications of human error are used when human error studies are performed, for example, using the Task Error Analysis technique described below.

7. HUMAN FACTORS DESIGN GUIDELINES

Human factors issues have been largely ignored in the design of process facilities yet this is the best time to apply human factors principles. This lack of application in design is due in part to a lack of awareness of the discipline of human factors but is also due to the lack of a complete set of human factors design guidelines and procedures for process facilities. While there are human factors handbooks available and some design guidelines exist, they are not well known in the process industries nor do we have a complete set. This is an area where effort to compile a handbook for the process industries would be well worthwhile.

8. RECOMMENDED APPROACHES FOR HUMAN FACTORS STUDIES

We believe that process safety and risk studies of human factors should cover:

- the consideration of human errors of all types as causes of accidents and process upsets
- the impact of all aspects of the design of a process on human error rates

This will enable recommendations to be developed for improvements in the human factors design of processes in order to improve safety and reduce risk. We also believe studies that address these two items will meet the requirements of regulators.

Some regulators have implied that both these aspects of human factors can be treated within a process hazards analysis. However, we believe a preferred approach is to perform a separate human factors study and follow it with the consideration of human errors in a PHA (Figure 7). This allows the human factors that influence human error rates to be better understood and the risks posed by human errors to be better managed. It can also be useful to perform a separate human error study prior to the PHA (Figure 7). This can be important when human errors are believed to be particularly important for a process or when there is high human involvement with a process.

A useful approach to performing an initial human factors review of an existing process is to perform a human factors engineering review (HFER). An HFER involves the use of a prepared checklist to evaluate a proposed design or an existing facility. This can usually be accomplished by a small team of analysts or even a single individual. A worksheet format is usually employed to guide the analysis and record the results (Figure 8). Typically a facility is divided into separate systems and all the relevant checklist questions applied to each system.
If a separate human error analysis is to be performed we recommend the use of task error analysis (TEA). This technique is used to identify the human elements in tasks and the potential for human error. It is a combination of task analysis and human error analysis.

Various forms of task analysis exist but we are using the term here to mean the detailed definition of the actions required of humans in the process, such as operators. Human error analysis is used to identify the types of errors that may be associated with the actions required of humans in a process. Often this includes the identification of any performance influencing factors and possible error causes.

A task is an activity that the operator sees as a separate, complete activity, e.g., transferring material from storage to a hold tank. Task error analysis involves breaking down each task into steps and individual units of behavior, e.g., set valves in transfer lines is a step; open valve A is a unit of behavior. This breakdown is normally accomplished by tabulating information about each specific human action in a worksheet (Figure 9). Specific potential errors are identified for each unit of behavior, e.g., "open valve A" may have errors of omission (valve A not opened) or commission (wrong valve opened). This is where the classification of error types by mode is used. As is seen in the example, there may be multiple possible errors for each unit of action.

There may be factors that influence human performance such as adverse environmental conditions. A checklist is usually employed to assist in their identification and they are entered in the TEA worksheet. Underlying causes of errors are optionally identified. This can assist in formulating recommendations to reduce the error likelihood or eliminate its possibility.

TEA worksheets often provide additional information beyond the simple example given in Figure 9. For example, columns may appear identifying equipment involved in the action, the location where the action is performed, numerical probabilities of individual errors, the means by which error may be detected, the consequences of errors, etc.

When these initial studies of human factors and human errors have been performed it is much easier to address these items in a PHA. We view the initial HFER as a very important precursor to PHA since human factors can be difficult to handle within a PHA. The initial TEA is desirable but not always necessary. Human errors can usually be treated adequately within a PHA. Techniques for treating human errors and human factors in a PHA have been described elsewhere (12).

9. CONCLUSIONS

Regulatory requirements for the consideration of human factors in process safety and risk management are motivating companies to address this subject and the importance of considering human factors in the process life cycle is beginning to be recognized by the process industries, both onshore and offshore. However, a number of issues must be addressed for the consideration of human factors to become standard. In particular, human factors needs to be more widely understood and tools need to be provided so that studies can be performed more routinely.

An opportunity exists for companies to explore the many benefits afforded by human factors studies of their processes. In particular, since this subject has been neglected for a long time, numerous opportunities exist for process improvements.

