2ND INTERNATIONAL WORKSHOP ON HUMAN FACTORS IN OFFSHORE OPERATIONS

Demystifying Human Factors

Practical solutions to reduce incidents and improve safety, quality and reliability

APRIL 8-10, 2002

INTERCONTINENTAL HOTEL, HOUSTON, TEXAS – USA

Edited By:

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MMS

Minerals Management Service

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1.0 LIST OF ORGANIZING COMMITTEE

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United States Minerals Management Service

3.0 EXECUTIVE SUMMARY

Five years have passed since the 1996 International Workshop on Human Factors in Offshore Operations. Over this period, we learned that the level of knowledge of human factors has increased dramatically. We also made significant advances in applying human factors disciplines more effectively within an organization. In order to invest the necessary resources, technical specialists, engineers and corporate leaders need to be confident that the human factors tools they choose to implement will meet the desired goals.

To this end, the 2002 International Workshop on Human Factors in Offshore Operations (HFW2002) brought together six key work groups to help those who wish to develop more effective human factors measures to reduce risk, improve safety and production performance. Each group was successful in developing a set of guidelines, tools and references that are invaluable to those active in the design of new facilities, maintaining the integrity of existing facilities, managing the workforce, conducting incident investigations, developing, implementing and controlling health, safety and environmental (HSE) management systems and managing behavioral processes. The applications and tools discussed by each working group during the course of the workshop documented practical approaches for applying human factors techniques in many areas. These reflect state-of-the-art practices within industry.

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 applying human factors.

All six (6) working groups enjoyed a balanced number of representatives from industry, government and institutions who pro-actively discussed applications 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 a roadmap for the practical application of human factors in the life cycle of an offshore facility.

The purpose of HFW2002 was to provide practical applications and economical solutions to effectively establish and implement human factors as accepted practice vs. an add-on to existing practice. The workshop was successful in providing tools, references and guidelines to more effectively integrate human factors into six key areas targeted by the workshop to improve safety performance and reduce risk:

- Incident Investigation
- Design of New Systems
- Design of Existing Systems
- Operations / Work Force
- Management System Practices and Policies
- Behavior Processes

It is up to Industry to develop its own specification(s) of acceptable performance with input from peers, regulatory agencies, certification bodies, institutes and specialists to reduce risk and improve safety performance. This workshop brought together representatives of all of these organizations from different corners of the world to work together toward this common goal. The application of integrating human factors can be overwhelming without going through a long learning curve and being exposed to expensive time consuming lessons. With the aid of information developed by the HFW2002 Chairs, Co-Chairs and many participants, organizations have started to acquire the fundamental knowledge needed to integrate human factors in the lifecycle of offshore operations. What is now needed is for these organizations to start, or those that have already started, to continue, to apply the knowledge from the Workshop in their day-to-day design and operations. There is no single war to be won to improve human factors and safety; it is a never ending battle, seeking to continuously improve the safety performance.

At the conclusion of the workshop one key point was clear: ignoring human factors will result in an increase not a decrease in incidents, lower safety performance and increased costs. Human factors are paramount to all aspects of offshore operations and essential in reducing human performance-related risks.

4.0 SCOPE

The scope of HFW2002 included the following:

- Establish awareness of what human factors is
- Identify existing tools for human factors that can be used or developed to prevent incidents
- Integrate principles for human factors into offshore design by assessing guidance and identifying gaps and barriers
- Define the status of the science and technology of human factors in the management of safety, behavior and environmental hazards for offshore operations and facilities
- Provide an international forum, attracting participants from all aspects of human factor disciplines (e.g. corporate leadership, offshore facilities designers, human factors, behavioral science and safety engineers, practitioners, certification body representatives and regulatory leaders)
- Produce a record describing the current practice, science and technology of human factors engineering & ergonomics, process safety and behavioral science and the opportunities and tools for using human factor disciplines in the management of safety, behavior and environmental hazards for offshore operations and facilitiesFurther promote the use of human factor disciplines to personnel and contractors responsible for managing, performing and verifying work activities in offshore facilities design, construction, operation, decommissioning, and maintenance

5.0 WORKSHOP OVERVIEW

The format of HFW2002, like the 1996 Workshop, was a carefully balanced, two and a half (2-1/2) day workshop with presentations on the state of the art of human factors and interactive working group sessions. A total of three (3) Supporting Remark presentations, two (2) Keynote Address presentations and nine (9) 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 human factors in offshore operations:

1. **Incident Investigation Working Group -** *"Improving Incident Investigation through Inclusion of Human factors"*
2. **New Facilities Design Working Group -** *"Effectively Including Human Factors in the Design of New Facilities"*
3. **Existing Facilities Design Working Group -** *"Application of Human Factors in Reducing Human Error in Existing Offshore Facilities"*
4. **Work Force Working Group -** *"Solving Human Factor Issues as Applied to the Work Force"*
5. **Management Systems Working Group -** *"Effective Integration of Human Factors into HSE Management Systems"*
6. **Behavior Based Process Working Group -** *"Effective Application of Behavioral Based Processes in Offshore Operations"*

Each working group started with the presentation of the group's white paper which identified the needs required to practically apply human factors related to each work group topic. Barriers to the progress of integrating human factors into operations as-well-as guidelines and references were also discussed. 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 practical application of different aspects of human factors. In addition, supporting papers were submitted to some working groups focusing on specific topics of concern.

The atmosphere of the workshop was extremely positive and upbeat. All participants felt that the level of understanding of human factors technology has undergone significant progress since the 1996 workshop. Each participant received a clearer understanding of the tools available to formally integrate human factors throughout the lifecycle of an offshore facility. Participants also learned that more fundamental human factors programs are needed to resolve issues unique to offshore operations and to understand and control human factors related failures. It is up to industry to develop its own specification(s) of acceptable performance with input from peers, regulatory agencies, certification bodies, institutes and specialists to reduce risk and improve safety performance. This workshop brought together representatives of all of these organizations from different corners of the world to work together toward this common goal. The application of integrating human factors can be overwhelming without going through a long learning curve and being exposed to expensive time consuming lessons. With the aid of information developed by the workshop Chairs, Co-Chairs and many participants, organizations have started to acquire the fundamental knowledge needed to integrate human factors in the lifecycle of offshore operations. What is now needed is for these organizations to start, or those that have already started, to continue, to apply the knowledge from the Workshop in their day-to-day design and operations. There is no single war to be won to improve human factors and safety; it is a never ending battle, seeking to continuously improve the safety performance.

At the conclusion of the workshop one key point was clear: ignoring human factors will result in an increase not a decrease in incidents, lower safety performance and increased costs. Human factors are paramount to all aspects of offshore operations and essential in reducing human performance-related risks.

5.1 Supporting Remarks

Supporting remarks were given by:

Dr. Chris C. Oynes — Regional Director, Gulf of Mexico Region, U. S. Minerals Management Service (MMS)

Mr. Ken Arnold — Chief Operating Officer, Paragon Companies

Mr. Tom Theriot — ExxonMobil Production Company, Manager, Safety, Health and Environment

5.2 Keynote Addresses

The following keynote addresses were given:

"An overview of what was accomplished in the 1996 workshop and the status today"

Mr. Mahdi Hasan, Vice President, Shell Exploration and Production

"Integration of Human Factors into Classification / Certification"

Mr. James Card, Senior Vice President, American Bureau of Shipping

5.3 Theme Presentations

The following theme presentations were given:

"Overview of the P-36 Incident"

Mr. Carlos Tadeu Da Costa Frage, E&P Structural & Naval Technology Manager
Petrobras Exploration & Production

Mr. Jose Barusco Filho, E&P Structural & Naval Technology Manager
Petrobras Exploration & Production

"Return on investment in Use of Human Factors in Offshore Systems"

Mr. Harrie J. T. Rensink, R.e., Eur Erg., Group Advisor Human Factors Engineering

Shell International Health Services

"Analysis of Human Factors Related Accidents and Near Misses"

Prof. James Reason, University of Manchester

"An Integrated Approach to Behavioral Based Safety"

Mr. Jim Spigener, Vice President, BST

"New Method for Integrating Human Factors into the Design of Offshore Command and Control Systems"

Mr. Adam Balfour, Managing Director, Human Factor Solutions

"Capitalizing on Behavior Based Safety to Address Human Resource Development Needs"

Mr. Ron Newton, President, Peak Incorporated

"Incidents and Near Misses"

Rear Admiral John Lang, Chief Inspector of Marine Accidents, Marine Accident Investigation Branch U. K., Dept. for Transport, Local Government and the Regions

"Working Offshore: Its Effects and their Management"

Mr. Mark Shrimpton, Community Resource Services Limited, Socio-Economic Consultants

"Accident Investigation Trends – A Safety Management Perspective"

Mr. Frank Pausina, Senior Accident Investigation Coordinator, MMS

5.4 Working Group Papers

There were six working groups, topics, chairs and co-chairs are identified below:

1 Incident Investigation Working Group - *"Improving Incident Investigation through Inclusion of Human factors"*

Group Leader Anita Rothblum – U. S. Coast Guard, USA

Co-Chairs: Captain David Wheal and Stuart Withington,
UK Marine Accident Investigation Branch, USA

William Boehm, Stolt-Nielsen Transportation Group, USA

Marc Chaderjian, California State Lands Commission, USA

Scott A. Shappell, FAA Civil Aeromedical Institute, USA

Douglas A. Wiegmann, University of Illinois at Urbana-Champaign, USA

2 New Facilities Design Working Group - *"Effectively Including Human Factors in the Design of New Facilities"*

Group Leader: Johan Hendrikse – Paragon Engineering, USA

Co-Chairs: Rick Meyer, Shell, USA

Gerry Miller, G.E. Miller & Associates, USA

Ben Poblete, Lloyds Register, USA

Kevin McSweeney, American Bureau of Shipping, USA

George Conner, ChevronTexaco, USA

Paul Atkinson, ExxonMobil, USA

Pat O'Connor, BP America Inc., USA

Hilde Heber, Norwegian Petroleum Directorate, Norway

Eileen B. Hoff, Paragon Engineering, USA

3 Existing Facilities Design Working Group - *"Application of Human Factors in Reducing Human Error in Existing Offshore Facilities"*

Group Leader: Jeffrey Thomas, ExxonMobil, USA

Co-Chairs: Clifford C. Baker, American Bureau of Shipping, USA

Thomas Malone, Carlow International Incorporated, USA

John T. Malone, Carlow Associates, USA

Ivan C.L. Rezende, Petrobras, Brazil

Christina L. Hard, BP America Inc., USA

Sally Carvana, BOMEL Limited, UK

Mark Witten, ChevronTexaco, USA

4 Work Force Working Group - *"Solving Human Factor Issues as Applied to the Work Force"*

Group Leader: Bob Miles – Health and Safety Executive, UK

Co-Chairs: Dennis Atwood, ExxonMobil, USA

Amy White, Minerals Management Service, USA

5 Management Systems Working Group - *"Effective Integration of Human Factors into HSE Management Systems"*

Group Leader: Denise McCafferty – American Bureau of Shipping, USA

Co-Chairs: Rodger Holdsworth, RRS Engineering, USA

Kevin P. McSweeney and Clifford C. Baker,
American Bureau of Shipping, USA

6 Behavior Based Process Working Group - *"Effective Application of Behavioral Based Processes in Offshore Operations"*

Group Leader: Jim Spigener – Behavioral Science Technology, USA

Frank Amato, Paragon Engineering Services, USA

Co-Chairs: Gillis Gaupreaux, Shell, USA

Brian N. Craig, PhD, CPE, Lamar University, USA

6.0 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 Texas and Texas A & M University graduate students were asked to assist in facilitating the work of each working group and four RRS Engineering staff, Ms. Christy Franklyn, Ms. Donna Hamilton, Ms. Jennifer Summers and Ms. Cathy Malek 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.

Speaker Presentations

Rodger Holdsworth Director, Management Systems Risk, Reliability and Safety Engineering	**Welcome/Introductions**
Dr. Chris Oynes Regional Director, Gulf of Mexico Region, U.S. Minerals Management Service	**Opening Remarks**
Ken Arnold Chief Operating Officer Paragon Companies	**Opening Remarks**
Tom Theriot ExxonMobil Production Company Manager, Safety, Health and Environment	**Opening Remarks**
James Card Senior Vice President American Bureau of Shipping	**"Integration of Human Factors into Classification/Certification"**
Carlos TadeuDa Costa Frage E&P Structural & Naval Technology South/Southeast Division, PETROBRAS **Pedro Jose Barusco Filho** E&P Structural & Naval Technology Manager, Exploration & Production, PETROBRAS	**"Overview of the P-36 Incident"** **(PLEASE NOTE: FOR BEST VIEWING, "MAXIMIZE" THE MOVIE PLAYER ON YOUR COMPUTER SCREEN.)** **Faster Computers Please Use:** **Movie 640x480 - P36_movie.avi, 275 MB)** **Slower Computers Please Use:** **Movie 320x240 - P36_movie.avi, 105 MB)**

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Workshop Overview

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1996 WORKSHOP PURPOSE

Define the status of human factors spanning the life cycle of an offshore facility including design, fabrication and installation, field operations, management systems, standards and regulation and science and application.

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WHAT WE LEARNED

- **The 1996 workshop brought together three human and organizational factor disciplines:**
  - ***Engineering & ergonomics***
  - ***Process safety***
  - ***Behavioral science as applied to the life cycle of offshore operations***

WHAT WE LEARNED (CONT)

To apply human and organizational factor disciplines within an organization, engineers and corporate leaders need a high level of confidence that the approach(es) they choose will meet the anticipated objectives

WHAT WE LEARNED (CONT)

Practical application of time-proven science and technology, as related to each human and organizational factor discipline, supported by industry and regulatory consensus is needed for industry to embrace human factors as accepted practice as opposed to an add-on to existing safety programs

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HFW2002 WORKSHOP PURPOSE

To work together to demystify human factors by documenting practical solutions to reduce incidents and improve safety, quality and reliability in the lifecycle of offshore facilities

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Workshop Objectives

- Establish human factors awareness
- Identify human factors tools that can be used or developed to prevent incidents
- Integrate human factors principles into offshore design by assessing available guidance and identifying gaps and barriers

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WORKSHOP OBJECTIVES (CONT)

Further promote the use of human and organizational factor disciplines to personnel and contractors responsible for managing, performing and verifying work activities in offshore facilities design, construction, operation, decommissioning, and maintenance

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Most Common Questions and Answers

Who is responsible for facilitating each work group?

Workgroup Chairs together with Co-Chairs and Scribes will facilitate the discussion on each working group paper topic.

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Most Common Questions and Answers (Cont)

How can I provide input or contribute my knowledge and experience to the workgroup?

By submitting input and comments related to the working group paper at the workgroup session of choice or within 60 days following the workshop.

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Most Common Questions and Answers (Cont)

Can I move from one workgroup to another workgroup?

Yes, participants can move from one workgroup to another. However, it is requested that the flow of the discussion not be disrupted. Submit comments and input related to previous discussion during reviews or during breaks.

Most Common Questions and Answers (Cont)

When can I expect to receive the workshop proceedings?

Within 120 days following the workshop.

QUESTIONS?

2nd International Workshop on Human Factors in Offshore Operations

Opening Remarks

by

Chris C. Oynes

Regional Director, Gulf of Mexico Region

Minerals Management Service

April 8, 2002

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Industry Changes Since 1996

- A lot has happened since the first workshop in 1996
  - ♦ We have continued moving into deeper and deeper waters in search of resources.
  - ♦ The industry continues to develop new technology at a record pace.
  - ♦ There has been a great number of mergers in industry, resulting in fewer, but much larger companies.
  - ♦ Small, independent operators play a major role in the Gulf of Mexico, especially on the shelf.
  - ♦ Opportune to meet and discuss Human Factors

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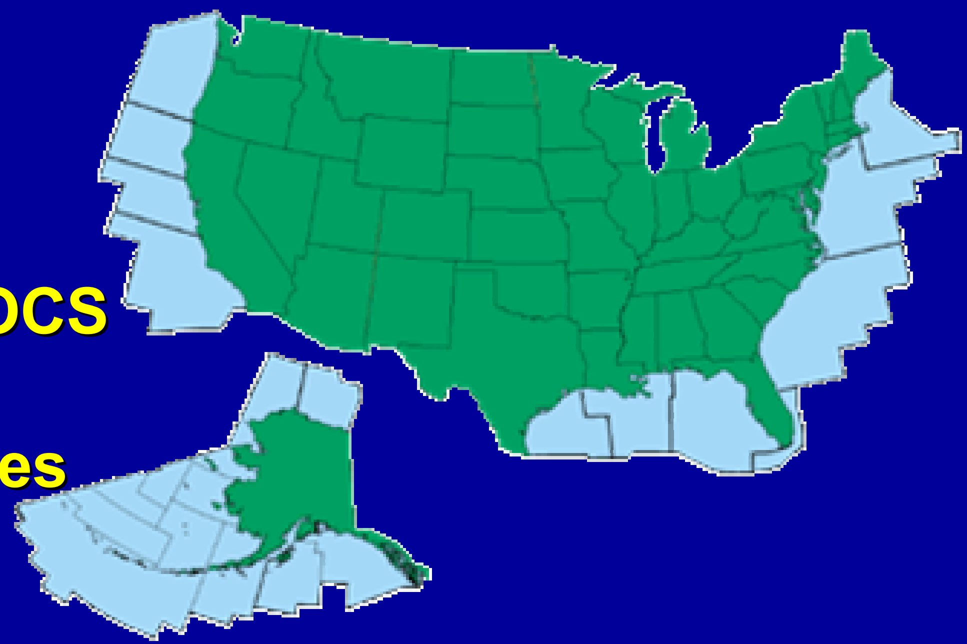
Human Factors

"It's not the panacea for today's problems."

Taf Powell UK HSE

MMS Responsibilities



- Administration of
  - ✓1.76 billion acres on the OCS
  - ✓Over 7,500 leases
  - ✓4,000 + production facilities
- OCS production
  - ✓25% of U.S. natural gas
  - ✓27% of U.S. crude oil
- Revenue collection for U.S. OCS
  - ✓Since 1953, almost $133 billion
  - ✓Nearly $10 billion in 2001

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Many Agencies Involved

- U.S. Coast Guard
  - Oil-spill response, port regulation, vessel inspection
- Office of Pipeline Safety
  - Pipeline inspections, standards
- Environmental Protection Agency
  - Air and water quality
- National Marine Fisheries Service
  - Marine mammals/endangered species
- Fish and Wildlife Service
  - Marine mammals/endangered species
- Department of Commerce
  - Coastal programs

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Safety & Environmental Protection

Two Core Objectives

Safe Offshore Operations

Promote incident free operations during exploration and development on Federal Offshore Lands.

Environmental Protection

Ensure that all activities on Federal Offshore lands are conducted with appropriate environmental safeguards.

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Varied Clientele

- Program must be responsive to operators
  - Some companies are small and operate single well caissons
  - Others are large multinationals who deal with cutting edge technology
- We require the same level of performance
  - Program does recognize that small operator may not have the same support staff as a major player

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The U.S. System—Process Rich

- 5-Year Program
  - Outlines size, timing and location of potential sales
- Individual Lease Sales—competitive bidding
  - Primary term for completing exploration
  - Site specific environmental and safety requirements
  - Financial terms (minimum bid, royalties, rentals)
- Review of exploration and development plans
- Adaptations for deepwater activity

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Regulatory Strategy

- Crossroads of developing new regulatory systems
  - Focus on performance while maintaining prescriptive features
- Consensus standards development
  - Mutual benefits for government and industry
- Industry collaboration
  - Through OOC, IADC, API & ISO
- Coordination and collaboration with other regulators around the world

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Deepwater Operations Plan

- DWOP requires 3 Parts - conceptual, preliminary & final
  - Early dialogue - focus on “total system”
  - MMS approval prior t
    financial commitment
  - List alternative compliance and departures
- Avoid unnecessary regulatory rewrites

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Guiding Principles for Program

- Operator responsibility
- Understanding human factors & mechanical systems interface
- Measure performance
- Make sure poor performance carries a price

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Accident Investigation

- An important responsibility - Industry & MMS
  - Should be integral part of operator's SEMP
  - Both should review data & conduct investigations
    - Determine root causes
    - Identify trends
    - Share information to prevent future incidents
- Use information to revise requirements and direct research
- Share results through safety alerts and workshops
- Information exchange with <u>international</u> colleagues

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Human Factors Roles In Accidents

- Relationship between human factors and management system failures
- Negative human interaction with the system
- Need to find the deepest underlying cause of the accident

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Management System Failures

- Failure may include the following:

  - failure to identify hazardous aspects of an operation
  - failure to provide guidelines for the safest way to accomplish a task
  - failure to effectively implement the corporate safety program

- Need to address these failure modes to prevent future accidents

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Riser Package Accident

Control Panel

A Crane Accident

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Annual Performance Reviews

- Continuing dialogue - MMS & operators
- Safety - ensure corporate focus
- Regulatory practices - feedback for MMS
- Poor performance - identify/suggest remedies
- Correct problems before they become serious

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In Conclusion

- MMS continues to seek way to improve its regulatory program
- Human Factors aspects of safety management is an integral part of our program
- We want companies to keep HSE issues a top priority
- We all have much to gain in maintaining good safety and environmental performance

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Is There Room for Human Factor Engineering In Design?

By

Kenneth E. Arnold

Paragon Engineering Companies

April, 2002

What Does HFE Address?

- Trip, slips and falls
  - Reduce Injuries
- Simplifying Maintenance and Operations Tasks
  - Reduce Downtime
  - Reduce Injuries
  - Reduce Fatalities (Low to Medium Number/Occurrence)
- Reacting to Abnormal Situations
  - Reduce Loss of Installation
  - Reduce Injuries
  - Reduce Fatalities (Medium to High Number/Occurrence)

Trips, Slips and Falls

- **Easiest Place to Concentrate (New Design)**
- **Well Covered in Literature**
- **Standards - Ladders, handrails, stairways, walkways, etc.**
- **Implement by Training and Auditing**
- **Still Major Problem On Existing Facilities In GoM & North Sea**

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Simplifying Maintenance and Operations Tasks

- **Medium difficulty to implement**
  - **Access, Access, Access!**
  - **Lifting, Lifting, Lifting!**
- **Task analysis with help from O&M Staff - Rethink design**
- **No longer a matter of simply applying standard. Have to think through and visualize the O&M process.**

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Reacting to Abnormal Situations

- **The real prize! The most difficult to obtain!**
- **Major accidents are almost always caused by a series of escalating events.**
- **At any point human interaction can accelerate or decelerate the magnitude of consequences.**
- **How do we design so that the natural reaction is to take action which midigates the consequences?**

Human Factors

- **“80% of all accidents are caused by human error” (Bob Bea)**
- **Amato corollary “and 80% of these are caused by failure of management systems”**
- **Arnold corollary “yes, but 80% of all accidents are also caused by design which does not encourage the correct human response”**
- **Examples**
  - **Three Mile Island ($4B)**
  - **Ocean Ranger (84 Fatalities)**
  - **Piper Alpha (167 Fatalities)**

Three Mile Island (1979)

- Popular conception - Operator training
- What happened
  - Steam System Went Down
  - PV Valve on Pressurizer tank opened
  - As Pressure Decreased Control Room Light Went Out Indicating Signal to Open PV Valve No Longer Existed
  - Pressure Relief Valve Stuck Open, Staff thought it had closed
  - Pressure Decreased Further in Pressurizer Tank. Water Level Rose
  - To keep from packing the pressurizer tank leading to an immediate overpressure. Operators dumped water.
  - 110 alarm lights flashing
  - Fixed on lowering water level in pressurizer tank

Three Mile Island (1979) - Continued

- **Given low pressure in pressurizer tank but high level, multiple alarm sirens and no direct indication of leak, operators fixed on controlling level. Ignored other indicators of loss of water in cooling system: temperature rise in containment building, vibration of circulating pumps (cavitation)**
- **Design problems**
  - **No water level indicator in reactor**
  - **Temperature of PV drain limited by computer to 280°F max output even though actually 600°F**
  - **No direct readout that PV was actually closed**
  - **Too many alarms**

Ocean Ranger (1982)

- **Popular Conception - Operator Training**
- **What happened -**
  - **Storm wave breaks port light window shorting ballast control panel**
  - **Sea valves started opening and closing randomly**
  - **Shut-Off Power - Valves close**
  - **Decided to turn on power to deballast to higher level**
  - **Started settling by bow**
  - **Screwed in brass by-pass rods to cause valves to close**
  - **By-pass rods actually caused valves to fail <u>open</u>**
  - **Could not launch survival craft in storm with list**

PARAGON ENGINEERING SERVICES INCORPORATED

Ocean Ranger (1982) - Continued

- **Design problems**
  - **Easy to short out panel in ballast control room**
  - **No way to isolate panel and still activate pumps or check status**
  - **Brass by-pass rods opened sea valves**
  - **No way to launch survival craft with rig tilted down by the bow**

Piper Alpha (1988)

- **Popular Conception - Failure of Permit to Work System, Operator Training**
- **What happened -**
  - **Day crew isolated pump for maintenance**
  - **Day crew removed PSV on condensate pump for annual safety check**
  - **Did not properly install gasket, blind flange and bolts**
  - **Night crew unaware and put pump in service**
- **Design Problem**
  - **Decoupled PSV from Pump It Protected**
  - **Gas Heard Escaping In Compressor Room But Source Unknown**