Figure 1. CLASSICAL MODEL OF MAN-MACHINE INTERFACE

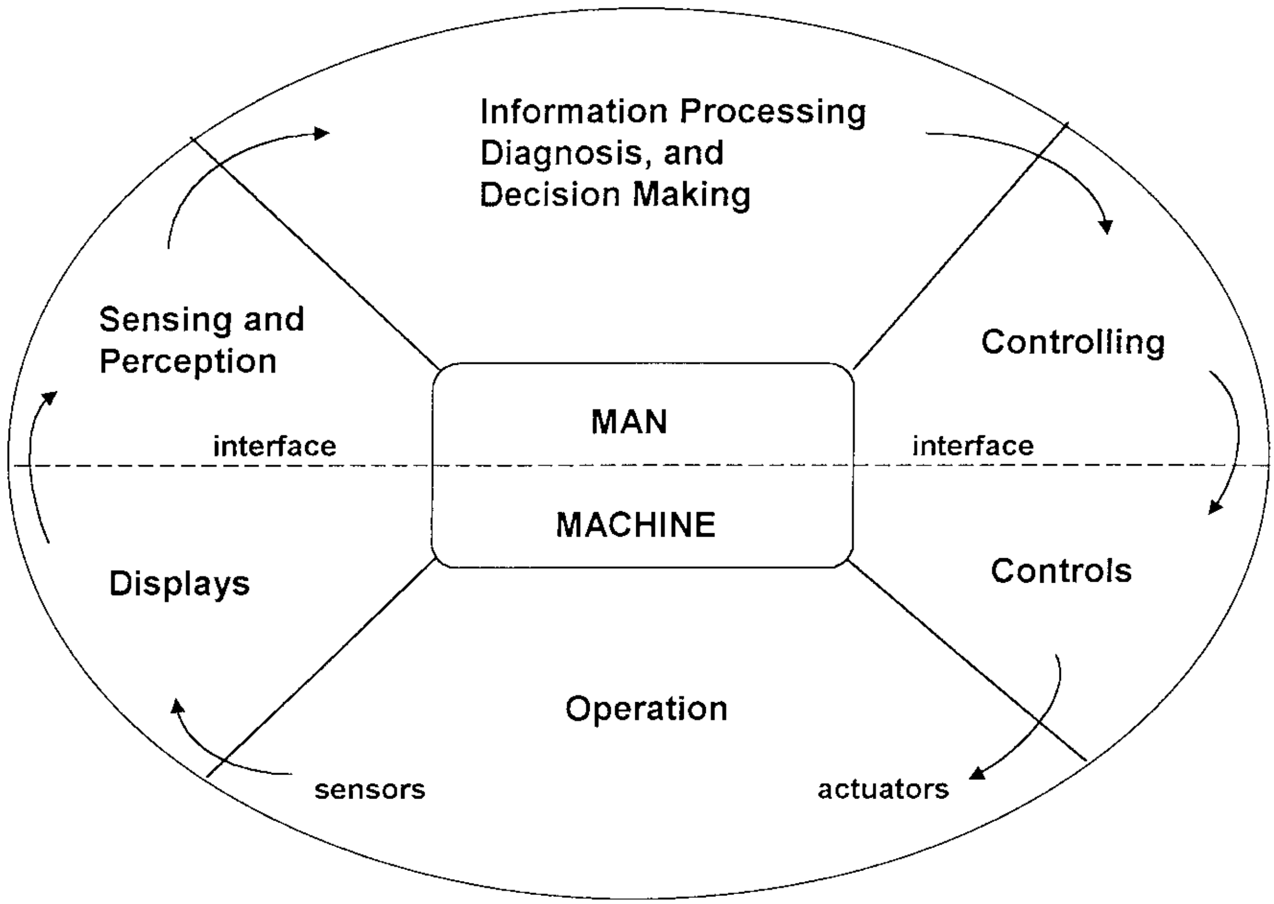

FIGURE 2. MODEL OF A HUMAN

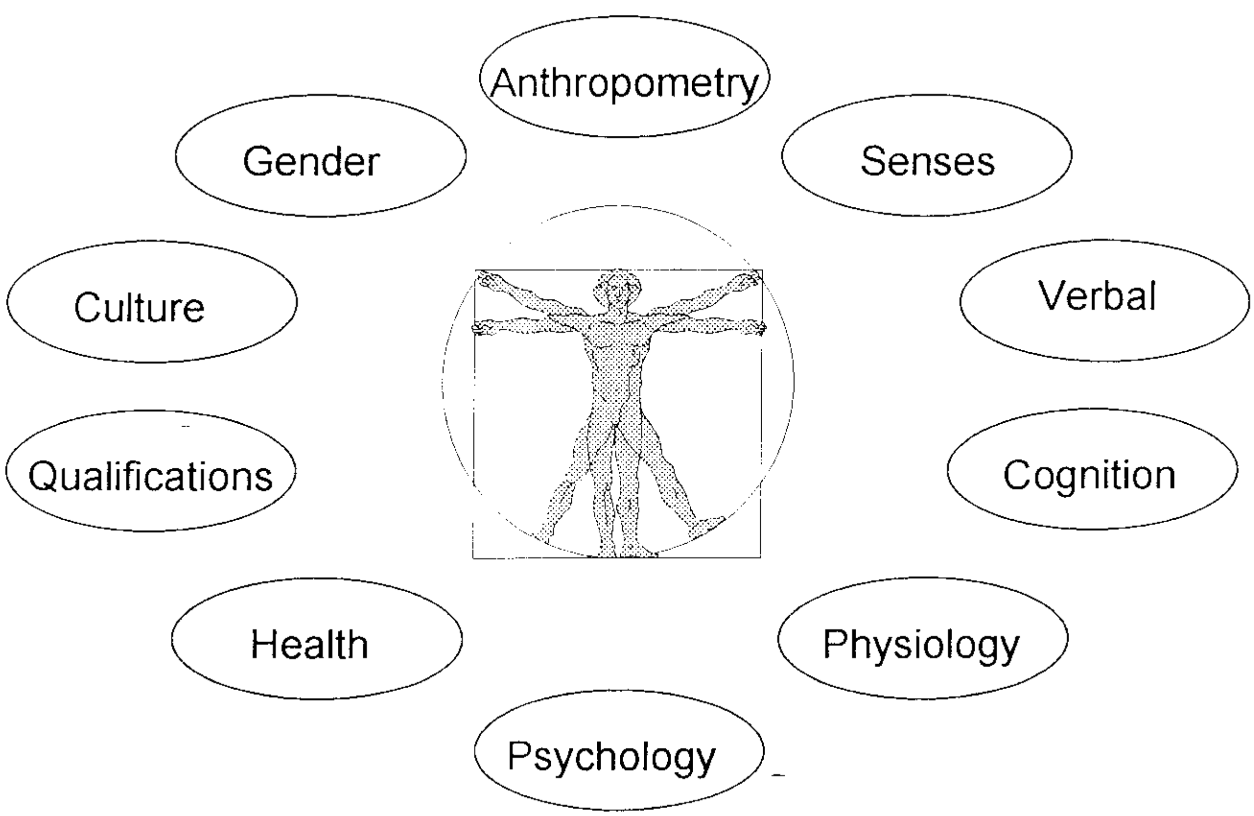

FIGURE 3. MODEL OF A FACILITY

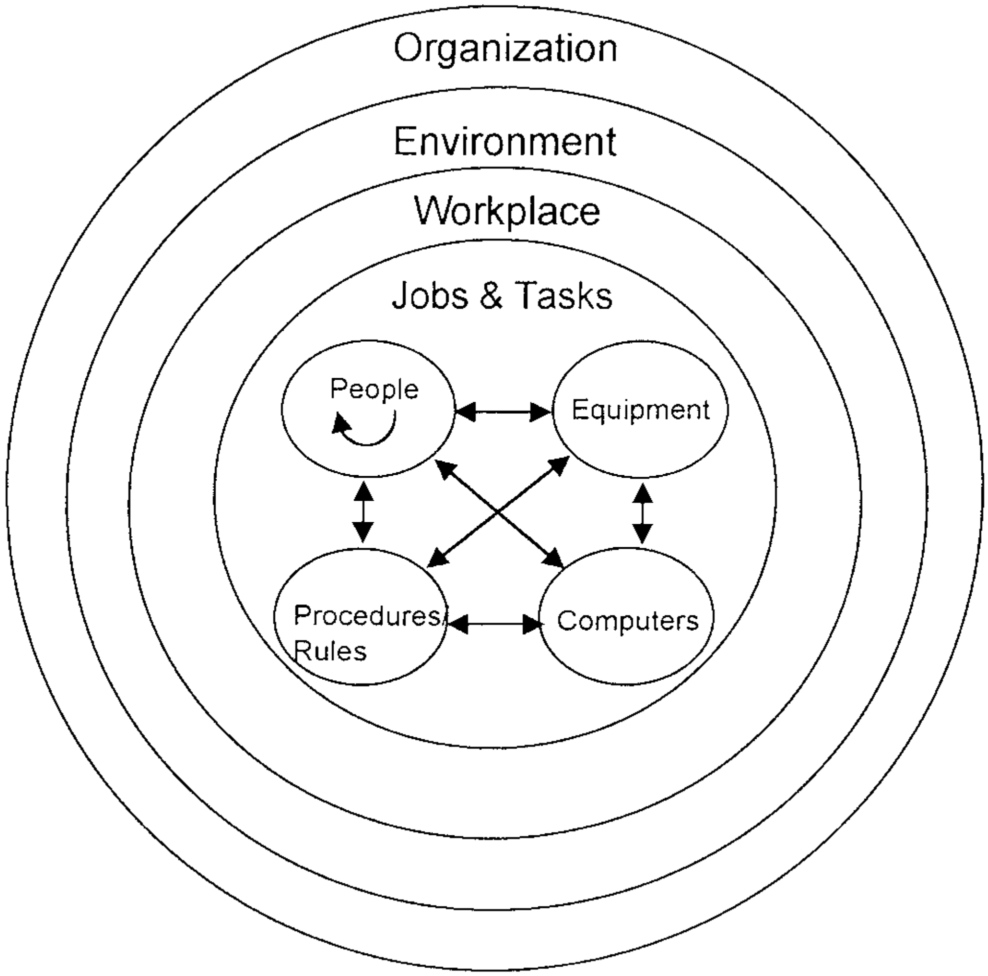

FIGURE 4. MATRIX MODEL OF PROCESS

	People	Equipment	Procedures	Computers	Jobs/Tasks	Etc.
People						
Equipment						
Procedures		Process	Interactions			
Computers						
Jobs/Tasks						
Etc.						

FIGURE 5. MODEL OF HUMAN ERROR

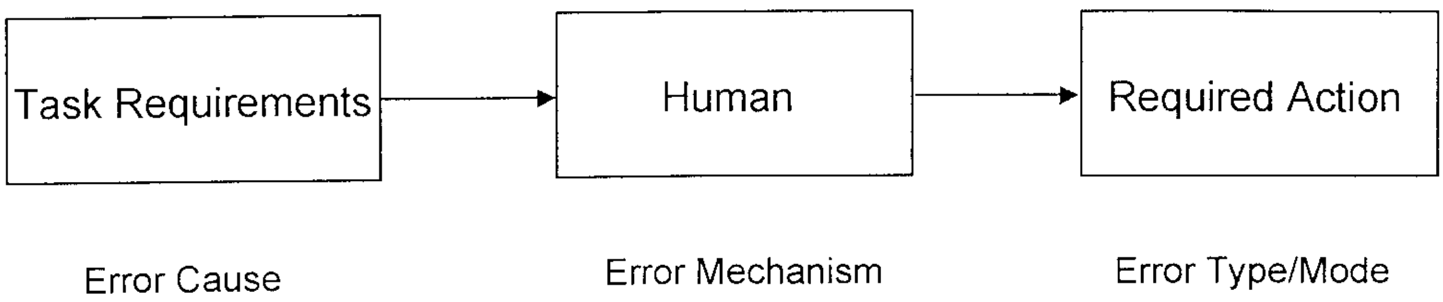

FIGURE 6. MECHANISTIC CLASSIFICATION OF HUMAN ERRORS

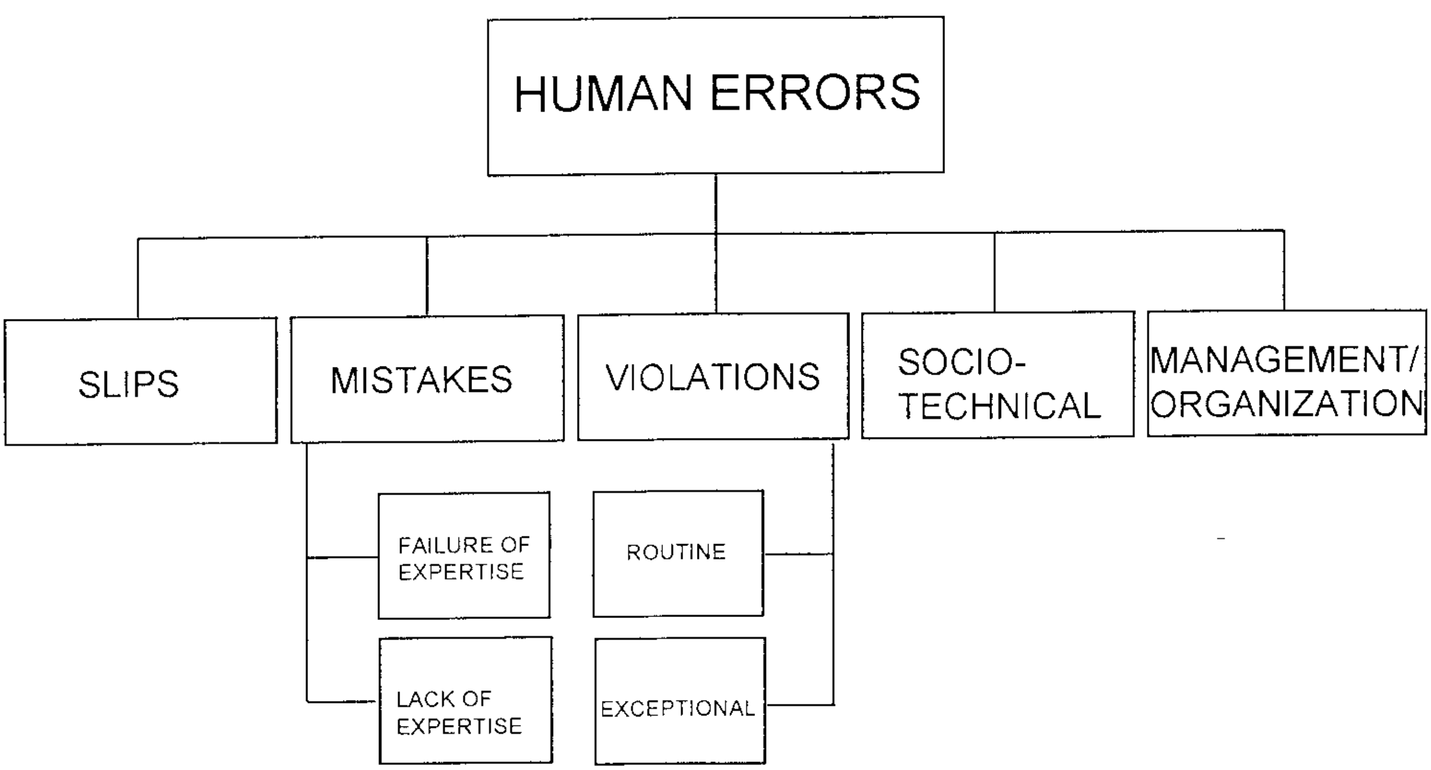

FIGURE 7. APPROACH FOR TREATING HUMAN FACTORS IN PROCESS SAFETY MANAGEMENT