Why Did Paragon Form HFE Group

- Improve designs by better safety, operability and maintainability
- The client deserves the option. (Problem: Will he pay?)
- Implementation
  - Upper Management Support
  - Acquire/Develop Expertise
  - Develop Specifications and Standards
  - Develop Implementation Plan
  - Train Engineers and Designers
  - Convince Project Managers to Include HFE as Integral Part of Team
  - Convince Clients of Value
- Need for HFE Professionals
  - Educational Background
  - A thought process and not just “common sense”
  - Compromises will be made

Paragon Success Stories

British Petroleum Mardi Gras Pipeline

- HFE has been integrated into project from inception
- Reduced time for redesign by implementing HFE standards and comments into initial design
- Improved safety for maintenance, materials handling and pigging operations by incorporating HFE principles
- As a result of this work we are providing HF training and support to project members of the other projects that form part of BP GoM Deepwater Development Program

FPSO Project

- HFE involvement in evaluation and design of LQ save $5 -10 million by reducing square footage requirement

Paragon Success Stories (Continued)

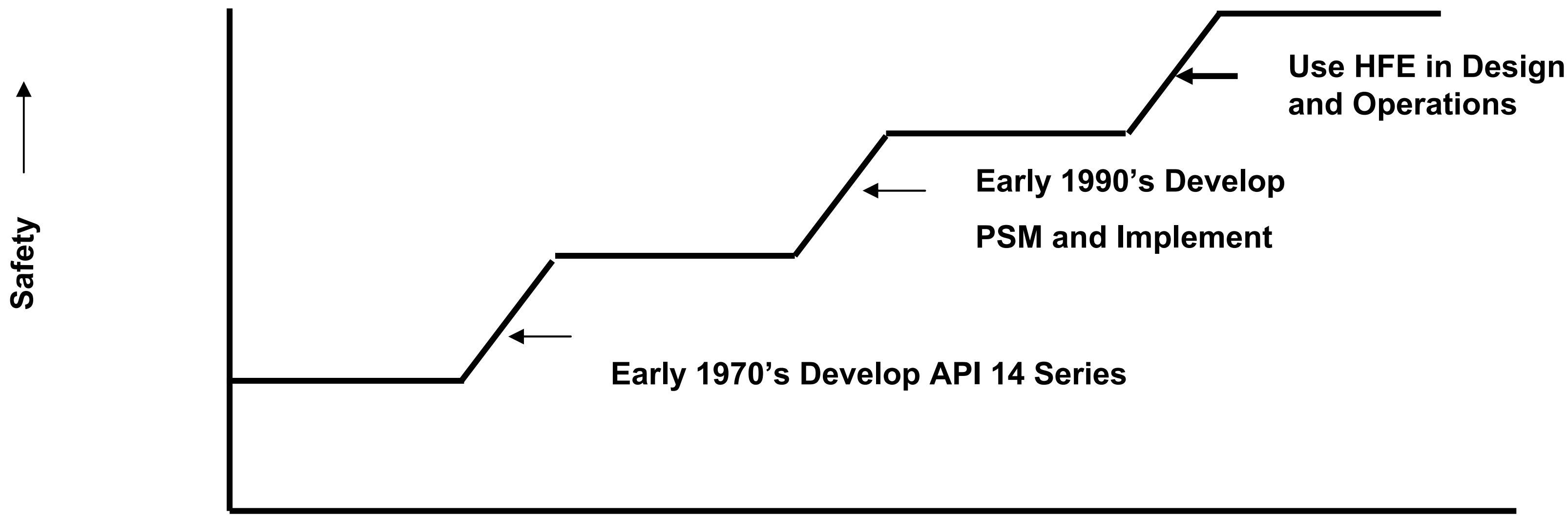
Shell Offshore Inc URSA Platform

- Implementation of redesigned control room has improved worker satisfaction
- Operability and maintainability of the control room equipment has been improved through well thought out design
- Environmental characteristics have been improved through application of proper lighting, noise and ventilation control
- As a result of this work we were also asked to conduct a HF review of Auger control room

Survival Capsule Study

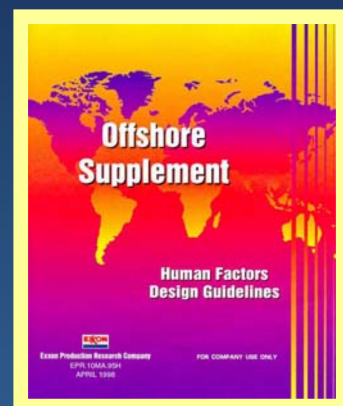
- Research showed that capsules could not accommodate the rated number of persons due to difference in physical size between the "average" offshore worker and population anthropometrics used in the design and rating of the capsules
- MMS has issued a safety alert as a result of this work
- A number of GoM operators have de-rated the capacity of some survival capsules at their facilities due to this research

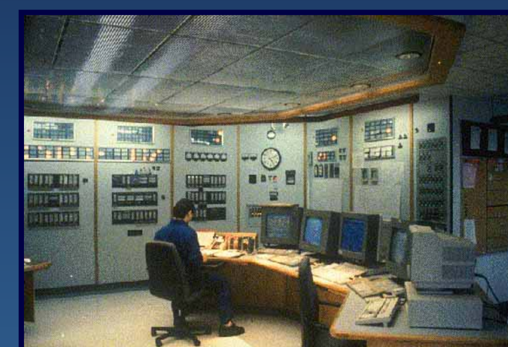
Where Are We In Design Safety



- **We are today where we were with regard to Hazard Analysis in 1980"s**
  - **"Common Sense"**
  - **" We do it already"**
  - **" Why do we need a separate hazard analysis?"**
  - **"It is only good engineering practice"**
- **The truth is we needed the discipline of Hazards Analysis to force us to make sure we implement what we knew.**
- **The one way to make a step change in safety after implementing SEMP is through HFE. We need the discipline of HFE professionals and an implementation plan.**

ExxonMobil's Approach to Human Factors





Second International Workshop on Human Factors in Offshore Operations

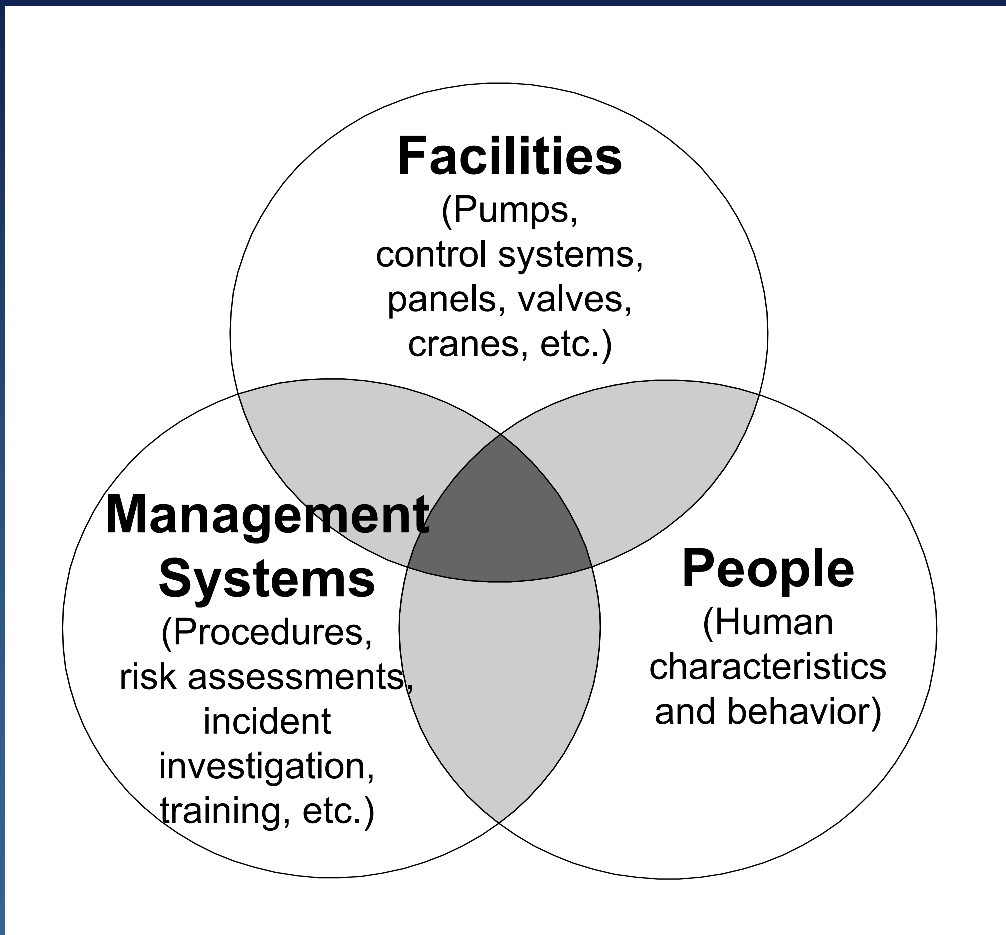
April 8-10, 2002

Tom Theriot, Manager Safety, Health & Environment
ExxonMobil Production Company

Presentation Outline

- Definition
- Objectives of Human Factors Efforts
- Background - Why Human Factors?
- Human Factors Spectrum
- Corporate Human Factors Strategy
- Human Factors Focus Areas
- New Human Factors Technology

Human Factors - Definition



Human Factors are:

the integration and application of scientific knowledge about

- people
- facilities
- management systems

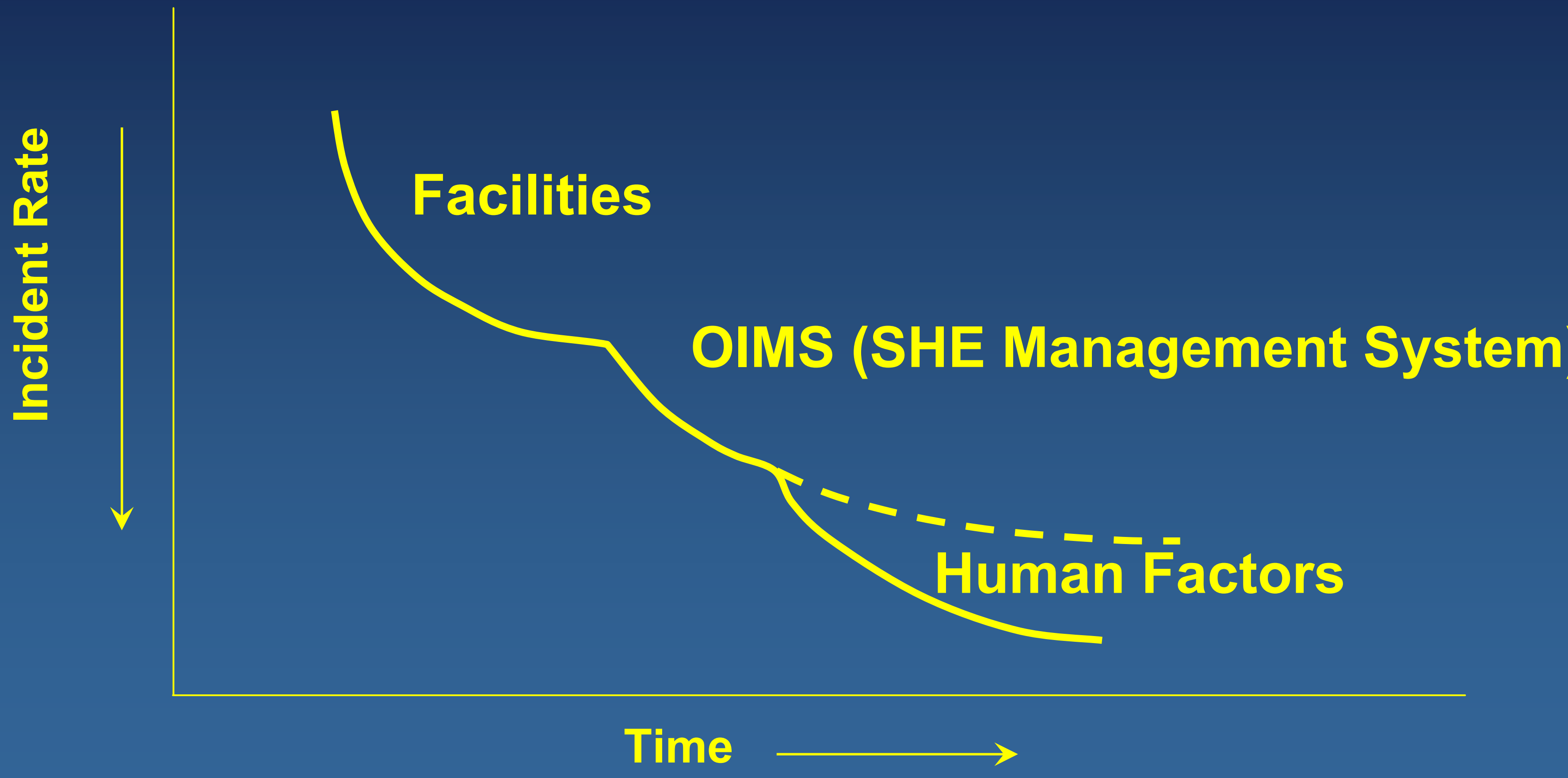
to improve their interaction in the workplace.

ExxonMobil

Objectives of Human Factors Efforts

- Our goal is to reduce human errors, resulting in . . .
  - ➢ safer operations (fewer incidents),
  - ➢ fewer production upsets,
  - ➢ higher efficiencies, and
  - ➢ enhanced quality.

Incident Performance Improvement History



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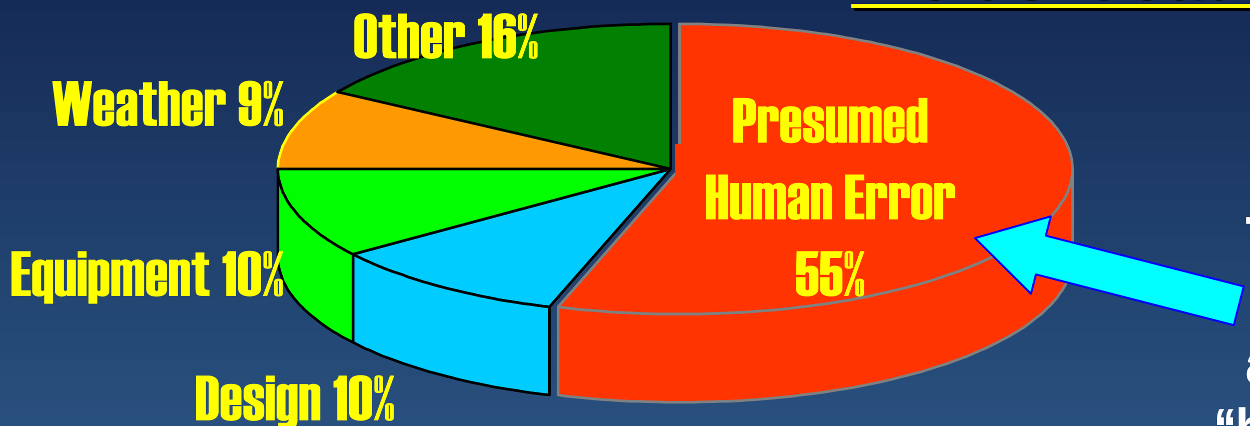
Why Are We Working on HUMAN FACTORS?

Incident Causal Factors



These are the incidents addressed by "human factors"

Implemented Hardware Solutions

- Protective Systems
- Added Safety Factors
- Reduced Operator Interventions

Pursued Traditional Approaches

- Training
- Motivation Campaigns
- Discipline for Violators

Implemented SHE Management Systems (OIMS)

- Management Leadership
- Risk Assessments
- Procedures
- Incident Investigations

BUT PEOPLE STILL MAKE ERRORS

WE MUST ADDRESS "WHY?"

The Human Factors "Spectrum"

ExxonMobil

Workplace Design

Equipment Design

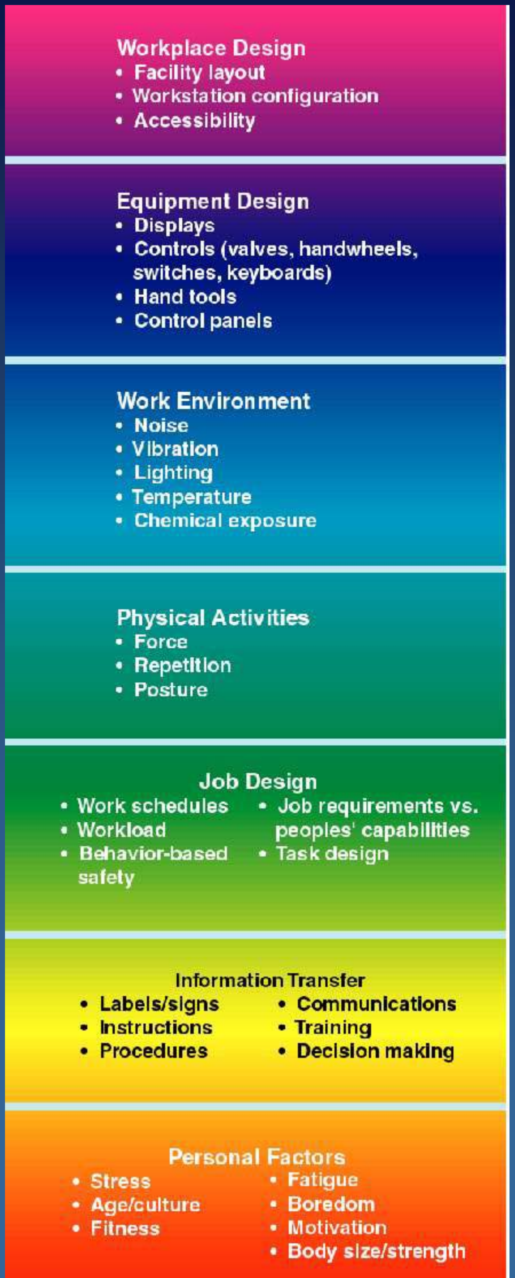
Work Environment

Physical Activities

Job Design

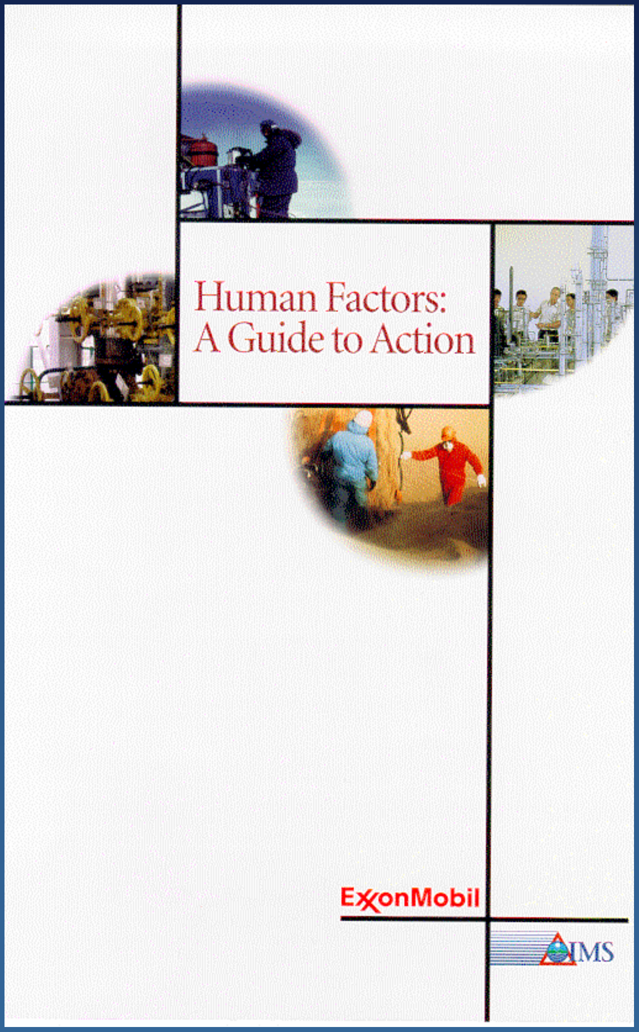
Information Transfer

Personal Factors



ExxonMobil

ExxonMobil's Human Factors Strategy

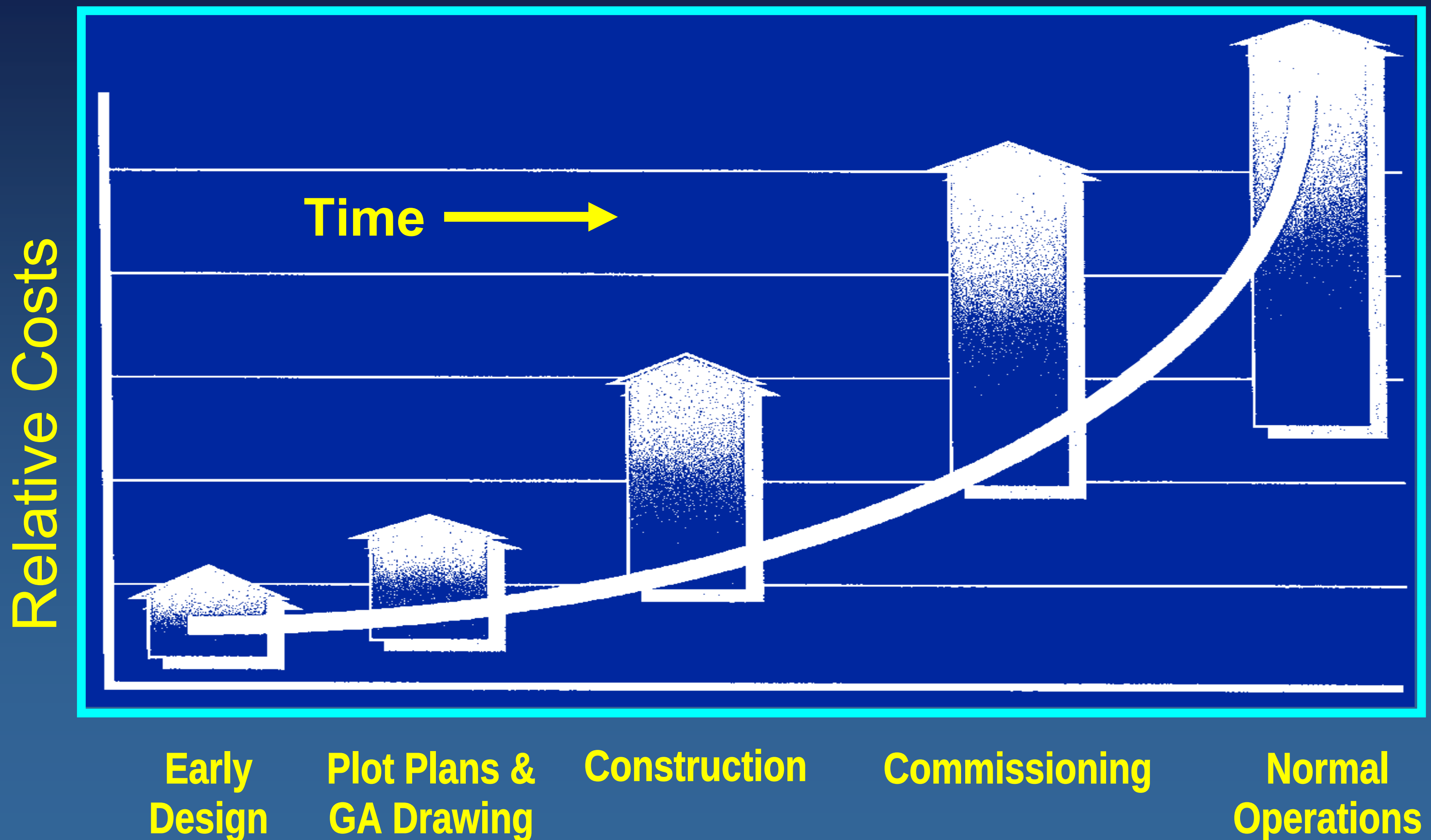


- HF efforts are driven by specific needs/opportunities for improvement
- Improvements are sustained by building HF into existing Management Systems, Engineering Standards, and Operating Practices
- Effective HF resources and tools are provided to aid implementation
- Roles and responsibilities for HF are clearly defined; management leadership key
- Results are evaluated and shared to enhance benefits and effectiveness

Human Factors Focus Areas

- Design of New Facilities
- Risk Assessment
- Incident Investigation
- Training
- Drilling
- Application in Existing Operations

The Cost of Using Human Factors in Design

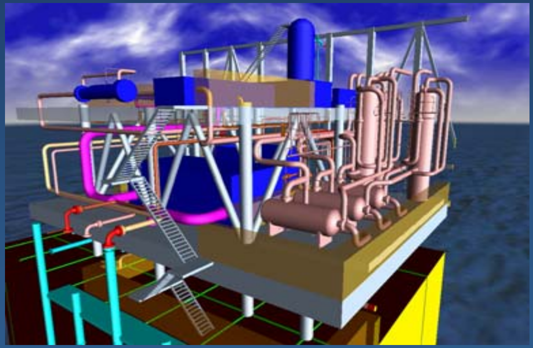


ExxonMobil

New HF Technology Applications

- **ExxonMobil research organizations identify new HF technology/tools through:**
  - leveraging off other industries (e.g., aviation, nuclear, aerospace)
  - obtaining input from operating/project organizations

3D CAD Projects



- Incorporate HF considerations (access, spacing, valve location) into 3D CAD models
- Create guidance document for designers

Automated Control Systems

- Develop standards for control system interfaces (screen design, alarms, displays, etc.)