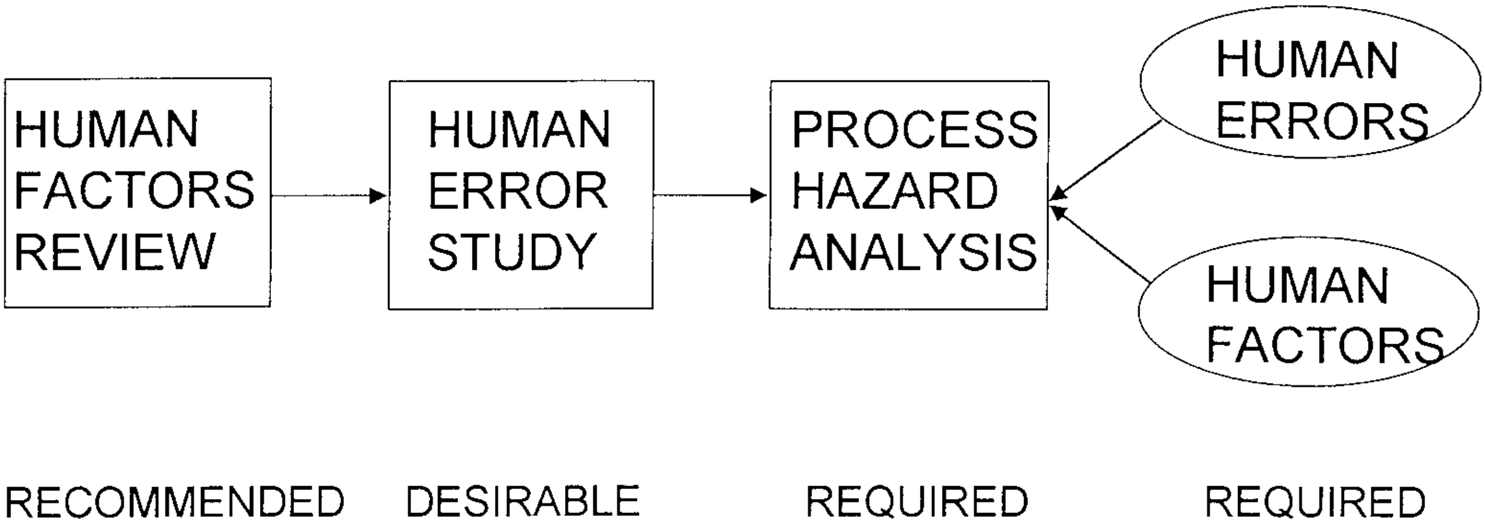

FIGURE 8. A HUMAN FACTORS ENGINEERING REVIEW WORKSHEET

HUMAN FACTORS ENGINEERING REVIEW

Facility: Bulk Chemicals Plant
Analyst: John Major   Date: 1/23/95
System: Chlorination Reactor   Category: Controls

QUESTION	A	REMARKS	RECOMMENDATIONS	BY
1. Are all required controls readily accessible?	N	1. ESD is located away from reactor operator's normal work area.	1. Relocate ESD to location adjacent to reactor building exit	ENG
2. Are non-authorized personnel prevented from changing set points?	Y	2. Password is required for change of set points in DCS		
3. Are controls grouped so as not to be confusing?	Y			
4. Are there enough controls available to adequately place the plant in a safe and stable state in the case of an emergency?	I	3. Control room air supply is not isolable from that of the reactor building	2. Relocate air intakes for control room	ENG

\=menu   F6=zoom   F8=functions   F10=pop-up

FIGURE 9. A TASK ERROR ANALYSIS WORKSHEET

TEA WORKSHEET

FACILITY: Resin Production Plant

ANALYST: John Smith | DATE: 1/14/92

TASK: Pump Solvent

STEP: Reset System

UNIT	PIF's	ERRORS	CAUSES	RECOMMENDATIONS	BY
1. Reset blender valve	Hot environment	1.1 Omission 1.2 Selection 1.3 Incomplete		Consider labeling valves	SAF
2. Close pipeline valve on vessel bank	None	2.1 Omission 2.2 Selection		Consider providing indication that valve is closed.	ENG
3. Ensure all pipeline valves are closed	Requires use of PPE	3.1 Incomplete		Consider upgrading training program	TRN
4. Disconnect hose from vessel bank	High noise	4.1 Omission		None Identified	
5. Place hose in drain	Distractions	5.1 Omission		Consider requiring use of a checklist	OPNS
6. Disconnect hose from pump	None	6.1 Selection		None Identified	

TABLE 1. IMPORTANT ATTRIBUTES OF PEOPLE

- Anthropometry
  - Height
  - Weight
  - Reach
  - Hand size

- Senses
  - Vision
  - Color-blindness
  - Hearing
  - Kinesthetics

- Verbal skills

- Cognition
  - Attention
  - Decision making
  - Diagnosis
  - Information processing
    - Quality
    - Speed
  - Judgement
  - Language skills
  - Memory
  - Mental workload capacity
  - Perception
  - Problem solving
  - Reading ability
  - Reasoning
  - Recognition
  - Thinking

- Physiology
  - Motor skills
    - Reaction time
    - Speed of movement
    - Regulation of movement
  - Strength (static and dynamic)
  - Dexterity
  - Stamina
  - Physical workload capacity
  - Physical conditioning

TABLE 1. IMPORTANT ATTRIBUTES OF PEOPLE (contd.)

Psychology
- Aptitude
- Attitudes
- Beliefs
- Biases
- Emotions
- Feelings
- Habits
- Moods
- Motivation
- Perception
- Personality
- Stress

Medical and health
- Side effects from prescription drugs
- Drug or alcohol abuse
- Ill health or stress
- Handicaps
- Aging factors

Qualifications
- Education
- Experience
- Knowledge
- Skills
- Training

Culture

Gender

TABLE 2. PEOPLE TYPICALLY INVOLVED WITH A PROCESS

Design engineers

Construction engineers

Process Engineers

Operators

Maintenance engineers

Supervisors

Managers

TABLE 3. EXAMPLE OF HUMAN FACTORS CHECKLIST - CONTROLS

Are controls accessible?
Are controls easy to reach?
Can important and frequently used controls be reached and operated without strain from the normal working position?
Can controls always be reached when needed?
Can controls be reached and activated in the time available?
Are controls easy to use?
Can controls be manipulated easily?
Can controls be used without discomfort?
Are controls easy to distinguish?
Are controls subject to substitution errors (confusion of controls)?
Are controls subject to adjustment errors (inappropriate movement)?
Can the required use of controls be forgotten?
Can controls be moved in the wrong direction?
Does the movement of the control, either forward, to the right, upward or clockwise, result in increasing values or in a starting-up process?
Can controls easily be activated inadvertently or by mistake?
    Are controls located so that they cannot be inadvertently or accidentally activated?
Are safeguards used against mistaken or inadvertent activation of controls (e.g. guards, key interlock)?
    Is response time compromised?
If activation by a key is required for any of the controls, are the keys easily retrievable?
Are people provided with optimal amounts of information by the control system?
Are different controls distinguished by their shape?
Are controls that are critical to emergency operations clearly distinguishable?
Do labels explain control functions?
Are switches arrayed horizontally rather than vertically?
Is the range of movement of controls appropriate?
Are the resistance values of controls appropriate?
    Is the degree of force required to operate controls high enough to avoid inadvertent activation?
    Is the degree of force required to operate controls low enough to avoid muscular fatigue?
Are devices used by operators to increase leverage over manual controls?
Do controls provide adequate tactile feedback?
    Will gloves reduce tactile feedback from controls?
Is adequate control-response feedback provided?
Is the control/response rate adequate?
Will gloves or other clothing prevent the operation of controls?
Are control surfaces too hot or too cold to touch?