2nd International Workshop on Human Factors in Offshore Operations.

Demystifying Human Factors - Practical Solutions to Reduce Incidents and Improve Safety, Quality, and Reliability

James Card

Senior Vice President, American Bureau of Shipping

Integration of Human Factors into Classification / Certification

1996 Conference

- Nearly six years since the first workshop in 1996
- PTP was getting underway
- Four pillars of Maritime Safety:
  - Management
  - Work Environment
  - Behavior
  - Technology Application

ABS
FOUNDED 1862

ABS, Classification Societies

- ABS founded in 1862
- Mission has been to promoting the security of life, property, and the natural environment

ABS
FOUNDED 1862

Human Error and Accidents

- 80% of marine casualties and accidents (IMO, USCG)
- 90% of ship collisions (NTSB)
- 85% of ship accidents (Navy Safety Center)
- 66% of marine oil spills (UK)
- 62% of hazardous materials spills (OTA)
- 75% of merchant ship accidents (Republic of Germany)

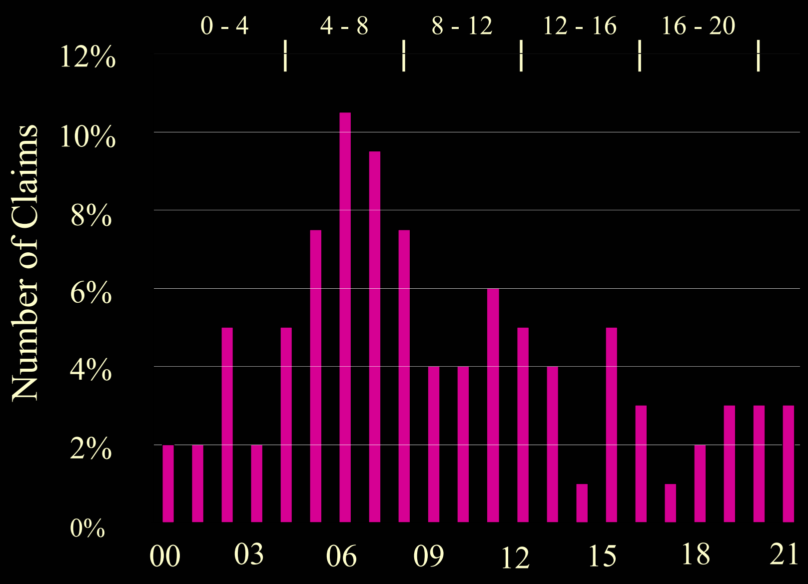
ABS

Human Factors Issues in Classification / Certification

ABS has organized it's approach around into four human factors areas

ABS - Management and Organizational Issues

- Reviewing Accident and Near Miss Data Bases
- Develop a scheme for root cause analysis which includes human factors related causes



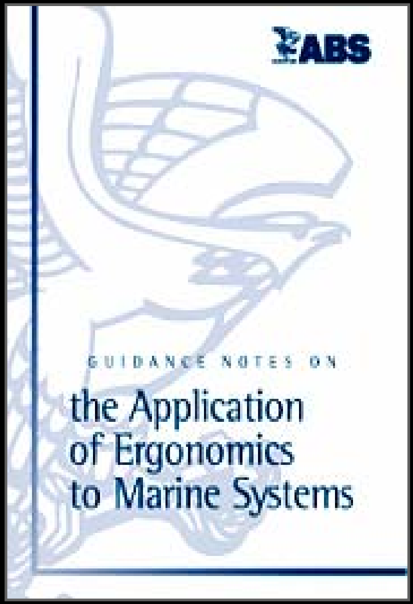
ABS - Management and Organizational Issues

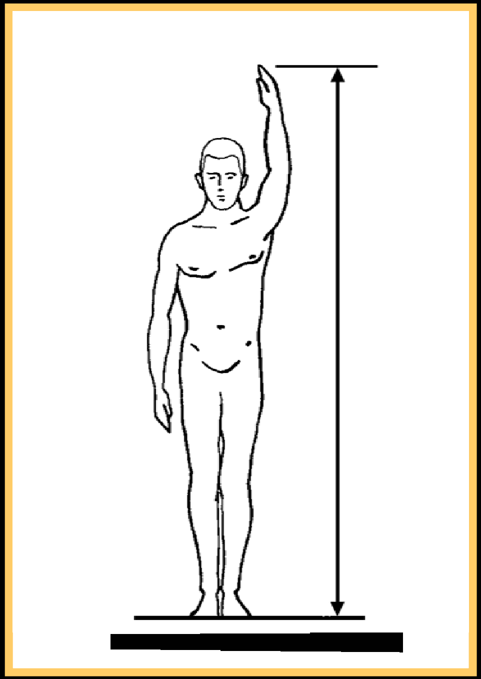
- Installation-to-Marine Vessels, Installation-to-Helicopters, Installation-to-Beach and Internal Installation Communications Guide

ABS

ABS – Installation Design and Layout

Guidance Notes on the Application of Ergonomics to Marine Systems





ABS – Installation Design and Layout

ABS Guide to Crew Habitability on Offshore Installations

ABS

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ABS – Installation Design and Layout

- ABS Guidance Notes for Human-Computer Interfaces

ABS
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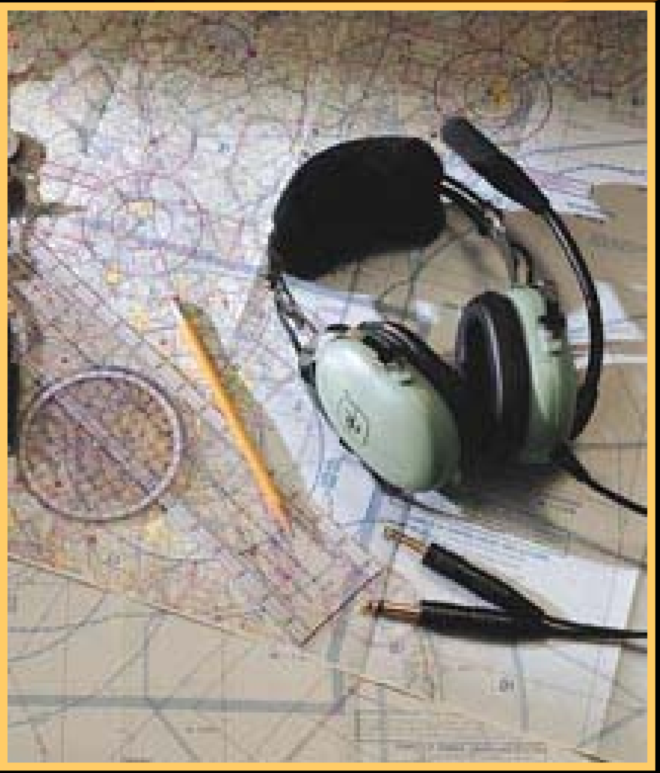
ABS – Ambient Environment

ABS Guide for Crew Habitability on Offshore Installations

ABS – People Issues

- Development of Personnel Verification Tools
  - Qualifications
  - Personnel Selection
  - Training
  - Crew Endurance
  - Risk Tolerance



ABS

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ABS – People Issues

- Workload and Situation Awareness Assessment

Different Models – Same Message

Questions?

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Theme Presentations

Harrie J.T. Rensink, R.e., Eur Eng. Group Advisor Human Factors Engineering Shell International Health Services The Netherlands, The Hague	***Return on Investment in Use of Human Factors in Offshore Systems***
Dr. James Reason University of Manchester Manchester, UK	***Analysis of Human Factors Related Accidents and Near Misses***
Jim Spigener Vice President BST Ojai, CA	***An Integrated Approach to Behavioral Based Safety***
Adam Balfour Managing Director Human Factor Solutions Norway	***Experience Using the Norwegian Petroleum Directorate's (NPDs) Method for Auditing Human Factors Aspects of Command and Control Centers***
Ron Newton President Flower Mound, TX	***Capitalizing on Behavior Based Safety to Address Human Resource Development Needs***
Mark Shrimpton Community Resource Services Limited Socio-Economic Consultants St. John's Newfoundland, Canada	***Working Offshore: Its Effects and Their Management***
David Dykes MMS	***Accident Investigation Trends - A Safety Management Perspective***
Cyril Arney Consultant Houston, TX	***Summary of Working Group Activities***

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Return on investment in use of human factors in offshore systems

"Closing the gap between conceptual design and engineering, field construction activities and operations"

Harrie J.T.Rensink, R.e., Eur.Erg.

Shell International Health Services The Hague
0031- 70- 3771690 or Harrie.J.Rensink@SI.shell.com

Agenda

- SI HE Client portfolio
- Why Usability and HFE in projects?
- EMIS ® HFE quality system
  - Examples of *Smart design tools*
- Added value & Critical Success Factors

Objectives

- To improve awareness for ‘human centered design’
  - integrated *front end* engineering activity
  - ‘*first time right*’ principle
  - economical and non-economical benefits

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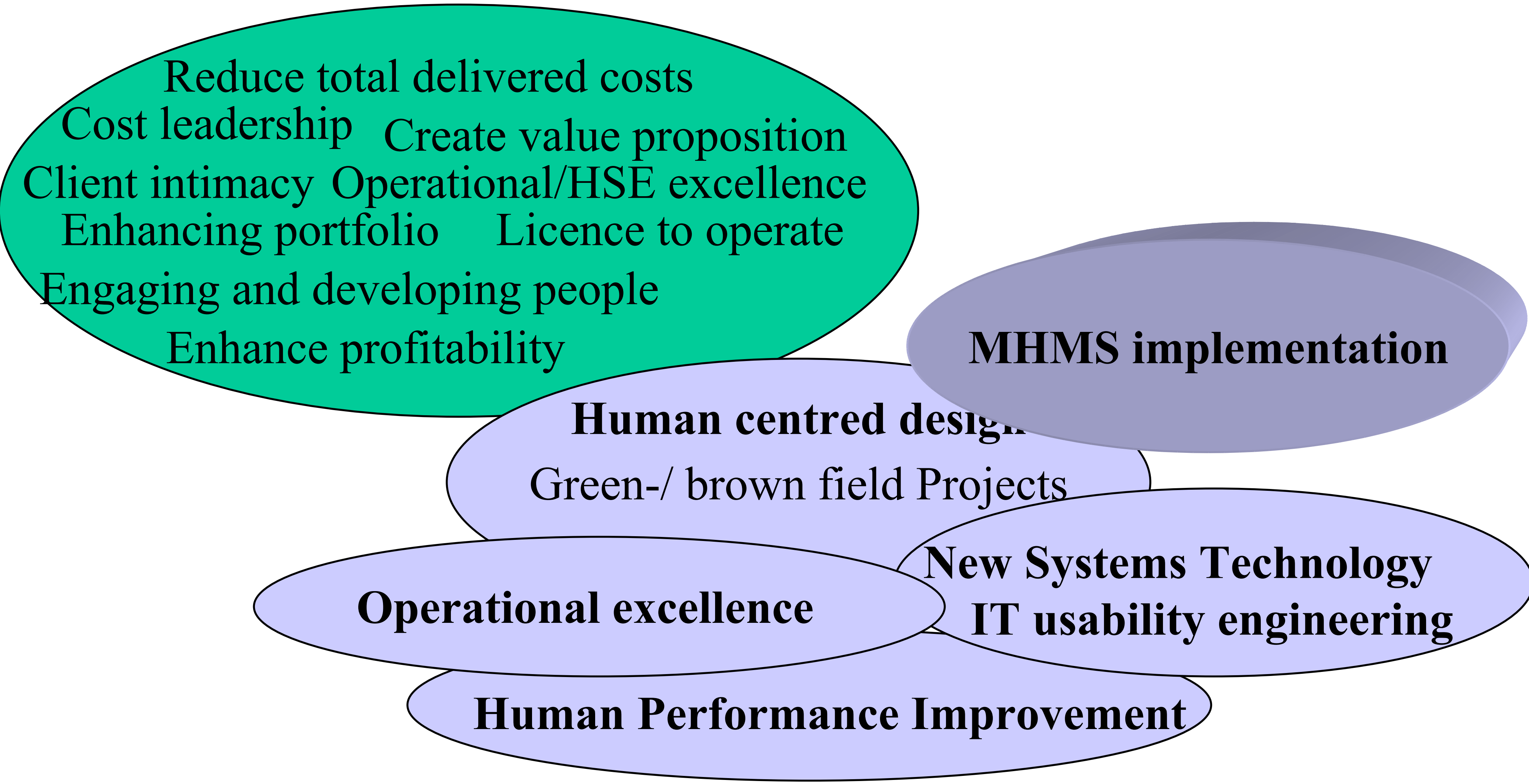

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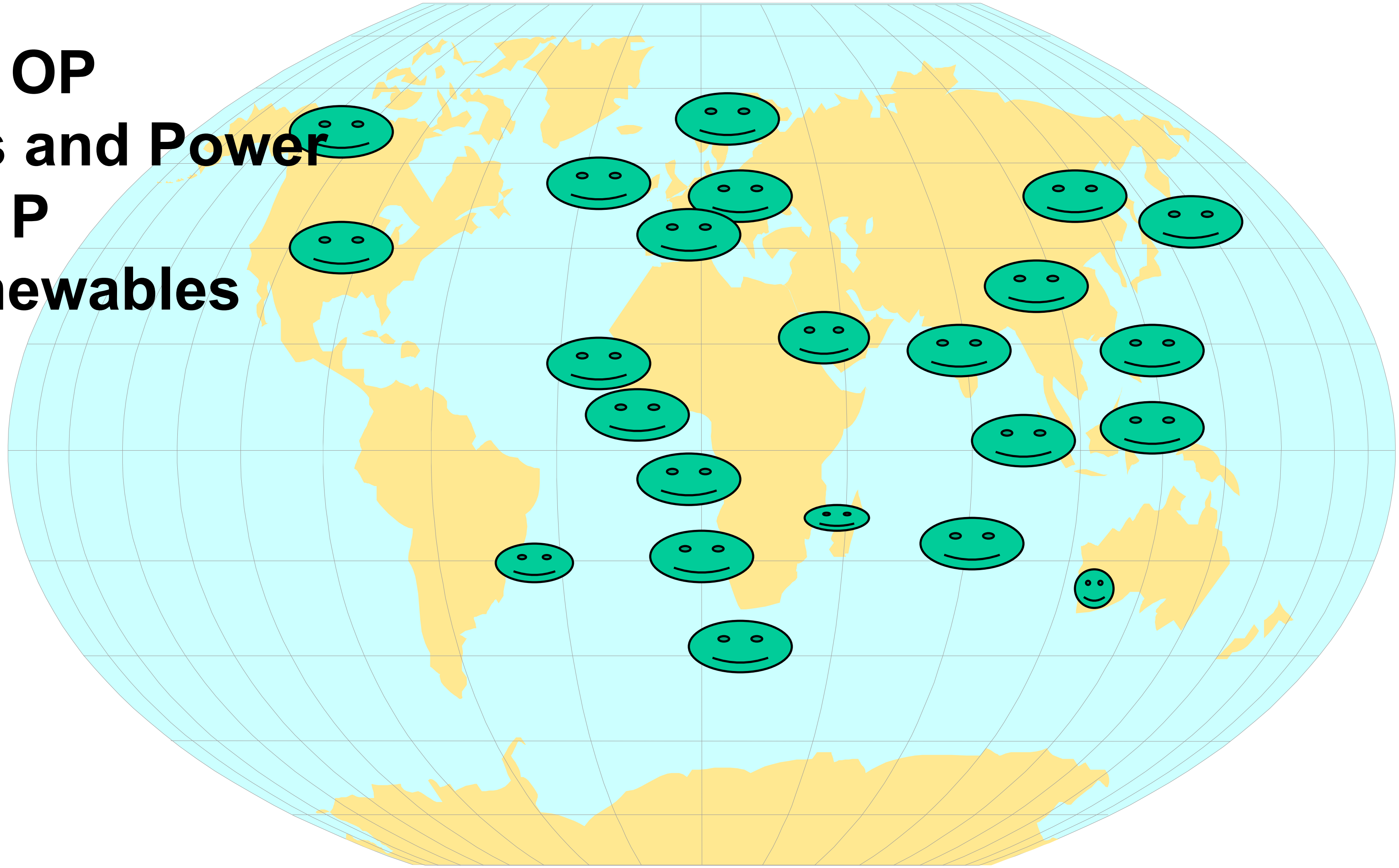
Client Portfolio & Projects

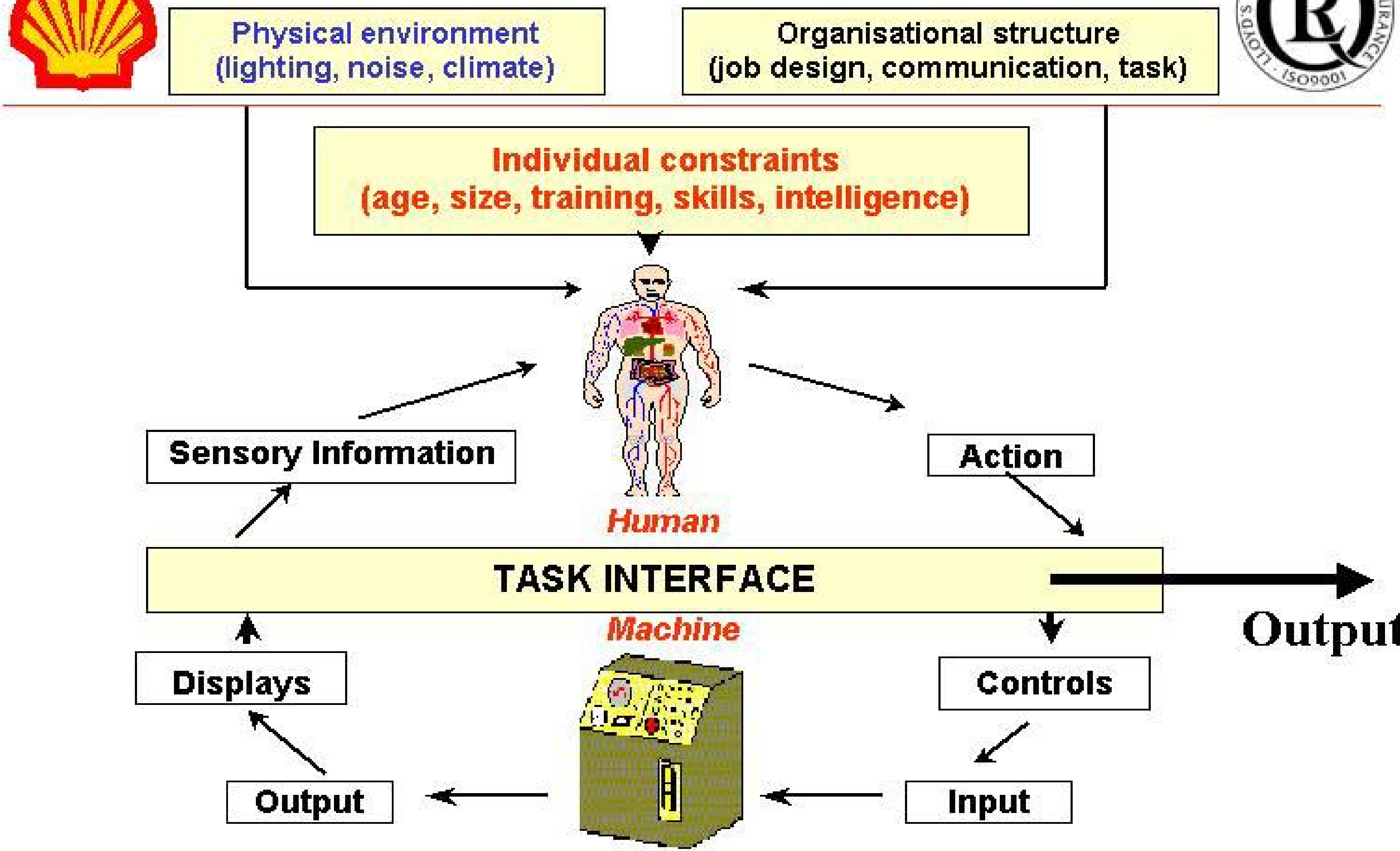
SC, OP
Gas and Power
E & P
Renewables



Business Objectives

- Eliminate *intrinsic* Human Machine Interface reliability-, efficiency, usability- and H & S risks
- Improve project profitability via:
    - Front end engineering
    - Use of ‘first time’ right ‘smart’ design tools
    - Use of “knowledge floor”
    - Structured “buy in” process of stakeholders

Human Machine Interface Model



Physical Interface

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Cognitive Interface

Business case

Why improving operations and maintenance tasks?

Conclusion pre start-up safety review Hycon (1988)

"It has to be concluded that during engineering stage the opportunity could have been further exploited to optimise the design without increasing CAPEX in many cases.

This refers particularly to the fields of operability, accessibility and maintainability."

Business case

Why improving operations and maintenance tasks?

Lessons learnt RAYONG refinery project (1996)

"Basic concept not an operationally friendly machine".

Business case

Why improving operations and maintenance tasks?

RAYONG project (1996) lessons learnt

Instrumentations

- DCS graphics were designed by main contractor with minor input of Ops. at an early stage
- too much information on screens
- to go through 5 screens to get to an alarm
- far too complex which complicates start up
- alarms poorly specified
- risk of panel men loosing confidence in system!

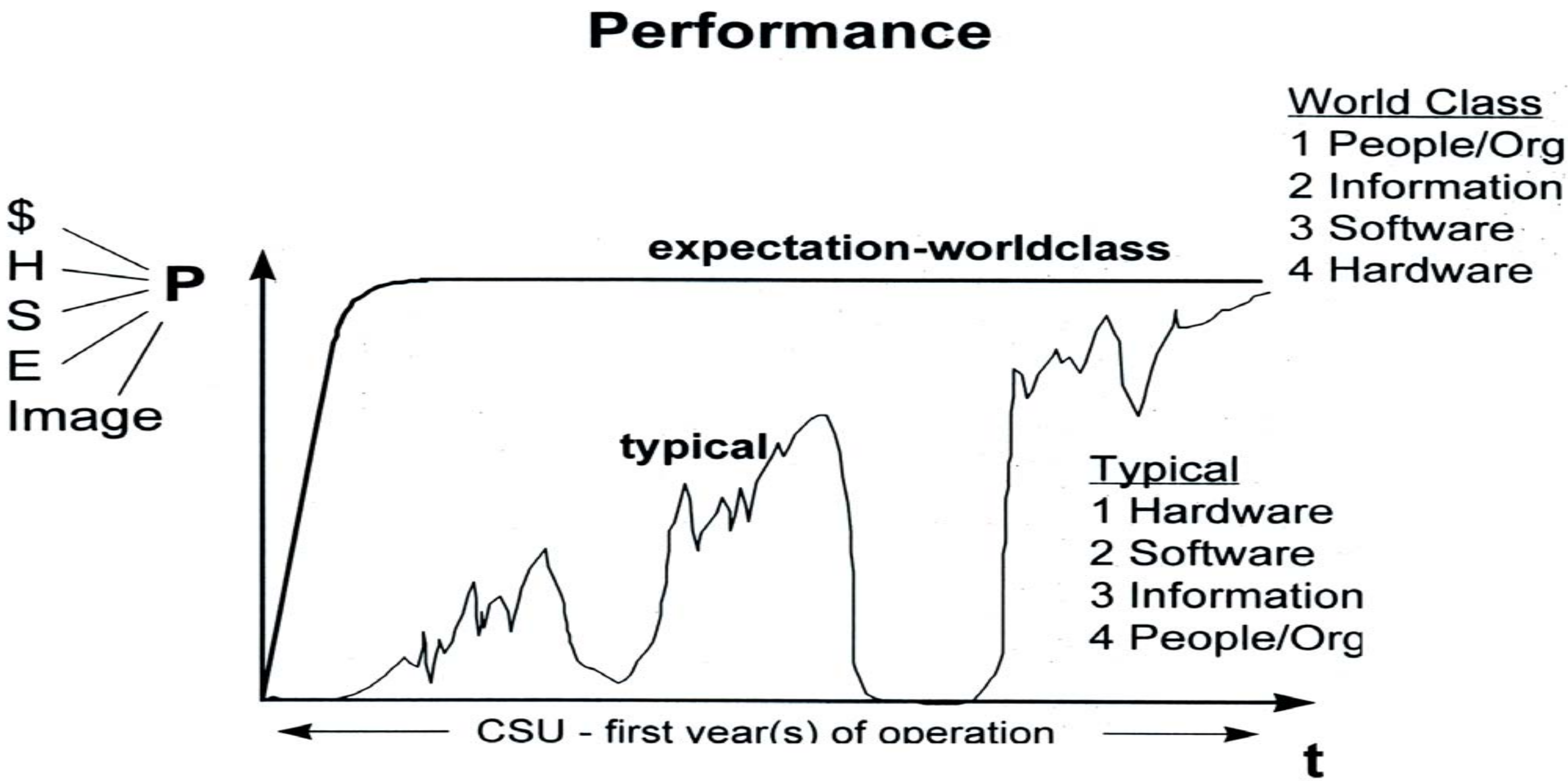
Business case

Why improving operations and maintenance tasks?