Note: This is not a complete checklist. It is provided for illustrative purposes only.

TABLE 4. EXAMPLES OF COMMISSION ERRORS

Action incorrect
Action inadequate
Action on wrong object
Action at wrong time
Action too long / too short
Action too great / too small
Action repeated
Action in wrong direction
Action in wrong sequence
Action in wrong place

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AN AGENDA FOR IMPROVING SAFETY CULTURE

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Abstract

This paper reflects the views of Operational management, safety professionals and regulators arising from a seminar to discuss the way forward following a significant change in legislation. It provides an agenda for companies to examine their performance and consider where improvements can be made. It also provides human factors and other specialists with a list of areas in which they can provide tools to assist companies improve their performance.

Introduction

In 1998 the UK offshore industry faced a watershed after the Piper Alpha disaster. Lord Cullen's report into the disaster produced 106 recommendations which the Government and the industry has taken on board. The Offshore Safety Division (OSD) of Health and Safety Executive (HSE) took over the role as the Regulator for the industry and this year the final set of new regulations has been introduced.

The companies themselves now have to provide a document known as a *Safety Case* in which they demonstrate, that amongst other things, they have safety management systems in place to manage risks to persons on the offshore installation.

The Current Status of Risk Management in the UK Offshore Industry

The industry acknowledges that the Piper Alpha disaster and the subsequent Safety Case legislation has dramatically changes the way the industry manages risk. The safety case requires all major hazards to be identified and risk levels calculated. The legislation sets a maximum limit for risk and requires companies to drive risks lower.

The legislation requires companies to identify the risk control measures and set measurable criteria for these controls using a hierarchy of prevention, control and mitigation of risks. In addition, companies must have independent managerial systems to verify certain of these risk control measures.

The industry recognizes it now faces a second watershed. Since the safety case regulations were introduced the accident rate has fallen although this year it may be leveling out or showing a slight increase. Accidents are still happening, for example, in the last year or so two divers have been killed where in the previous ten years there were no deaths. A technician was killed testing a lifeboat, a drill crew member died when trapped by drill pipe, and there have been others. All of these accidents happened despite the new legislation and despite safety management systems.

In June 1996 the Health and Safety Executive (HSE) and the United Kingdom Offshore Operators Association (UKOOA) held a joint seminar entitled *A Living Safety Culture* (LSC) to discuss how safety management systems may develop beyond the present stage. The meeting was attended by senior safety and operations personnel in UK Oil and Gas industry. Papers were given by Operational Managers, Safety Professionals, Safety Representatives, and a representative from the U.S. Oil Refining Industry followed by a question and answer setting.

The discussion clearly showed that policies, standards, and procedures are in place, but attention needs to be given to the human aspect if progress is to be made. The message was clear – we need a cultural change to move to a regime in which improvement is self sustaining. While the discussion was largely about H&S, this subject cannot be divorced from management in general, hence the benefits to be gained from improvement should affect all aspects of the business. The issues raised during the day were collated and distilled to the topics listed in Figure 1. This framework provides an agenda for those working on the UK Continental Shelf, and since many multi-national companies were represented at the meeting, it may provide an agenda for companies in the international community to move forward. The topics listed are not ranked in any way, nor could they be. The relevance and ranking will be specific to each company.

Description of the Framework and Issues

The framework lists a number of issues and indicates whether they are a barrier or an aid to cultural change. The issues arranged vertically are directly within control of management. Civil litigation and media pressure are not as easily influenced but are having a significant impact on the business and have human factor links to stakeholders.

Commitment Gap – The delegates believed the workforce and executive management were on the whole committed to health and safety, but this was not the case at intervening levels. In some cases this is true – senior management are not committing resources. In other cases the issues may be a conflict in priorities or an inability to communicate commitment. The main message from the seminar being that lower levels of management are not demonstrating the commitment executive managers talk about. A safety professional believed management did not get offshore enough.

Management, Peer, and Self-Induced Pressures – There is significant evidence of pressure affecting people's behavior. There are examples of people being reluctant to ask questions in front of peers in case they appear foolish. Management pressures arise from many sources including style of management and threat of redundancy. Accidents have arisen from exuberance on behalf of the injured party.

Interfaces – Many companies have significant internal interfaces, e.g., between functional and operational groups, but with widespread use of contractors in the offshore industry external interfaces present significant barriers to understanding and ownership.

Lack of Transparency of Risk – If people offshore and onshore cannot understand the risks, then there is little likelihood that they will be committed to the controls. People offshore have difficulty understanding QRA, absolute risk figures, and how they personally influence risk. The workforce is requesting much more simple procedures and better access to safety professionals.