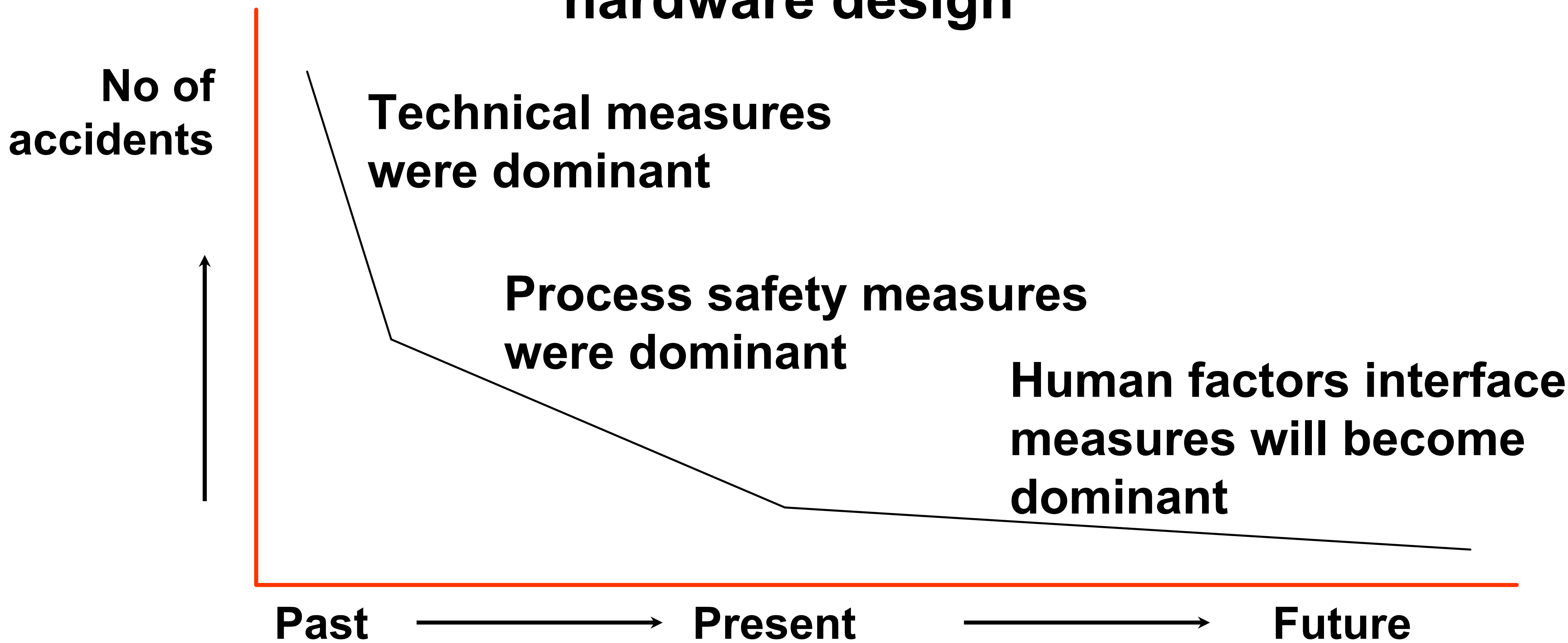
Project management issues

- **60 % of bottlenecks identified during Model review sessions are related to Operability and Maintainability**
- **Re-vamp/- design effort first 2 years after start up often related to solve operational and maintenance misfits as a result of insufficient input during Conceptual design**

World class Projects



Literature "Development HSE improvements in hardware design"



Conclusion 'traditional' design process

- No balanced input of process, safety, OPS. and Maintenance criteria during conceptual design
- Poor (too late) dilemma handling
- Limited input in conceptual design of future Ops./M. tasks
- Insufficient & ineffective input of "work floor" experience
- HMI specifications are no part of BOD/BDEP documents
- Lack of 'change mgt.' approach in critical , i.e new designs

↓

Sub optimal design of operational/maintenance tasks

↓

Increase of project & life cycle costs

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Ergonomic Management & Information System (EMIS®)

Policy & Organisation documents

Training
- Video/CD ROM
- Engineering workshops
- etc.

Project Management & QA
- Cost/benefit model
- Procedures
- Auditing
- etc.

Engineering tools
- FEEEM®
- IVA®
- Best practices
- Checklists
- etc.

Procurement
- Plant equipment,
- Skid Units
- Tools,
- etc.

Construction
- "Field run" equipment
- Contractor workshops

International Standards

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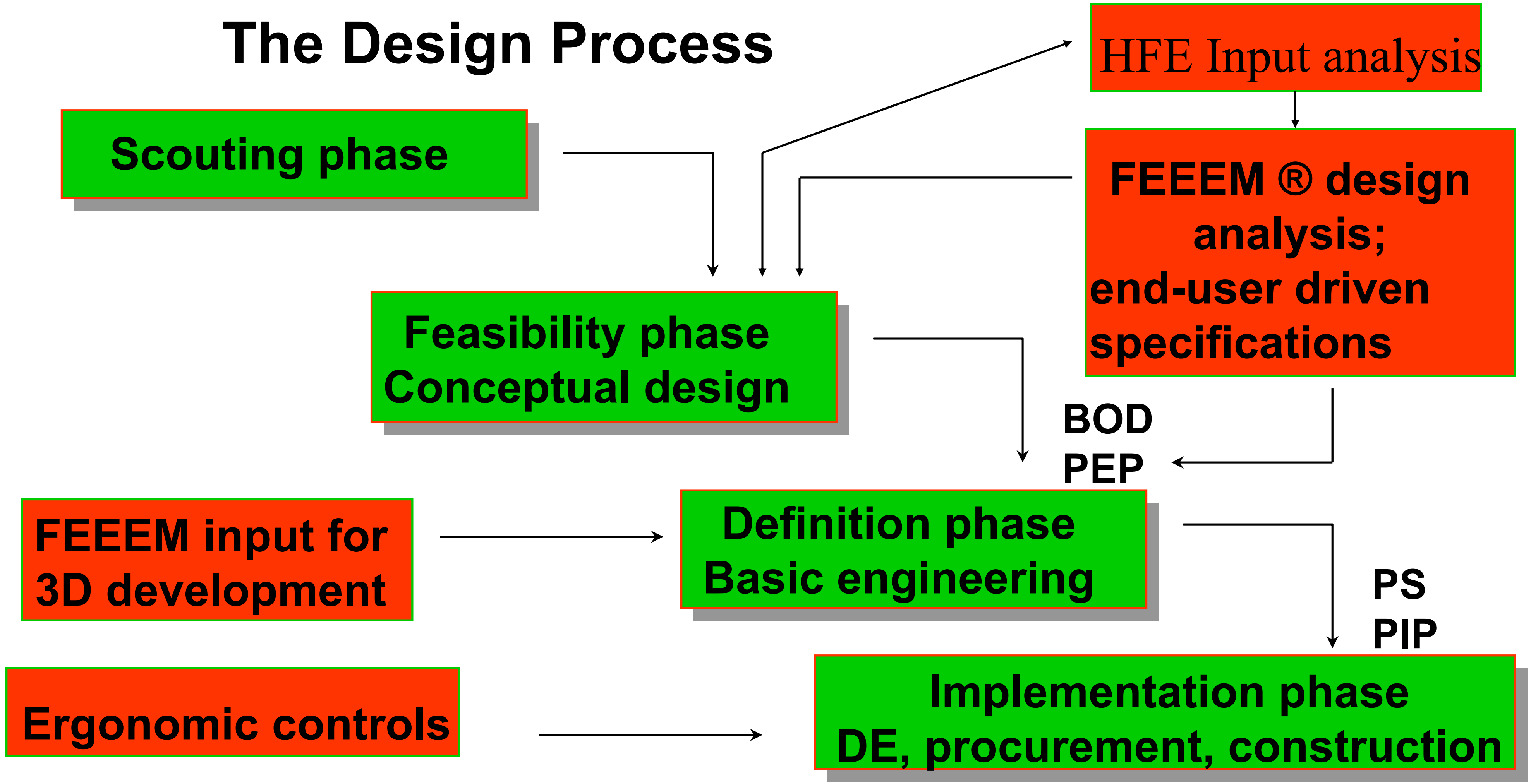
The Design Process



Evaluation of system efficiency after start up → Post Implementation Review

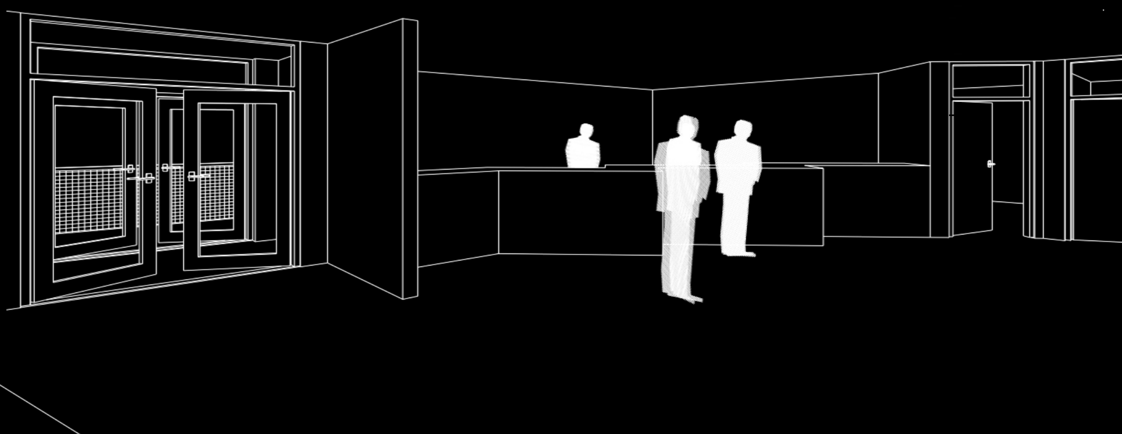
Examples *Smart* design tools

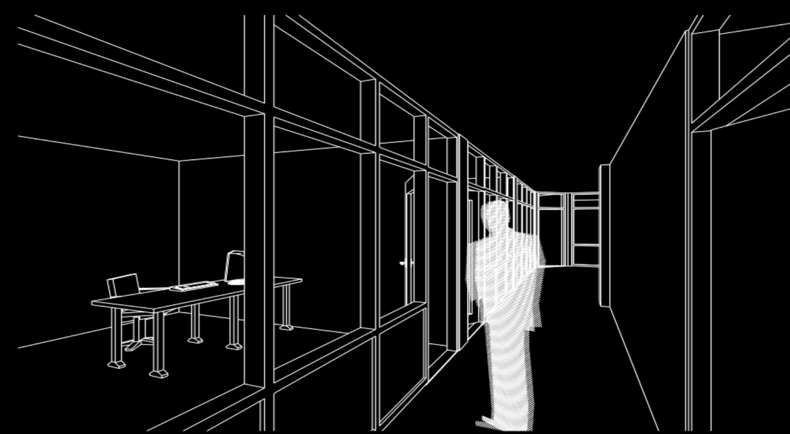
1. Functional Control room building and DCS cockpit design (FEEEM ® analysis)
    - Link analysis and Relation diagram
    - 3 D CAD visualizations

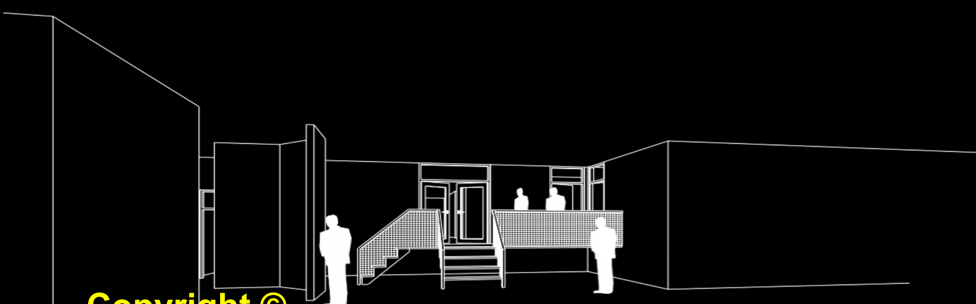
2. Plant lay out and Valve operations (IVA®)

3. Graphical design lay out process (AH coding ®)

Upgrader Main Control room Centre and Workshop Building
Athabasca Oil Sands Downstream Project
Shell Canada, Calgary

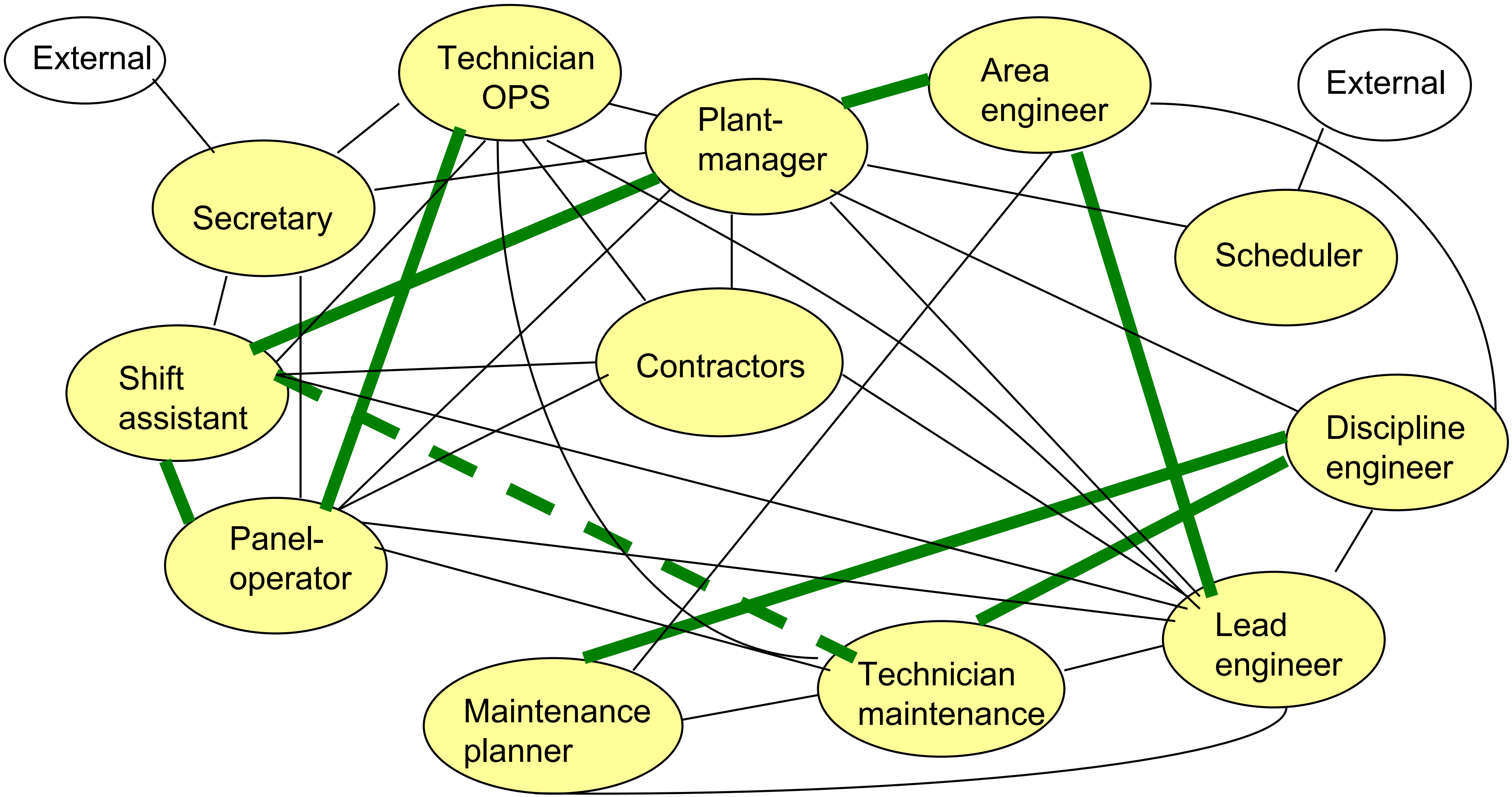






& Co architectuur en visualisatieBeukelsweg 34a 3022 GJ Rotterdam

Link-analyses CCR / Engineering Functions frequency daily communication



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LLOYD'S REGISTER QUALITY ASSURANCE · ISO9001

INTERFACE RELATIONSHIP MATRIX FOR CENTRAL CONTR

	Function	Area (sq.m.)*	Control Room	Storage (Bottles)	Exercise Space	Rackroom	OC (7x)	AMC (4x)	OE (5x)	Planning (2x)	UPS	Supervisory Comp.	Comm. Auxiliary	Shift Supervisor	Ext. Entrance to Bldg	Kitchen for Ops	Library/copier/fax	Permit	Smoke Area	Washrooms	Lab	Trai
1	Control Room	240		H	M	L	M	L	L			M	L	M		H	L		L	M		L
2	Storage (Bottles)	3	H																			
3	Exercise Space	8	M																			
4	Rackroom	75	L								L	H	L									
5	OC (7x)	105	M				H	H	H					M			M					M
6	AMC (4x)	60	L				H	H	M	H				M			M					
7	OE (5x)	75	L				H	M	H	L				L			M					
8	Planning (2x)	30						H	L	H				L			M					
9	UPS	65				L																
10	Supervisory Comp.	40	M			H																
11	Comm. Auxiliary	30	L			L																
12	Shift Supervisor	20	M				M	M	L	L							M					
13	Ext. Entrance to Bldg																					
14	Kitchen for Ops	35	H																			
15	Library/copier/fax	25	L				M	M	M	M				M								
16	Permit	20																				
17	Smoke Area	~~15~~	L																			
18	Washrooms	55	M																			
19	Lab	25																				
20	Training/Simulator	30	L				M															
21	Showers	10	L																			
22	Maint. Craft Offices**	90						M		M												
23	First Aid	10																				
24	Cloak Room/ERT	50													M / H							
25	Storage for Stationery	5	M																			
26	Meeting Room (2x)	60	M																			
27	Mech/HVAC	300				H																
28	Common Lunchroom	70																		H		
29	Janitor	5																				
30	Vending Machine	5																				
31	Optimization	20	H						H													

* Areas listed above represent an estimate of the space required for each function. These areas were estimated prior to development of layout drawings, and do NOT represent a

** Maintenance Craft Offices: (3x20) + (1x30) = 90

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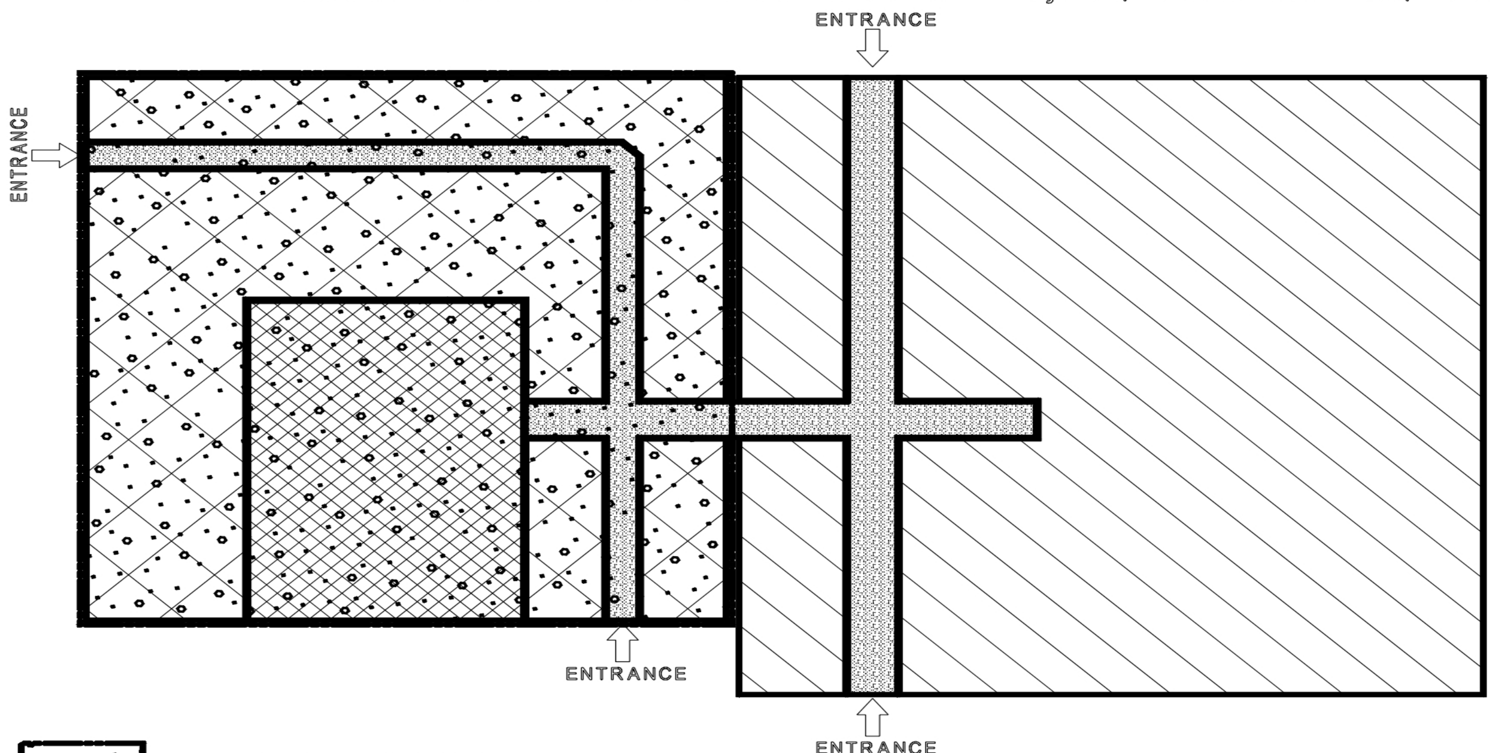
BLOCK MODEL
Upgrader Main Controlroom Centre and Workshop Building
Athabasca Oil Sands Downstream Project, Shell Canada, Calgary



Conceptual Design Guidelines

* Building concept allows for minimum blast proof area.
* To improve communications and optimise logistics, lay out is based on the functional requirements defined by the relation diagram analysis.
* The lay out of the control room building is designed to ensure acces to panel room is restricted to operations team and essential other users only principle is reflected by the one door entree only.
* The lay out of the panel room allows routine verbal communications between the various sections.
* The configuration of the console's allows 2 persons to function effectively during up set or emergency
* The lay out of the cockpit shaped console's allows sufficent space for integrated writing and reading tasks, thereby minimising other VDU workplaces in control room area, enhancing a quiet atmosphere.

BLAST PROOF AREA
CONTROL ZONE (PRIMAIRY PROCESS)
FACILITATING ZONE (SECUNDAIRY PROCESS)
THIRD PARTY ZONE (THIRD PROCESS)
CORRIDOR

& Co architecture and visualization Beukelsweg 34a 3022 GJ Rotterdam	
UPGRADER MAIN CONTROLROOM CENTRE AND WORKSHOP BUILDING Athabasca Oil Sands Downstream Project, Shell Canada, Calgary BLOCK MODEL Date 20-04-2000 Revision - Scale -	no 1 of 6
Copyright Human Factors Engineering, Health Services, Shell International BV The Hague Phone 00 31 70 3771690 Appendix to FEEEM® report HE00.027 Author H.J.T. Rensink & C. van Eijsden/ Custodian H.J.T. Rensink	

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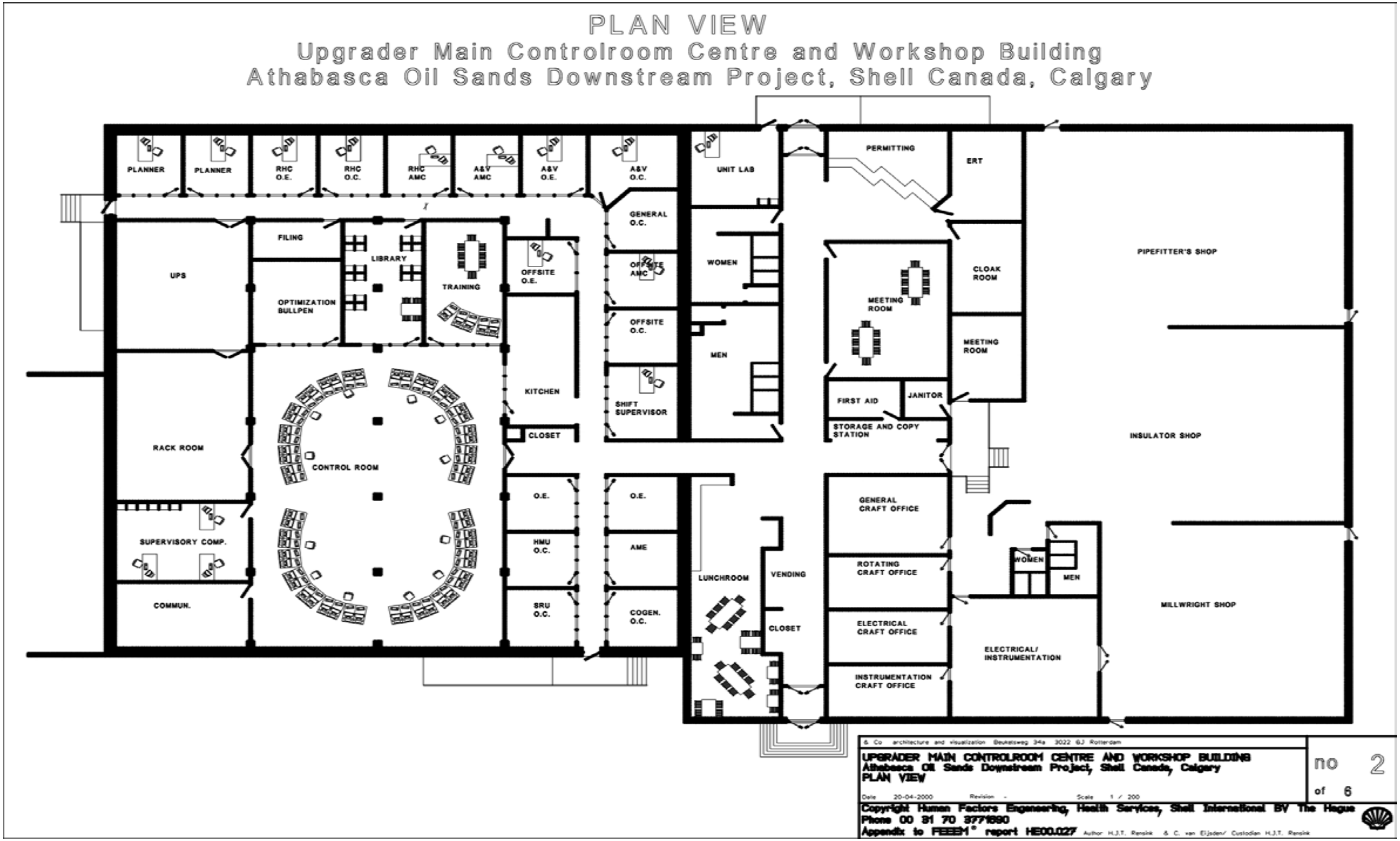

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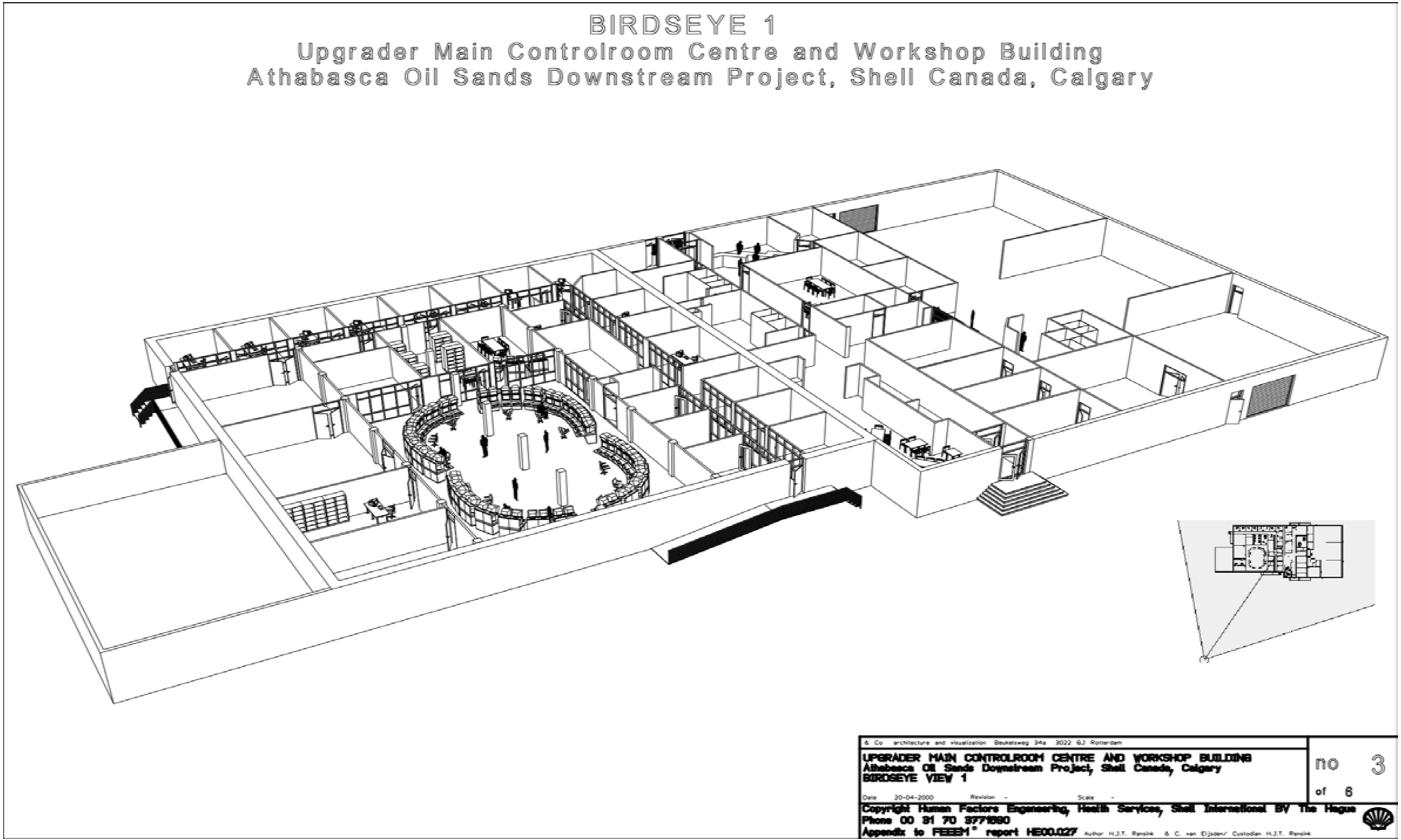

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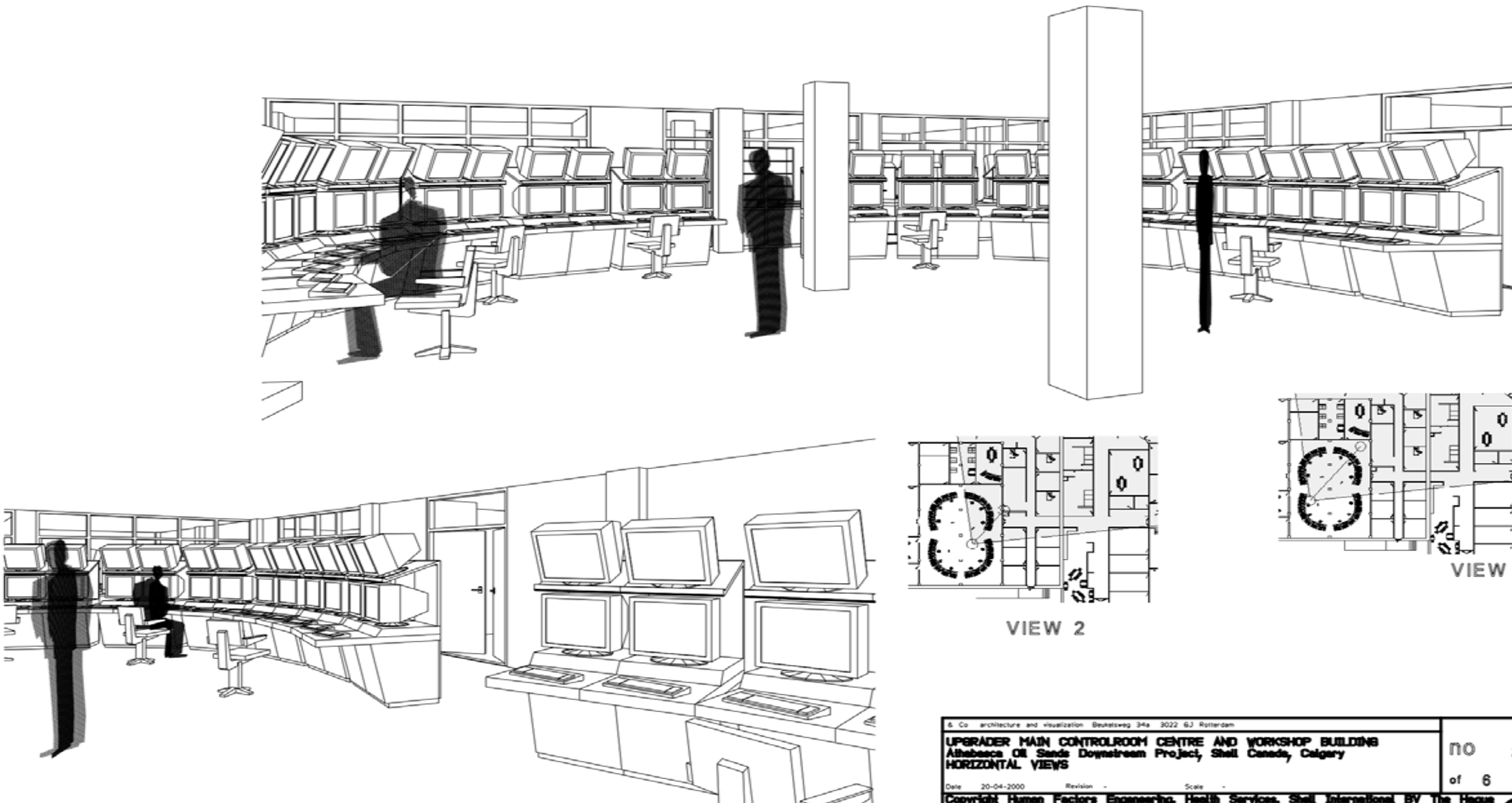
HORIZONTAL VIEWS
Upgrader Main Controlroom Centre and Workshop Building
Athabasca Oil Sands Downstream Project, Shell Canada, Calgary



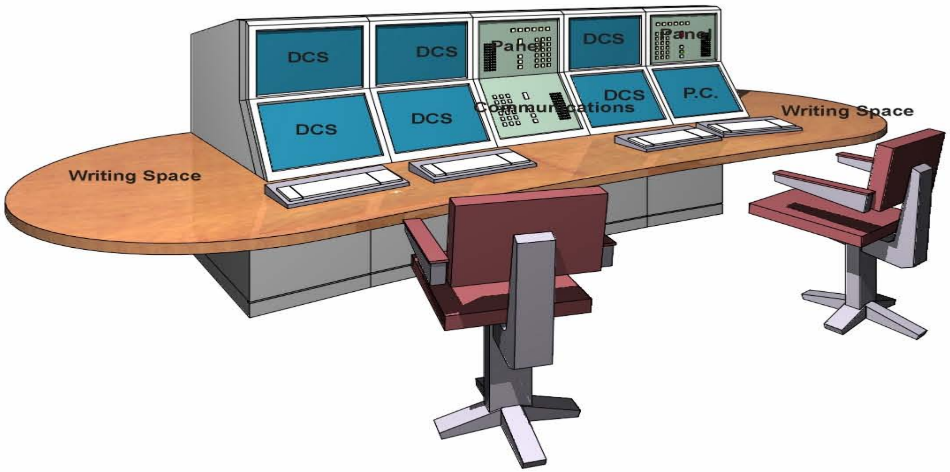
& Co architecture and visualization Beukelsweg 34a 3022 GJ Rotterdam	
UPGRADER MAIN CONTROLROOM CENTRE AND WORKSHOP BUILDING Athabasca Oil Sands Downstream Project, Shell Canada, Calgary HORIZONTAL VIEWS Date 20-04-2000 Revision - Scale -	no 5 of 6
Copyright Human Factors Engineering, Health Services, Shell International BV The Hague Phone 00 31 70 3771690 Appendix to FEEEM® report HE00.027 Author H.J.T. Rensink & C. van Eijsden/ Custodian H.J.T. Rensink	

ERGONOMICS

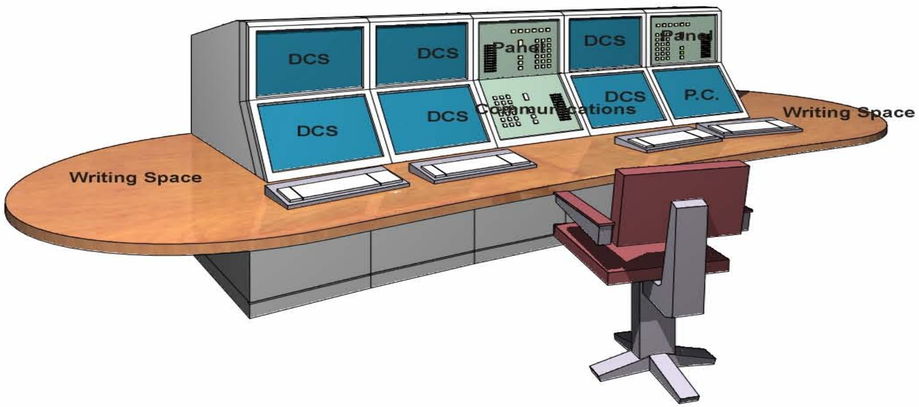
“Cockpit-design” DCS console’s principles

Variant 2 : DCS Separated Through Instrument Panel And Communications Panel

Critical operation mode : **2** paneloperators



Normal operation mode : **1** paneloperator



Based on : maximum DCS-screens in critical situations is 6 DCS screen’s

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CONTROL ROOM ERGONOMICS COCKPIT-DESIGN DCS CONSOLE'S PRINCIPLES Variant 2 Design C. van Eijsden Date 20-04-2000 Revision 30-05-2000 Scale -	no 2 of 3

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Appendix to FEEEM® report HE00.027 Author H.J.T. Rensink & C. van Eijsden/ Custodian H.J.T. Rensink

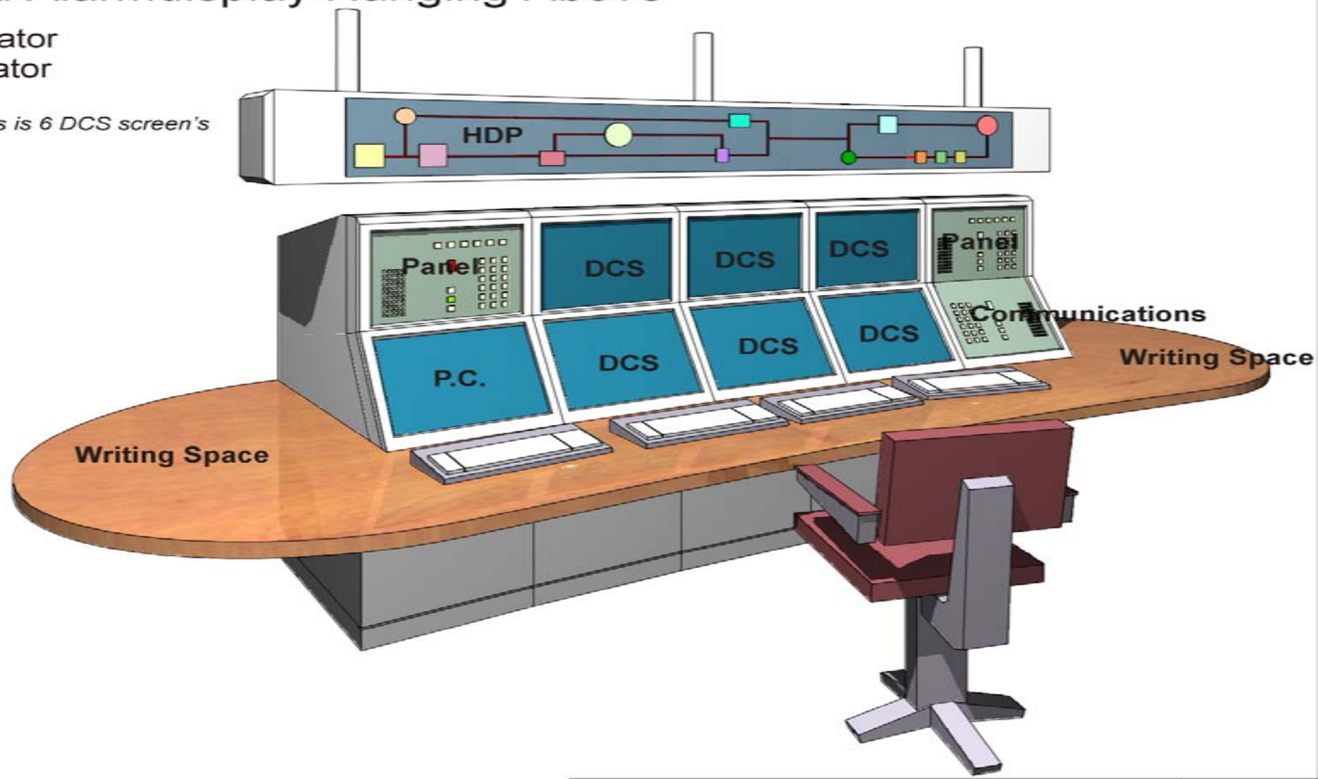
Shell International Health Services
Usability & Human Factors Engineering

ERGONOMICS

“Cockpit-design” DCS console’s principles
Variant 3 : Using Hardwired Alarmdisplay Hanging Above

Normal operation mode : **1** paneloperator
Critical operation mode : **1** paneloperator

Based on : maximum DCS-screens in critical situations is 6 DCS screen’s



& Co architecture and visualization Beukelsweg 34a 3022 GJ Rotterdam

CONTROL ROOM ERGONOMICS
COCKPIT-DESIGN DCS CONSOLE'S PRINCIPLES
Variant 3
Design C. van Eijsden
Date 20-04-2000 Revision 30-05-2000 Scale -

no 3 of 3

Phone 00 31 70 3771690
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Shell International Health Services
Usability & Human Factors Engineering

Smart tool for Improving Plant & Equipment lay out

Identification of Valves analysis (IVA ®)

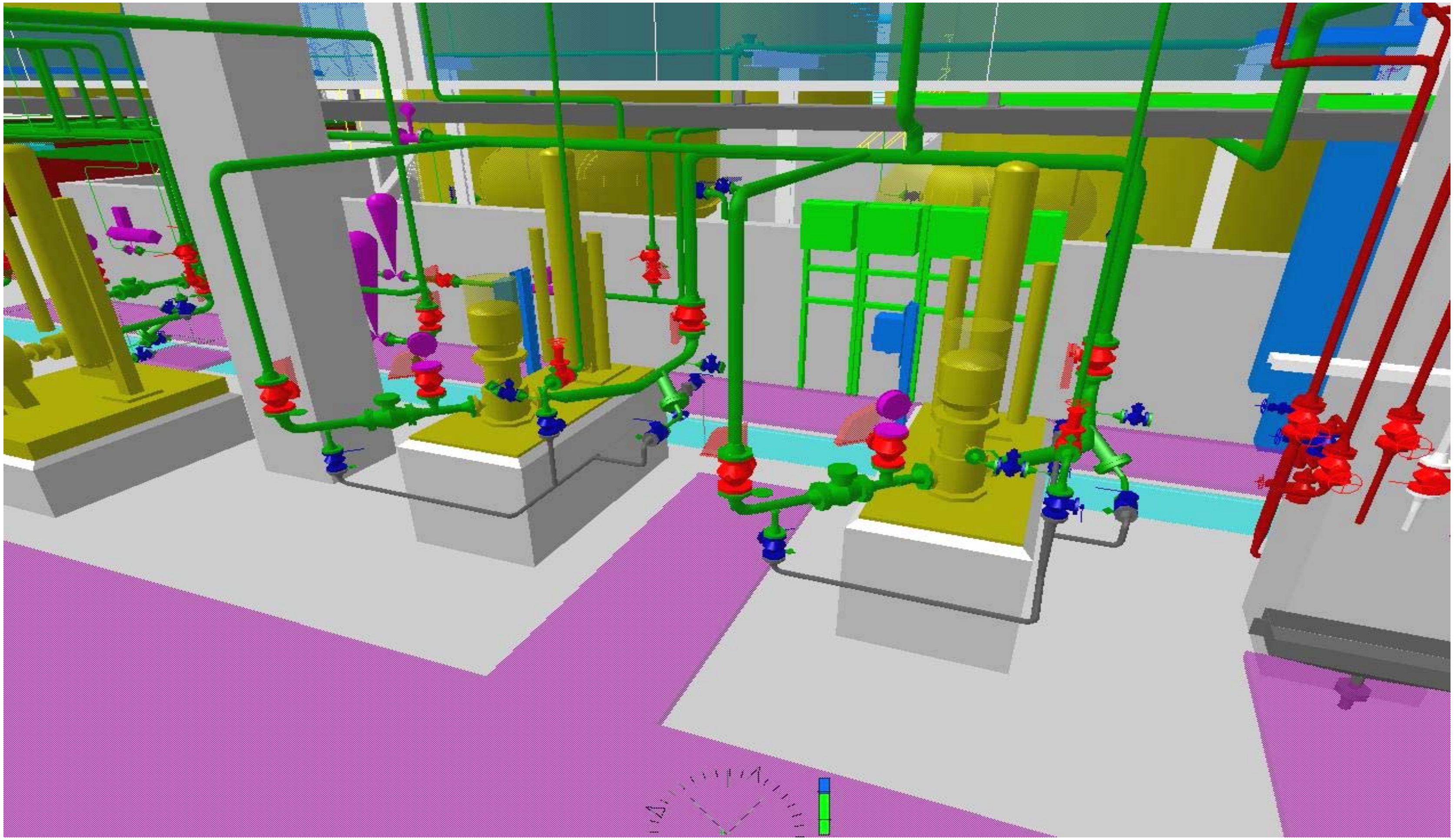
An *up front* identification and categorization process of Valves according:

- Category 1; Critical valves
- Category 2; Operational valves
- Category 3; Non operational

Aim :

to delete misfits in *Critical* valve operations and to manage 'fit for purpose' design for all valves operations

Assurance Category 1 valves via color coding in 3 D CAD



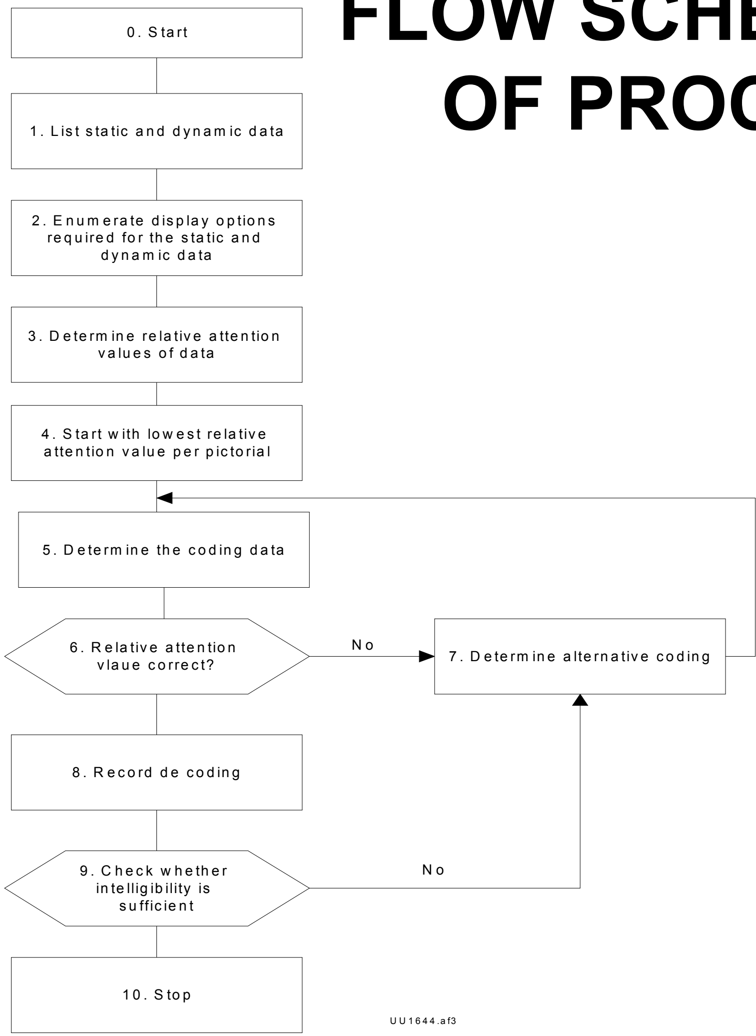
Graphical display audit results (reference project)

- Insufficient discrimination of alpha numeric characters is applied,
- Irrelevant information to the operator is shown,
- Generally accepted norms of application of colours are violated,
- Inconsistencies in static information presentation is present,
- Display design has been made decorative at the expense of their being readable and interpretable.

Conclusions

Graphical Display designs did not improve e.g. retrieval times, mis-readings and intuitive use of controls. The quality of the design of the Graphical Display leads to an unnecessary and unwanted higher risk for miss operations.

FLOW SCHEME FOR ERGONOMICS CODING OF PROCESS DATA FOR PICTORIALS



Benefits

Elimination of re-work.
Reduction of errors in ops.
Improved intelligibility of information
Reduction of search times.
Consistent reproduction of information
Standardization of pictorial layout.
Reduction of mental effort.
Intuitive and reliable operator control.