Lack of Ownership of Risk Controls – Ownership and empowerment are linked; people cannot be empowered, they can only empower themselves. The workforce is requesting increased involvement in task planning and hazops. They are requesting participation in accident investigation and auditing, including onshore procedures. This is certainly a sign of taking ownership.

Benchmarking – While the oil industry is competitive in some areas, safety is not seen in this light. There is a willingness and commitment to share safety information. Benchmarking and sharing best practices will improve standards.

Standardization of Systems – The UK has many itinerant workers who are not only faced with the prospect of different platform layouts, but also different alarm signals, emergency procedures, and isolation standards. The regulations will eventually harmonize alarm signals across North Sea installations.

Way Forward

The model provides an industry agenda to develop safety culture beyond that of safety management systems. Companies can compare their performance against the agenda and decide where they need to put their resources.

Human factors experts can examine the agenda and supply tools that stimulate operational management to demand their use. They should remember that it is the management who will ensure that the human factor techniques are used in the offshore industry and this industry is practical, down to earth, not prone to using sophisticated techniques for the sake of them, and above all cost conscious.

EVALUATING RISK ASSESSMENT APPROACHES IN OIL SPILL PREVENTION APPLICATIONS

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Steven D. Novak
Susan G. Hill

LMITCO Report, June 16, 1996

The Idaho National Engineering Laboratory has been engaged in the application of classic Probabilistic Risk Assessment (PRA) and Human Reliability Assessment (HRA) techniques to a variety of process control industries. These techniques have been developed and nurtured in the aviation, and over the past decade institutionalized in the commercial nuclear industry. PRA and HRA develop logic models that represent the probabilities of an accident scenario developing and the specific combinations of hardware failure and human error that will lead to these failures. These models are based upon the identification of an initiating event and an analysis of the hardware and human actions that follow that event in its evolution. There are entire scientific journals that are dedicated to the development of these methods and their application.

PRA is most commonly used to assist decision makers in the management of risks. It can be used to support policy decisions, understand potential sources of risk, and identify where different technologies, methods, or actions may be useful in reducing risk. It allows the identification of commonalties among what otherwise may appear to be unique accident scenarios, and provides a formal, scrutable model and framework to integrate data. Of late, there has been great interest in our recent work in applying PRA/HRA in the oil and gas industry. We have recently conducted a study, for the Department of Energy, to determine the suitability of these methods in prevention of oil spills.

The objective of this study was to determine how current risk assessment tools and techniques can be best employed to prioritize oil spill and leak hazards and evaluate the effectiveness of technologies proposed to deal with these hazards. Secondly, the study attempted to identify specific management strategies and technologies that can be employed to reduce spill risks and to identify problem areas/scenarios where better risk assessment tools and data are needed.

Thirteen case studies were reviewed to determine the applicability of PRA/HRA methods. Essential for these methods is the ability to identify and model an initiating event/safety function representation. This type of representation is the basis for an event tree/fault tree approach. The analysis conducted clearly demonstrated that a careful treatment of the pre-accident activities leads to the identification of safety functions whose failures contribute significantly to the occurrence of accidents. The types of initiating events identified included such things as pipeline installation, ship collision, flooding, hurricanes, maintenance, underground storage tank installation, and operator o-making. Also critical to the evolution of many of these scenarios were the roles that the humans played in planning, executing, monitoring, and recovering the event. The ability to model the human appeared to be critical in understanding the evolution of the event.

Risk reduction measures were identified as a result of these studies. The first measure came from the fact that four of the 13 events studies involved the disabled, ignored or missed oil spill detection alarms. This implies that organizational or technological improvements in dealing with these alarms could be very helpful in reducing spill risk. The second measures also involved humans. In five of the 13 events violations of operating procedures or industry standards also led to spills. Several factors contributed to this, including operator inexperience, mission urgency, excessive workload, fitness for duty, inattentiveness, and complacency. Again, organizational changes to deal with these reasons and ensure better adherence to procedures should reduce the likelihood of major spills. The third measure is technology related and deals with improving testing and or maintenance methods with fixed facilities.

The results of this study support the notion that current risk assessment techniques are adequate for dealing with oil spill problems. However, there are three specific areas where improvements could enhance the use of this method. The first area is in availability and quantity of data. Improvements in the data arena, including better techniques to collect, qualify, and use data would be useful. The second area concerns the development of oil industry specific models to analyze the success or failure of the generic safety functions. If stochastic models for ships in narrow waterways exist they should be incorporated into the risk assessment framework. The final area is the development of tools to adequately assess the quantitative risk impact of improved inspection or testing methodologies. These tools are necessary if formal risk optimization procedures are to be developed.