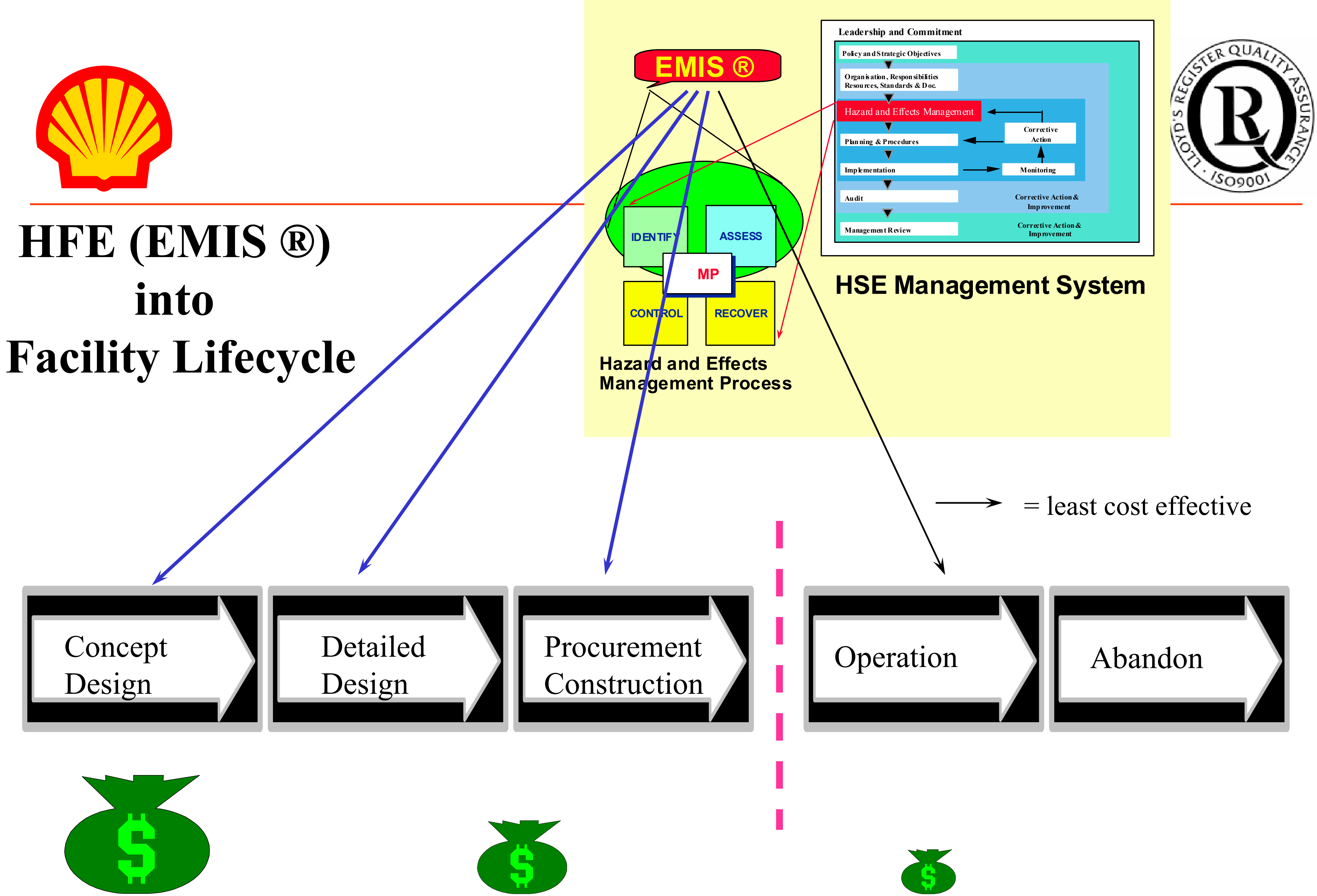
ATTENTION HIERARCHY (AH ®) CODING
SMART tool
Information presentation

Low attention level → High attention level

CODING POSSIBILITIES

Location	Shape	SIZE	Background	Color
Decentral	Thin line		Non	Grey
Domination increase	*Contrast increase*		*Contrast increase*	*Contrast increase*
Central	**Thick line**	SIZE	**Blinking**	**Red blinking**

↓ High attention level


HFE (EMIS ®)
into
Facility Lifecycle
EMIS ®
IDENTIFY
ASSESS
MP
CONTROL
RECOVER
Hazard and Effects Management Process
Leadership and Commitment
Policy and Strategic Objectives
Organisation, Responsibilities Resources, Standards & Doc.
Hazard and Effects Management
Corrective Action
Planning & Procedures
Implementation
Monitoring
Audit
Corrective Action & Improvement
Management Review
Corrective Action & Improvement
HSE Management System
LLOYD'S REGISTER QUALITY ASSURANCE
ISO9001
= least cost effective
Concept Design
Detailed Design
Procurement Construction
Operation
Abandon

Benefit areas Usability & HF Engineering

(reference EMIS.PMQ.07)

Relation to stakeholders

share holders & clients	Operability	Safety	personnel
		Health	
	Maintenance	Environment	society
	Reliability	Legislation	government
		Labour turnover	

Quantify and/or rank

Economical benefits User Centered Design

Based on historical data so far

• Reduction CAPEX	0.25% - 5%
• Reduction engineering hrs.	1% - 10 %
• Reduction re work: less rework, less late changes	1 % - 5%
• Reduction project duration time •reduced approval cycles	up to 40 %
• Reduction Ops./Maintenance TCoO	3 - 6 % per year

Non-economical benefits

Based on historical data so far

Improvement HSE/working conditions	H*
Improvement commitment end users	H
Improvement of client "buy in"	H
Improvement functional design; • versus gold plated design	H
Improvement competence of project team	VH
Competence improvement project team re. Ops./maintenance requirements	VH
Improvement communication Owner / Project team & EPC contractor	H

* impact ranking on issue: Low, Medium, High, Very High as per client feedback

Typical costs
Usability and HF Engineering

Based on historical data so far

Depending on complexity of project scope
0.004 - 0.9 % of Engineering costs (= 15 % CAPEX)

Critical Success Factors

- Awareness of cost/benefits
  - CAPEX reduction potential & TCoO commitment
- Management commitment *front end loading*
  - early availability of operational philosophy, staff
- Competence project participants
- Integration in Project QA system (Owner & EC!)
- Front end user participation
  - capture ‘work floor’ knowledge via FEEEM ® analysis process
- Multi-disciplinary dilemma handling
- Fit for purpose tools and procedures

When astronaut John Glen was asked what he was thinking about just before lift off from Cape Canaveral, he replied:

"*Here I' am sitting on top of thousands of critical components and all of them made by the lowest bidder !*"

2cnd International Workshop on Human Factors In Offshore Operations. April 8-10, Houston.

Analysis of Human Factors Related Accidents and Near Misses

James Reason

Emeritus Professor

University of Manchester, UK

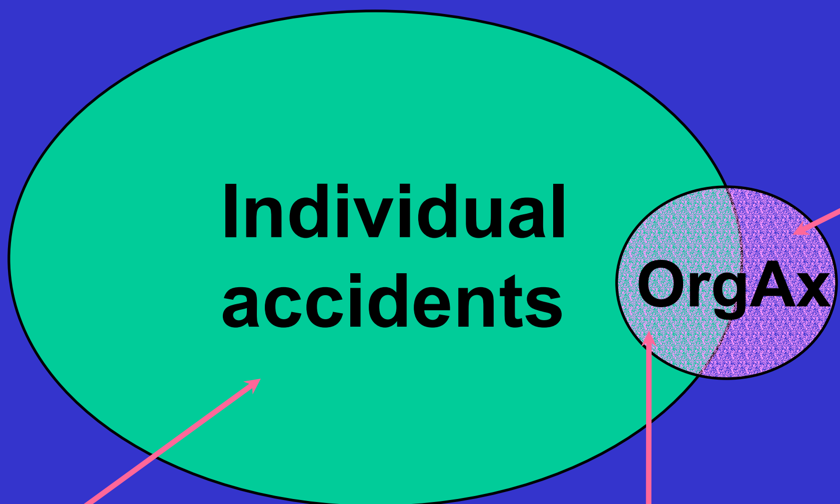
Two kinds of bad event

- Individual accidents: high frequency/low severity events—slips, trips, falls, bangs and knocks usually resulting in a few days absence from work (lost time injuries).
- Organizational accidents: low frequency/high severity events—explosions, collisions, collapses, releases of toxic substances, etc. Is system vulnerability adequately assessed by LTIs? NO!

Two ways of looking at human factors problems

- The PERSON approach
- The SYSTEM approach

Individual & organizational ax have different causal sets

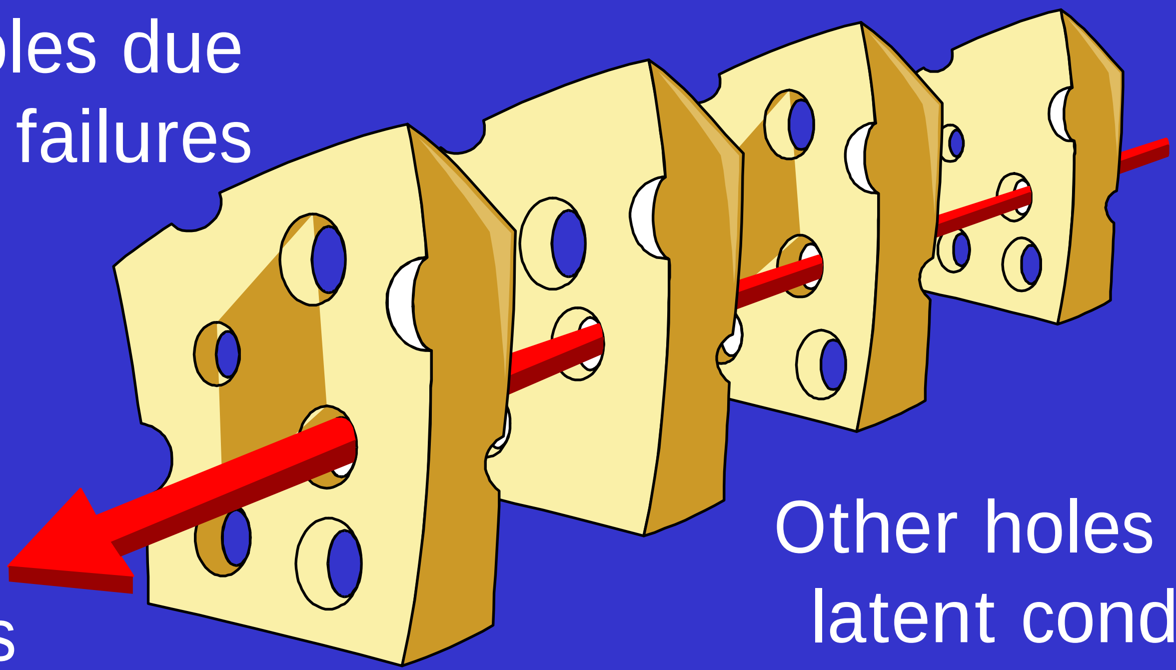


Arise from linked failures of multiple system defences (System model)

Failure of limited personal protection against injury (Person model)

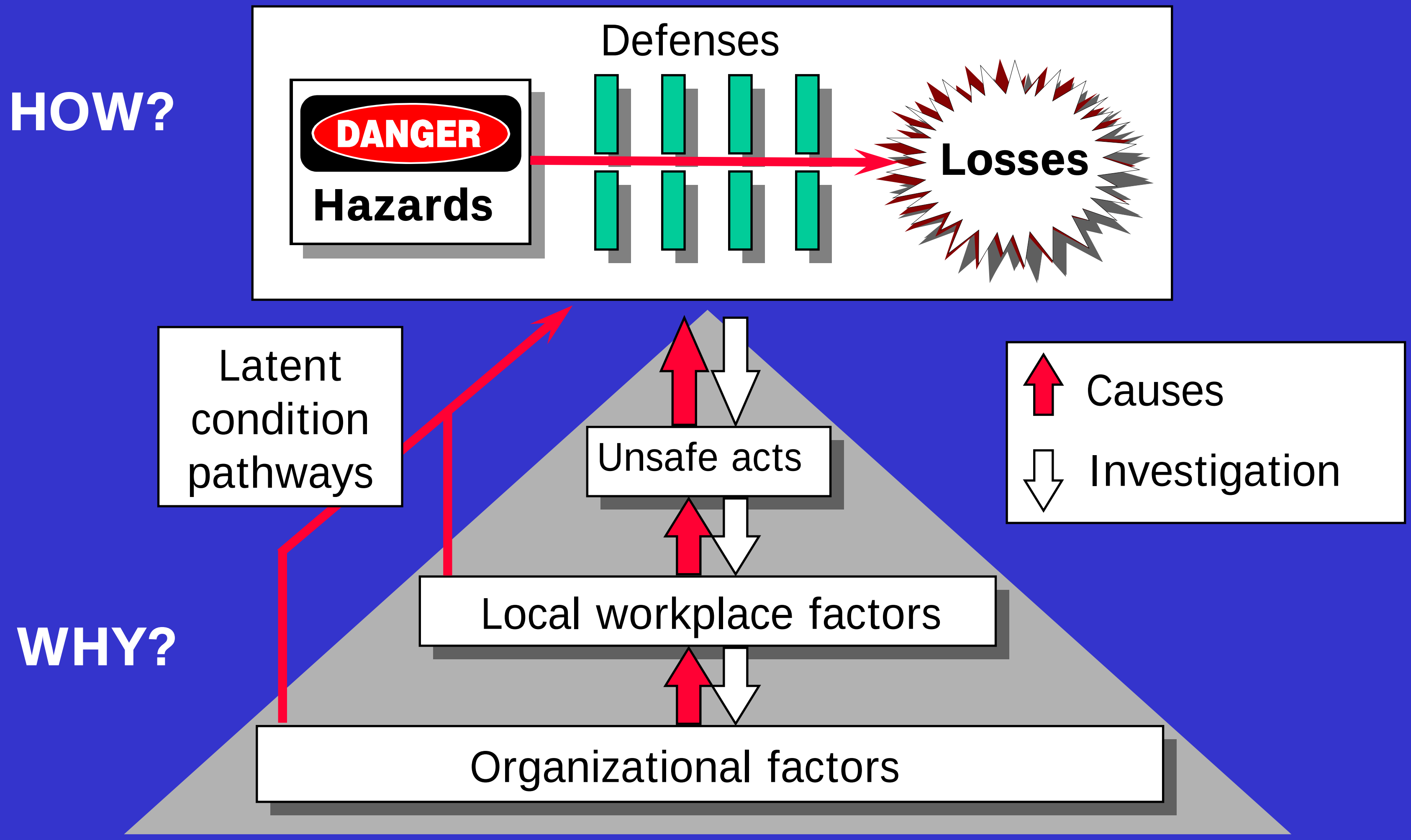
<u>Common ground</u>:
Inadequate resources
Poor safety culture
Commercial pressures

The 'Swiss cheese' model of accident causation



Successive layers of defences, barriers, & safeguards

How and why defenses fail



Matrix for defensive failures

FUNCTION / MODE	Engineered safety features	Standards policies controls	Procedures Instruction Supervision	Training briefings drills	Personal protective equipment
Awareness					
Detection Warning					
Protection					
Recovery					
Containment					
Escape					

Piper Alpha: Defensive failures

FUNCTION \ MODE	Engineered safety features	Standards policies controls	Procedures Instruction Supervision	Training briefings drills	Personal protective equipment
Awareness					
Detection Warning					
Protection					
Recovery					
Containment					
Escape					

Unsafe acts

- Slips, lapses, trips and fumbles
- Rule-based mistakes
- Knowledge-based mistakes
- Violations
  - Routine
  - Optimising
  - Situational

Rule-related behaviours

- Correct compliance
- Mistaken compliance (mispliance)
- Malicious compliance (malpliance)
- Mistaken circumvention (misvention)
- Successful violation
- Mistaken improvisation
- Correct improvisation

Workplace factors

- **Error factors**
  - Change of routine
  - Poor interface
  - Ambiguity
  - Educational mismatch
  - Negative transfer
  - Poor S:N ratio
  - Inadequate tools
  - Etc.
- **Violation factors**
  - Violations condoned
  - Equipment problems
  - Time pressure
  - Unworkable procedures
  - Supervisory example
  - Easier way of working
  - Poor tasking
  - Etc.

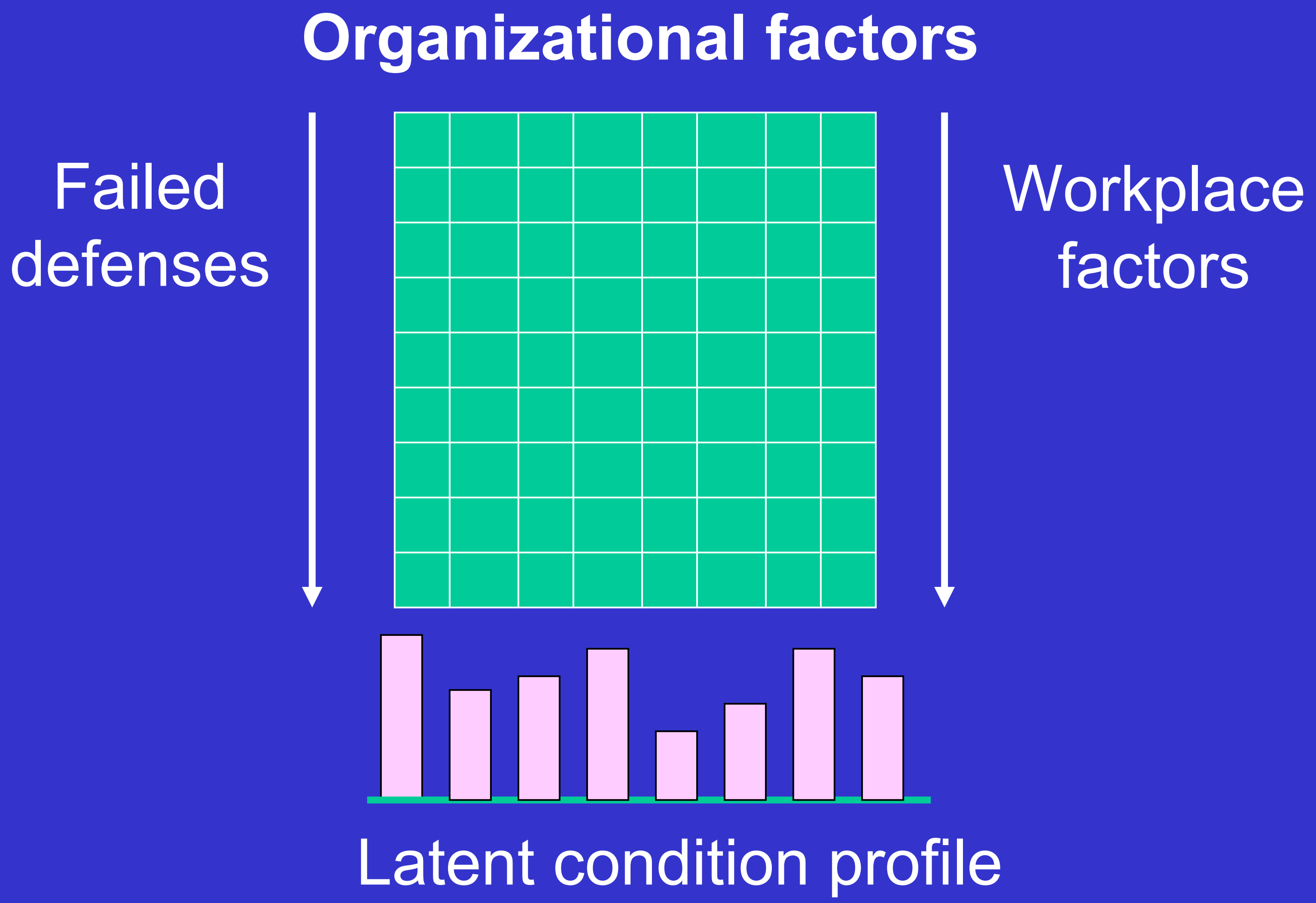
Organizational factors

- Training
- Tools & equipment
- Materials
- Design
- Communication
- Procedures
- Pressures
- Maintenance
- Planning
- Managing operations
- Managing safety
- Managing change
- Budgeting
- Inspecting, etc.

Accident investigation steps

- What defenses failed (mode/function)?
- How did each defense fail?
- Were there contributing unsafe acts?
- Workplace factors for each unsafe act?
- Organizational factors (latent conditions) contributing to defensive failures and workplace factors?

System contributions
(Single or multiple events)



Aims of HF event analysis

- Identify recurrent error traps
- Identify how and why defenses fail
- Identify upstream ‘pathogens’
- Rectify systemic weaknesses

TAKE HOME MESSAGE: YOU CAN’T CHANGE THE HUMAN CONDITION, BUT YOU CAN CHANGE WORKING CONDITIONS.

Behavior-Based Safety

Presentation

Human Factors Conference

Houston, TX

April 8th - 11th

2002

BST®

3 Types of At risk

- Enabled = within persons control - conditions and systems support
- Difficult = can be done but takes extra effort
- Non-enabled = not within persons control

Behavioral Science Technology, Inc.

The behavior-based performance improvement engine

Behavior-based Performance Improvement

- Production quality
- Customer service
- Error reduction
- Spill prevention
- Safety

Primary Concepts

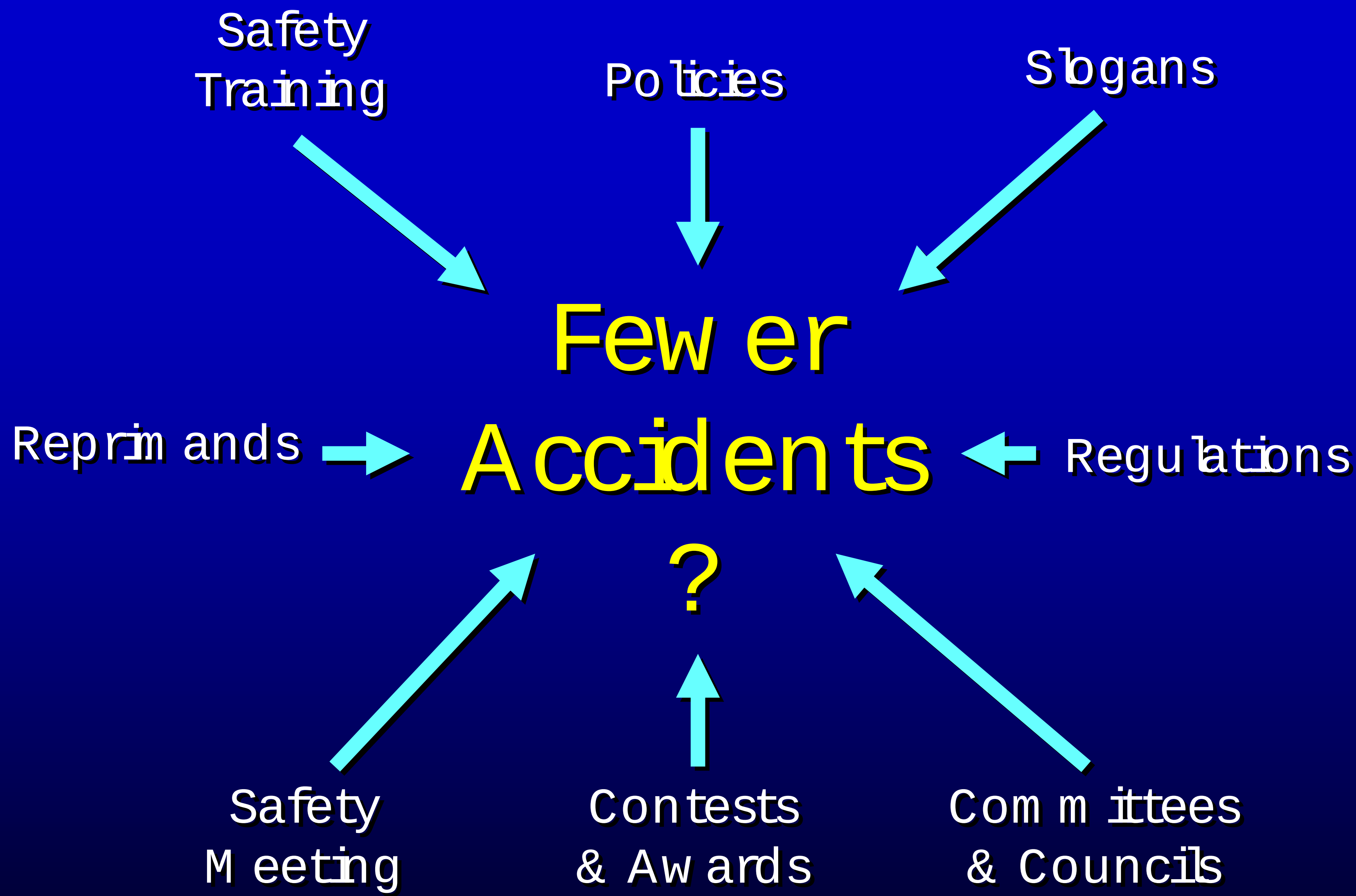
- Process not Program
- Adaptation vs adoption
- Employee Involvement
- Don't blame employees
- Parallels with quality
- Develop internal resources for implementation
- Objective: Continuous Improvement
- Mgmt & workforce must understand and buy-in

Barriers To Continuous Safety Improvement

Hazard recognition and response

- Business systems
- Rewards/recognition
- Facility and equipment
- Disagreement on safe practices
- Personal factors
- Culture
- Personal choice

BST®


Safety Training
Policies
Slogans
Fewer Accidents ?
Reprimands
Regulations
Safety Meeting
Contests & Awards
Committees & Councils

BST®

Safety Activities

Fewer At-Risk Behaviors

Fewer Accidents


Fatalities
Lost Time Accidents
Medical Treatment
First Aids
Near Misses
Non-enabled
At-Risk Behaviors
Enabled
Enabled
Difficult
Difficult
Non-enabled

Behavior

An
Observable
Act

ABC Analysis

Antecedents

Anything which precedes and sets the stage for Behavior

Behavior

An observable act

Consequences

Anything which directly follows from the Behavior

Understanding System Influences

ABC Analysis

Antecedents

Goggles don't fit

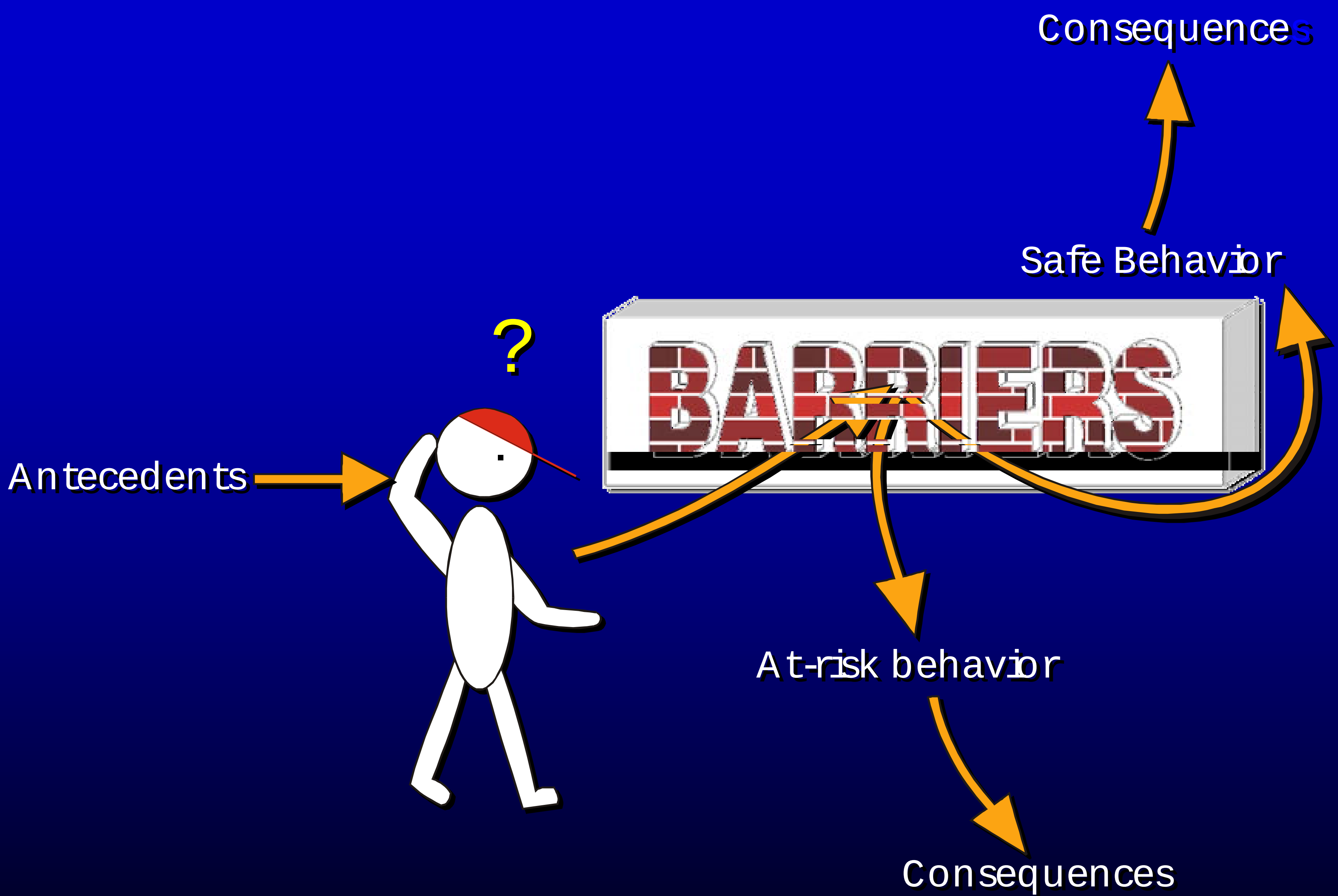
Goggles are in poor condition

Behavior

Worker fails to wear goggles when grinding

Consequences

Comfort   Better Vision   Exposure to Injury


Consequences
Safe Behavior
BARRIERS
Antecedents
?
At-risk behavior
Consequences

The CBI® Tools

- List of behaviors that have caused accidents
- Extracted from accident data
- Steering committee adds others based on their knowledge of workplace behavior

Part One — CBI® Data Sheet

Critical elements

- No names / no discipline
- Behaviors grouped into categories
- Selected variables used for sorting data
- Comment section

Part Two — CBI® Definitions

- Establishes in observable terms a consistent measurement of workplace behavior
- Ensures consistency between observers and observations
- Definitions are not a rewrite of rules and regulations

Example Definition

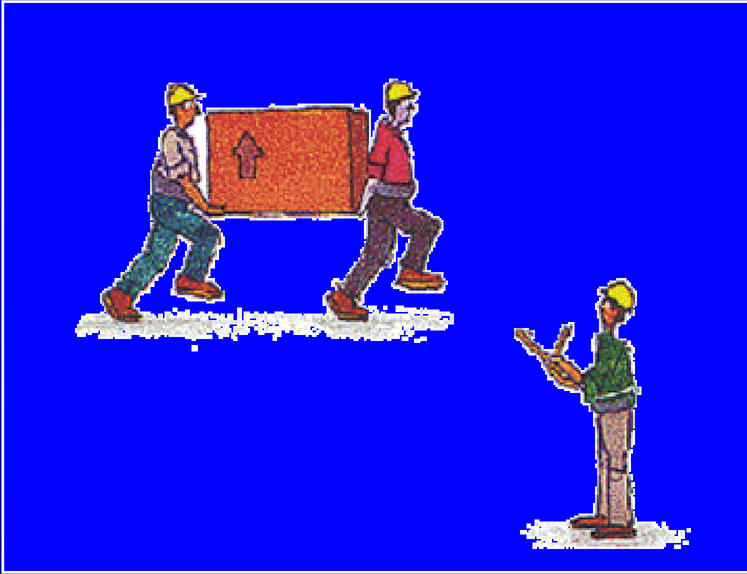
4.1 Line of Fire:

Is the person positioning self to avoid getting contacted, sprayed, overexposed, struck or hit by something if it lets go, gives way, releases or falls?

For Example –

1. Is person avoiding standing under suspended load?
2. Is person standing out of path of flying debris?
3. When breaking flange does the person break nuts farthest away first?
4. Does person avoid looking into pipe being rodded out?

Observers



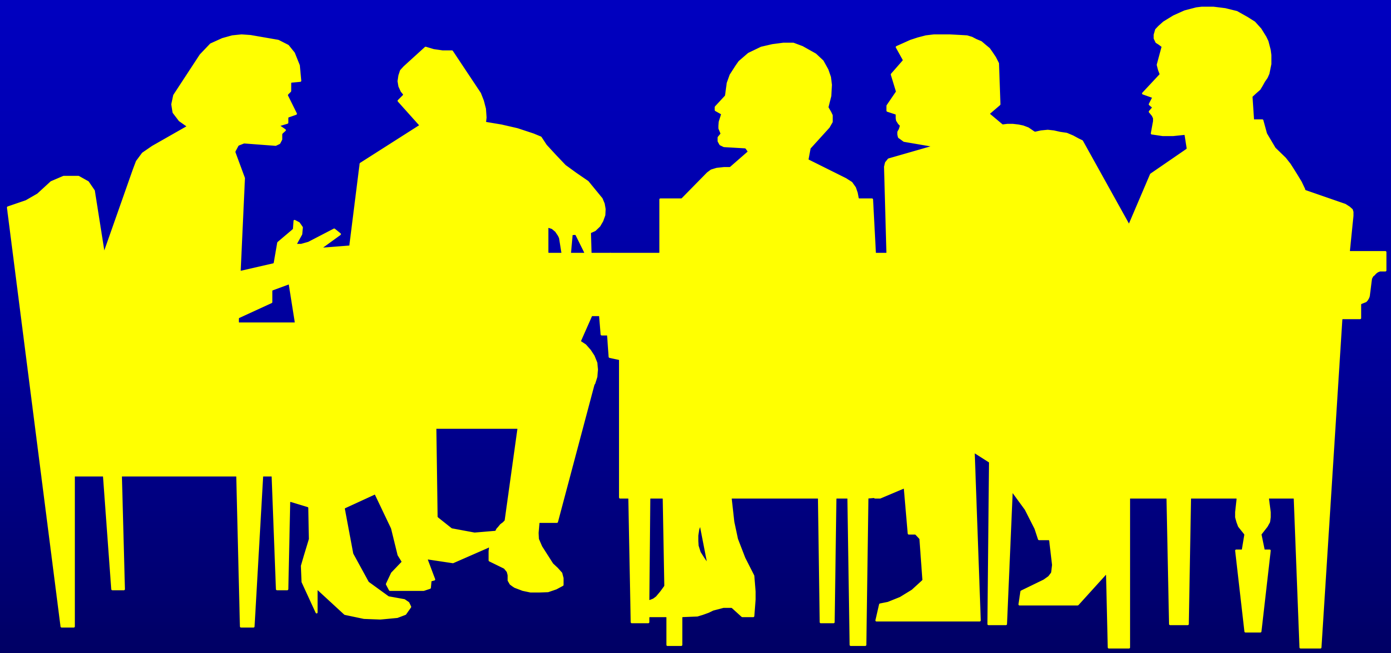
TO START: Train a Core Group of Hourly Workforce

GOAL: 100% of Site Population Trained

Typical Frequency of Observation

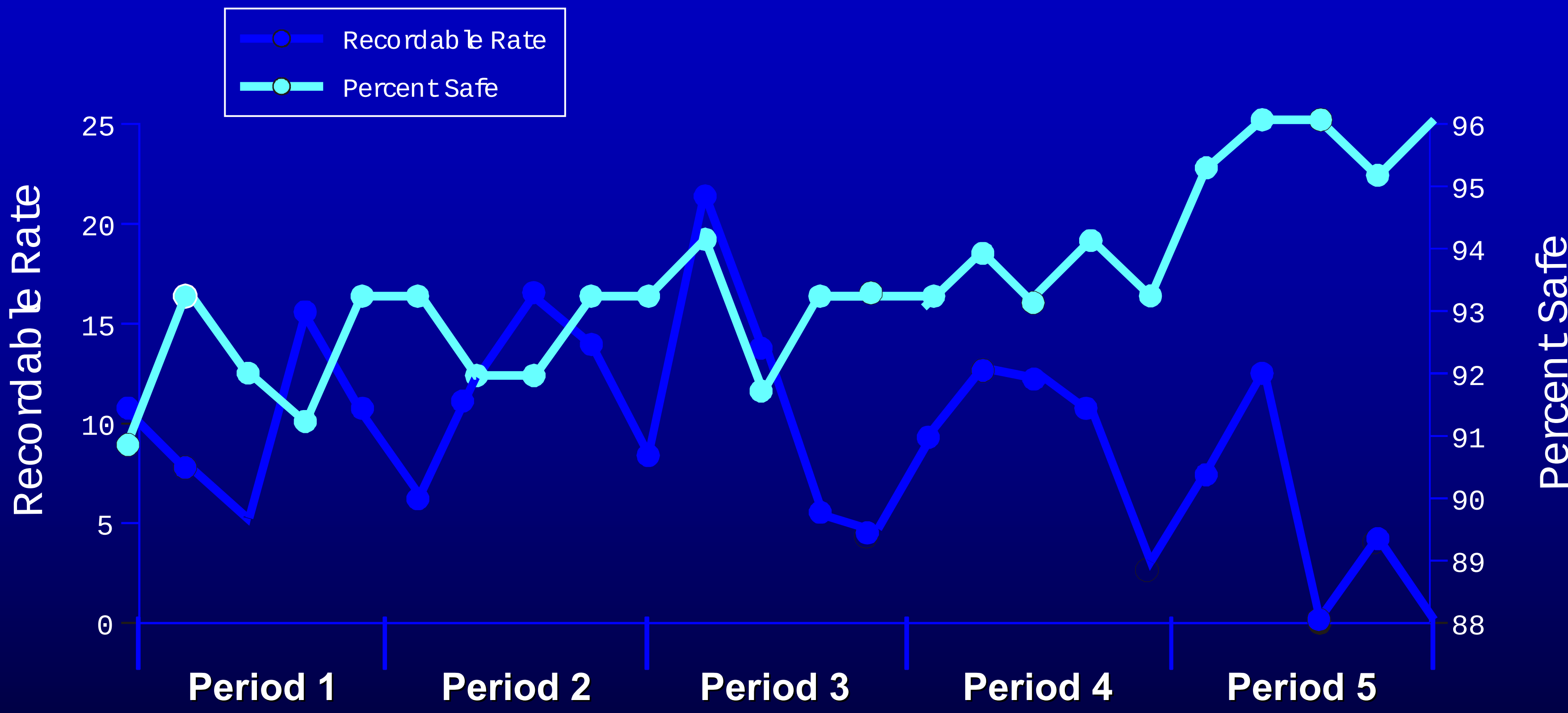
TO START: 2 per week Per Observer

DURATION: 5 – 30 Minutes

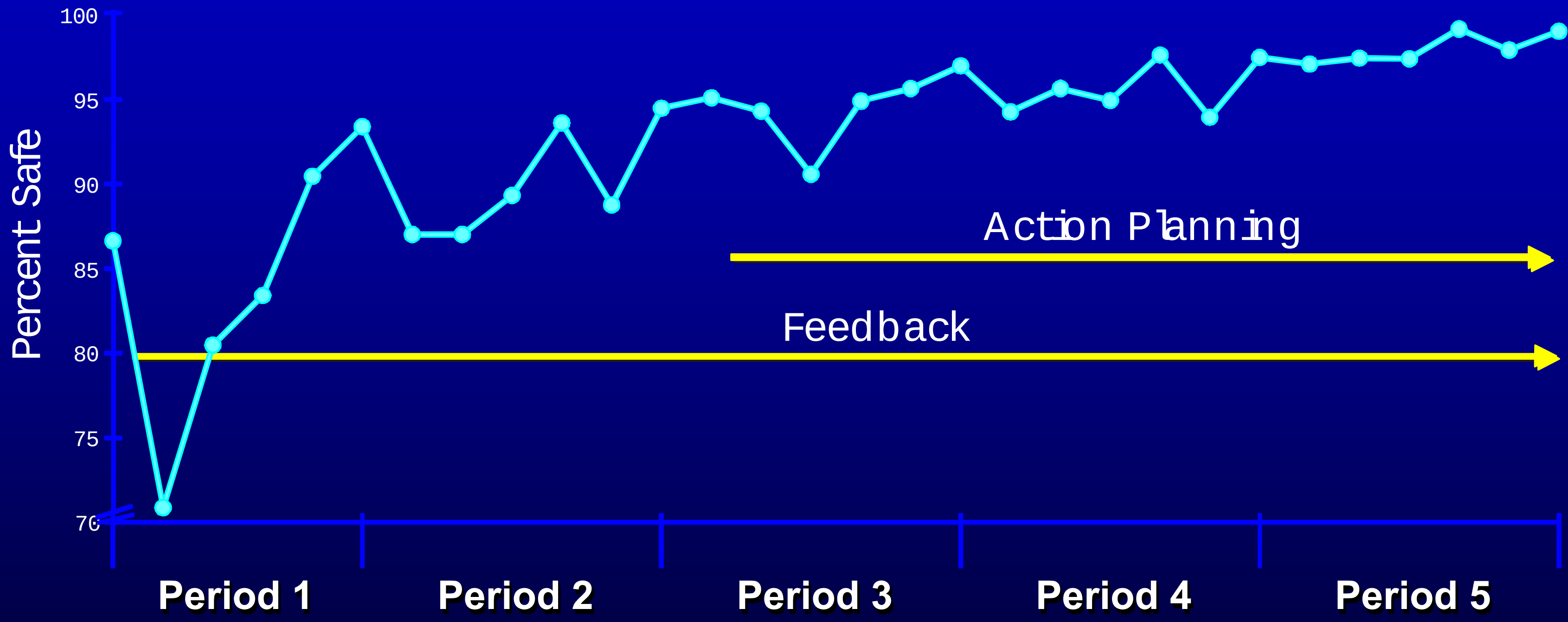


Analyze Data / Select Focus / Develop Action Plan

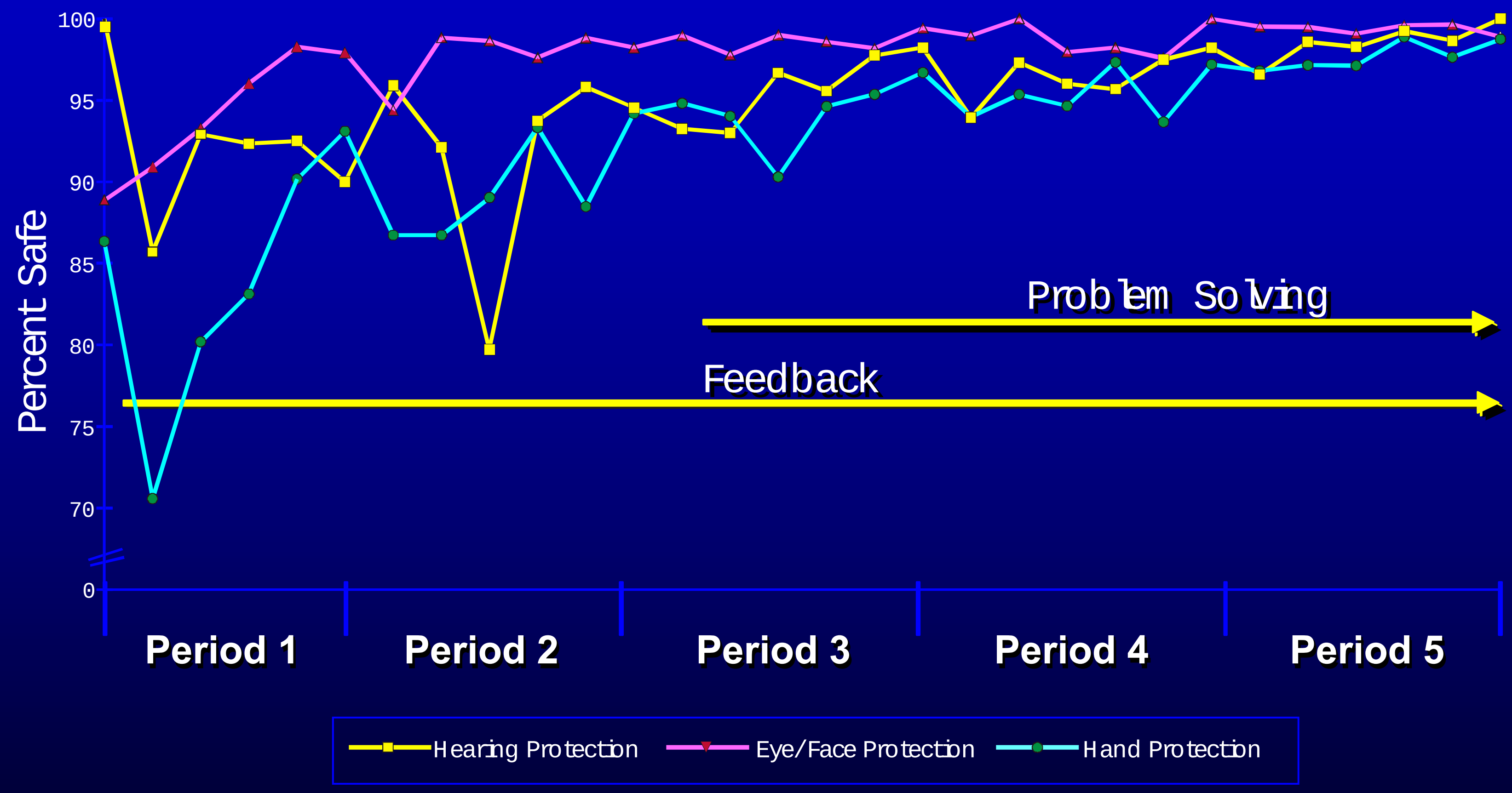
As Safe Behavior Increases, Recordable Rates Decrease



Hand Protection
Increased from 80% Safe to 98% Safe

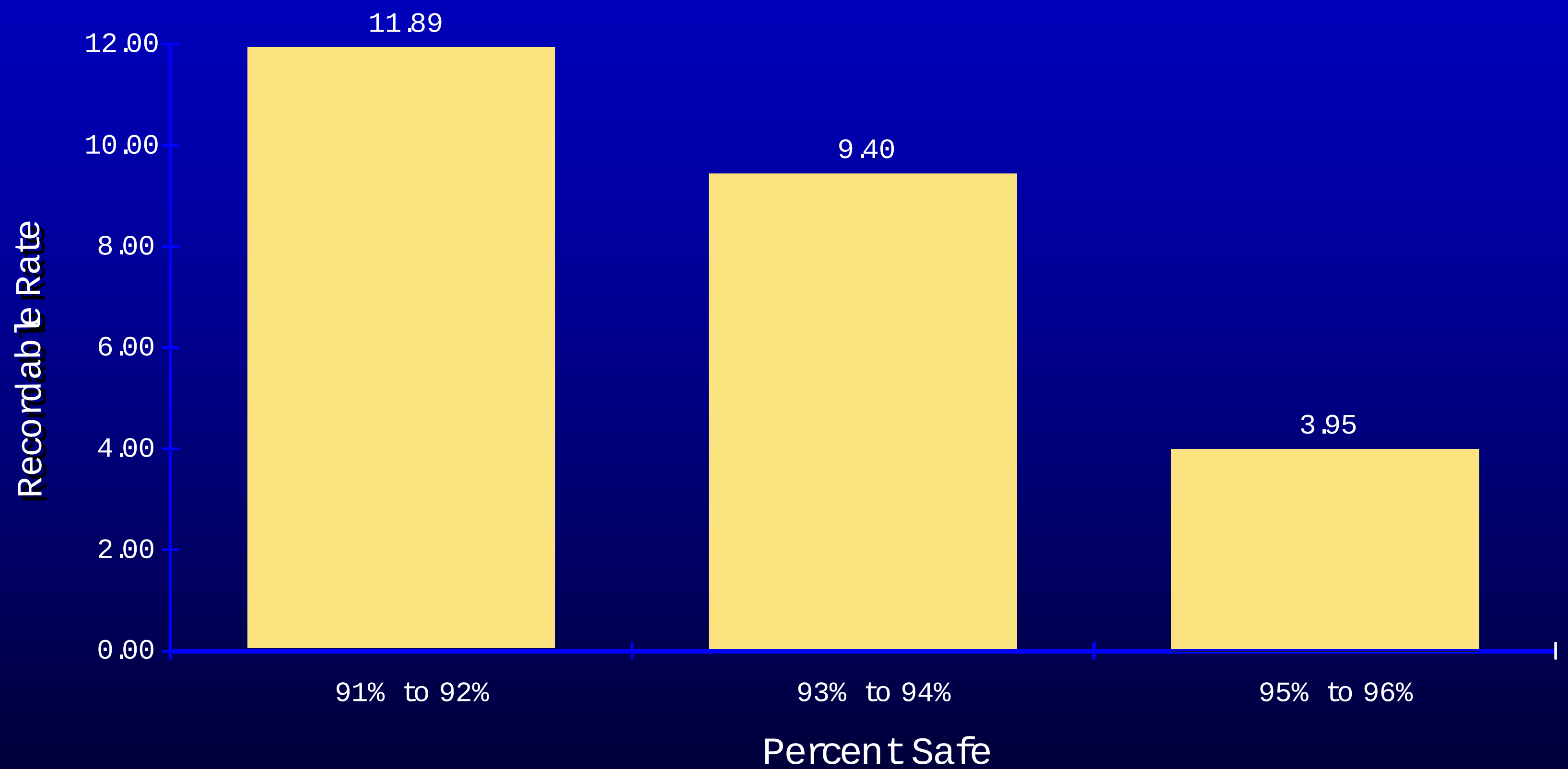


Industrial Hygiene Behaviors
Increases in Percent Safe over Time

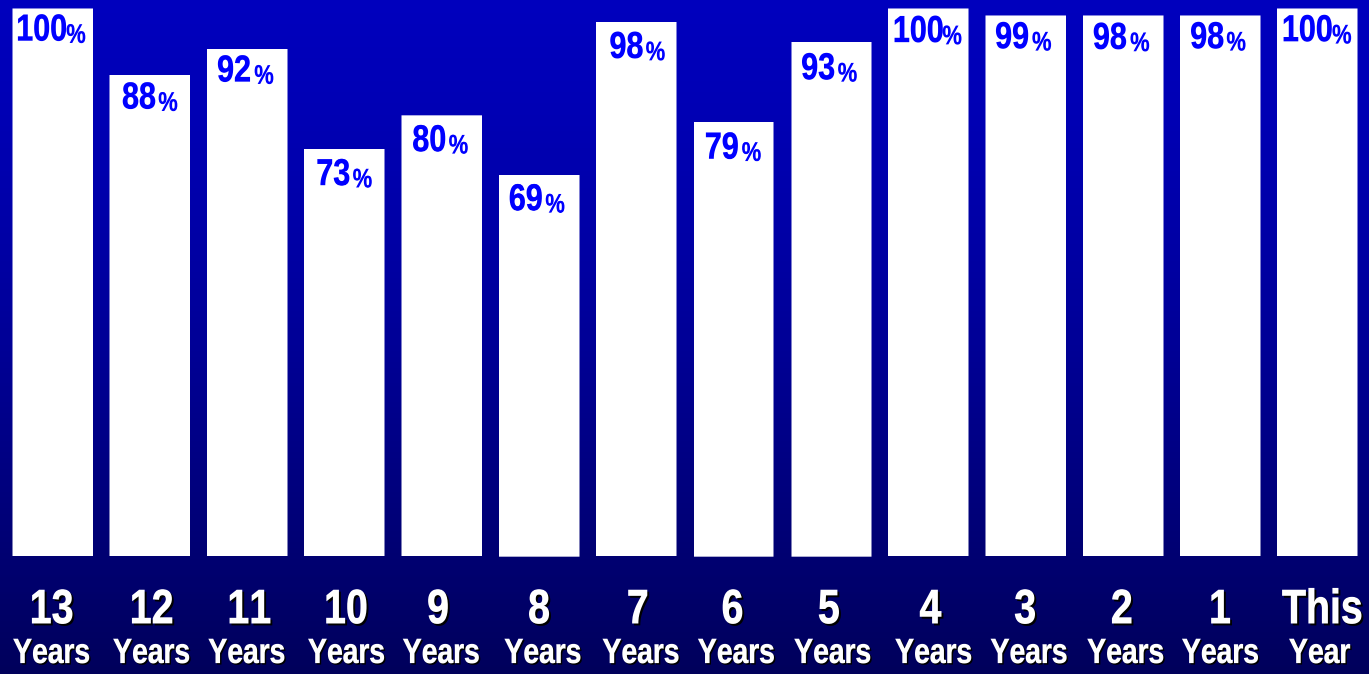


Lumber Mill

High Percent Safe Scores are Associated with Low Recordable Rates

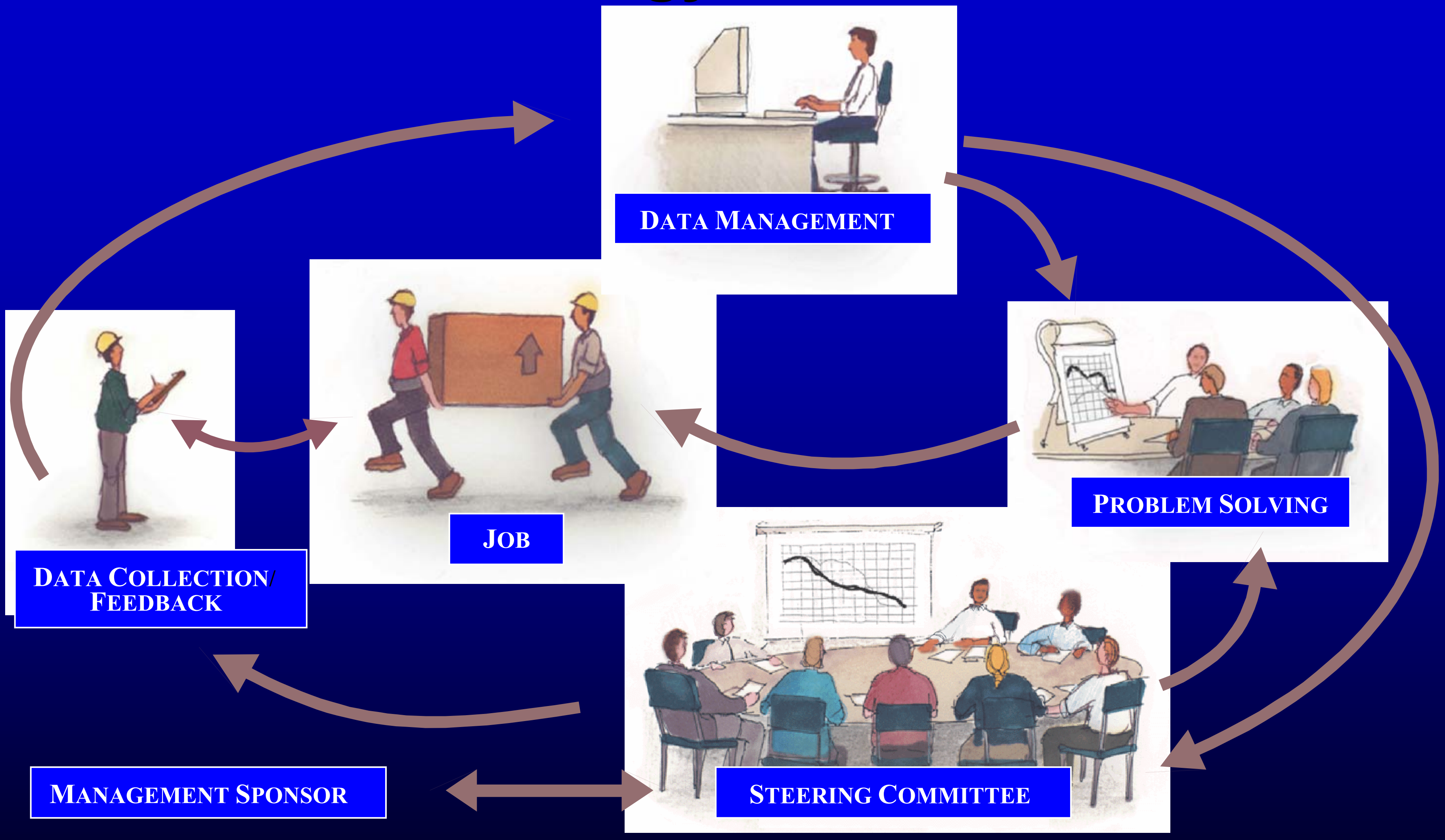


Sustainability of Implementations



Percentage Still Using Their Processes

BAPP® Technology Process Flow Chart



Revised method for reviewing Human Factors in the design of CCR`S

Adam Balfour

Human Factors Solutions - Norway

Human Factors Solutions - Norway

- Idea
  ABB – NPD – Safetec
- Concept
  Super Eva – Kristin
- Detailed
  Grane – Balder – West Future II
- Operation
  Jotun A
- Modification
  Eldfisk – Petrojarl – MMI-2
- V & V
  Kristin – Kvitebjørn – Oseberg C

ABBREVIATIONS

MMI-1

”A method for reviewing Human Factors in Control Centre Design”, NPD June 2000.

MMI-2

Revision of ”A method for reviewing Human Factors in Control Centre Design” , NPD October 2002

HFW 2002 GOALS

- MMI-2 - October 2002
- Share experience - MMI -1
- Gain YOUR experience - reviewing HF in CCR design

AGENDA

MMI-1

- Background
- Goals
- Preliminary results

MMI-2

- Goals
- Project plan
- Preliminary requirements
- Preliminary Concepts

ISSUES

1. ______________
2. ______________
3. ______________

MMI-1

BACKGROUND MMI -1 - NPD - AUDITS

- Too many alarms
- New functions in CCR
- Increased complexity and demand on staff
- New technology challenges established safety philosophy
- Reduced manning in CCR
- Remote control - onshore

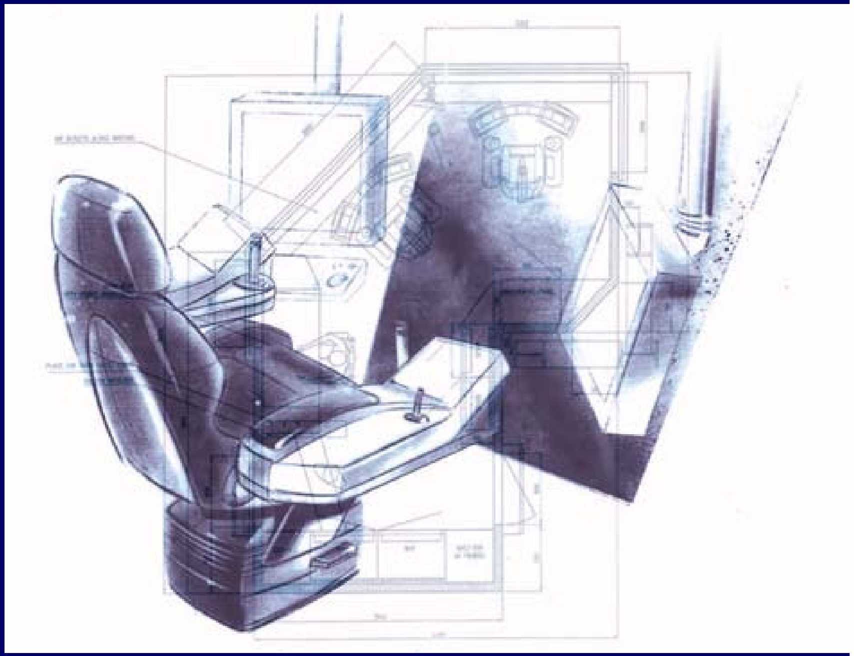


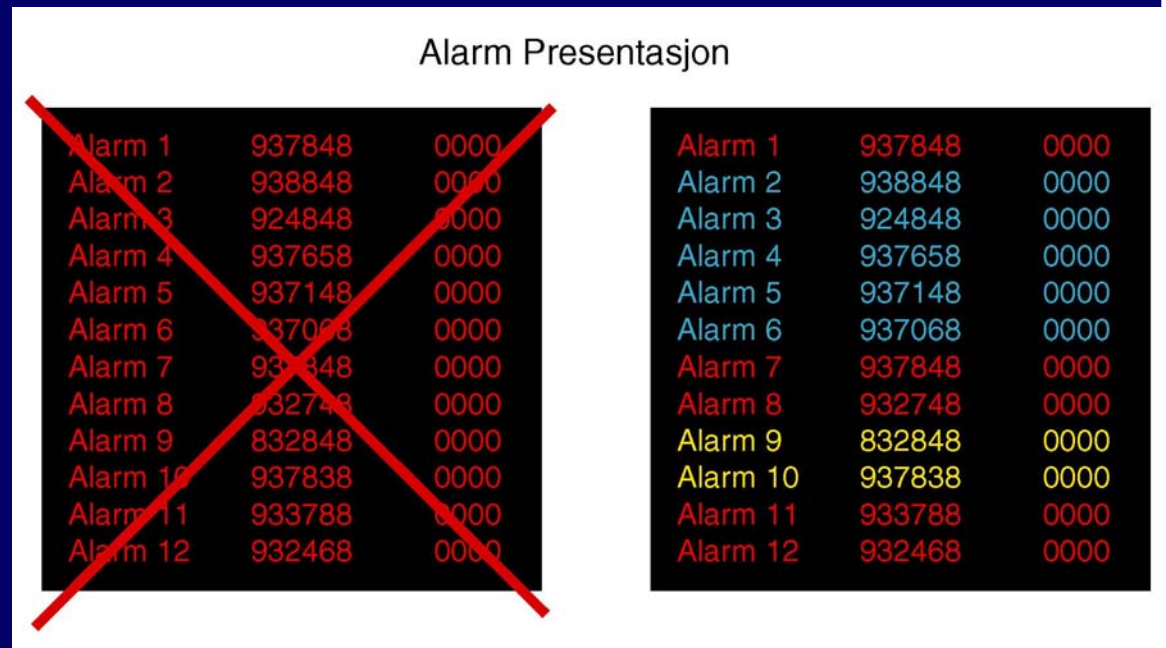
Illustration: Courtesy of Maritime Hydraulics, Norway

Consoles

- Space for paper, pens
- Location - contrast
- Large fixed keyboards
- Not adjustable

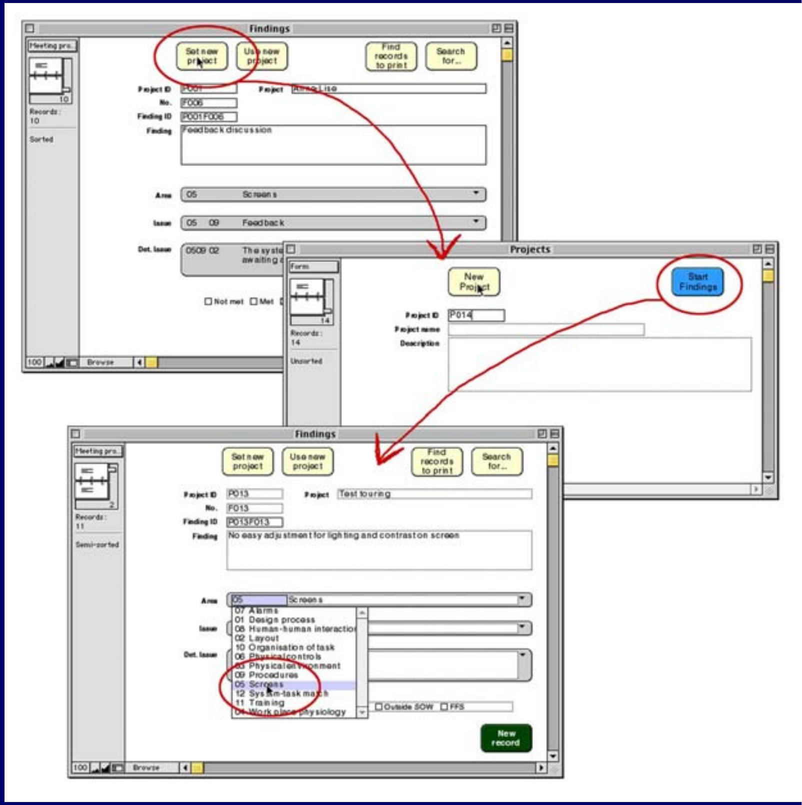
Alarm systems

- No philosophy
- Alarm list
- Too many
- Inconsistent
- No priority
- No grouping
- Incomprehensible

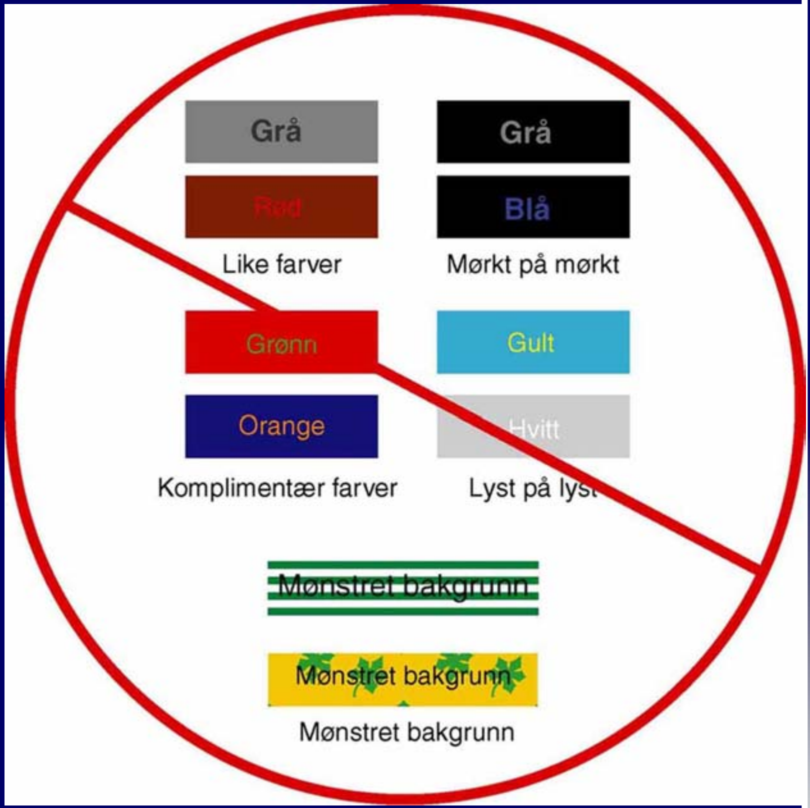


Navigation

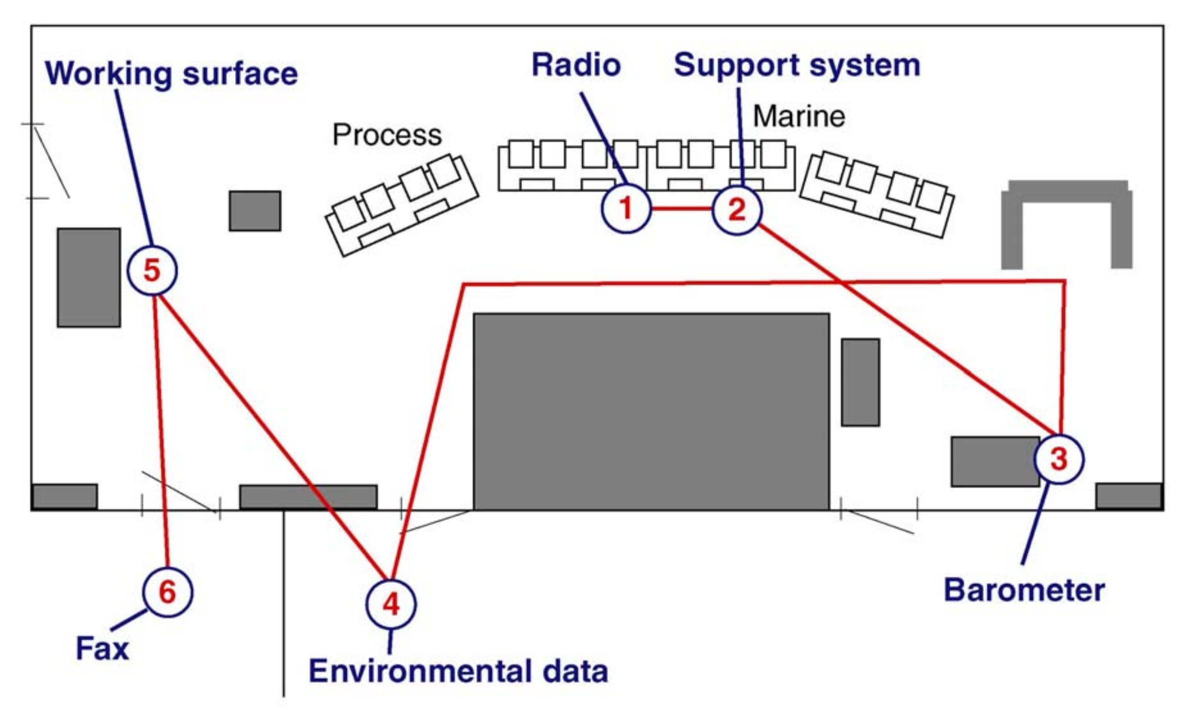
- Inconsistent
- Difficult - hierarchical
- Remember screen nr.
- Limited search functions



Colour /graphics



CCR Layout



Working surface
Radio
Support system
Marine
Process
1
2
5
3
6
4
Barometer
Fax
Environmental data

GOALS MMI-1

Goals : Provide NPD & industry with common basis for:
- safe working practices in CCR
- acceptable total workload in CCR
- reduction - human error
- structured HF methods
- evaluation of solutions vs regulations

Product: Systematic CCR audit tool (design - mod -incidents)

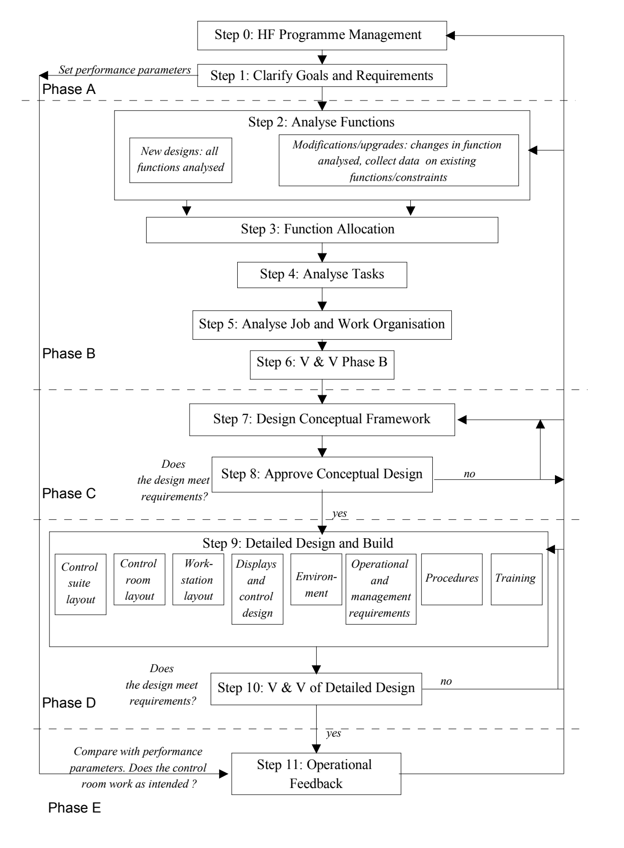
Users & Use: Authority- revision, incidents

Industry - management, planing, development revision, updates, modification

Based on: ISO 11064 structure and requirements

MMI 1 = ISO 11064 +

- Introduction
- Information sources
- Review guidance
- Audit questions
- 167 pages in English



MMI-2

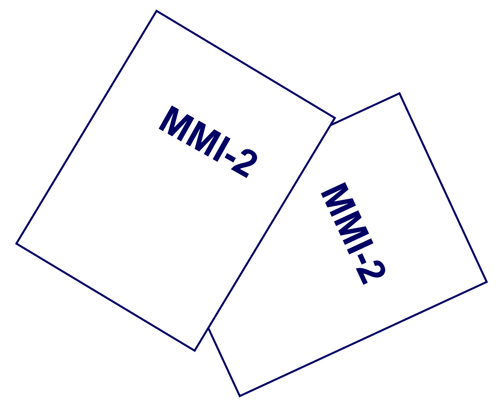
GOALS MMI-2

As for MMI -1

Revise and update, simplify and improve

DELIVERABLES MMI-2

1. Revision - Norwegian and English
2. Presentation material - MMI-2
3. Project plan - other cabins



PROJECT PLAN MMI-2

1. Clarify goals, requirements and specification

2. Interview stakeholders

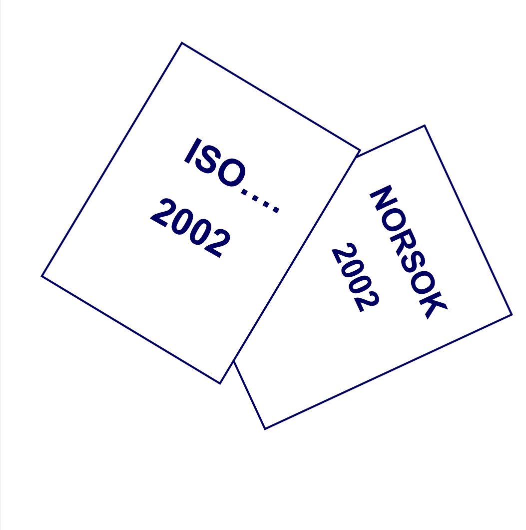
3. Observe use/audit of MMI-1

4. Test use of MMI-1

5. Review alternative methods, standards etc.

6. Develop and test concepts

7.   - Develop MMI-2
       - Presentation material
       - Project plan for other cabins



PRELIMINARY RESULTS - MMI 1

+

Systematic / useful

Professional content

Checklists useful

Puts HF on map

--

Not easy to use / Too large

Where to start ?

Iterative process unclear

Not related to oil industry

No change - human error

PRELIMINARY REQUIREMENTS 1/2

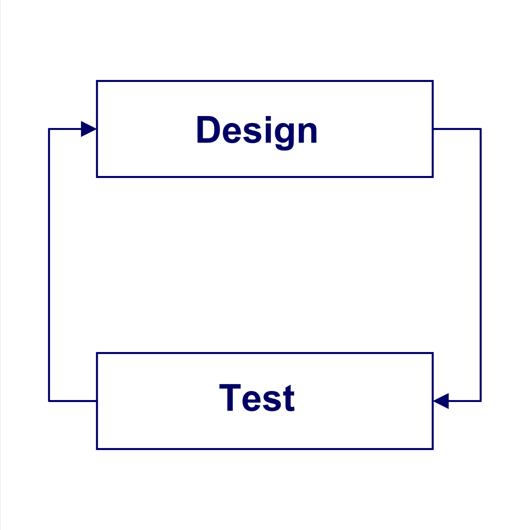
TECHNICAL CONTENTS

- Reduce volume - BUT more examples, checklists, guidance !
- Simplify / userfriendly - navigation
- Prosess vs results based ?
- Audit tool / design guide ?
- Add Human Error Assessment, HCI, Alarm Philosophy, +++
- MMI-2 - tool to get 1 answer from 10 different operators

PRELIMINARY REQUIREMENTS 2/2

ORGANISATION

- Experience transfer first
- Merge chapters
- Emphasize iteration
- Seperate parts: Users



INTRODUCTION MMI-2

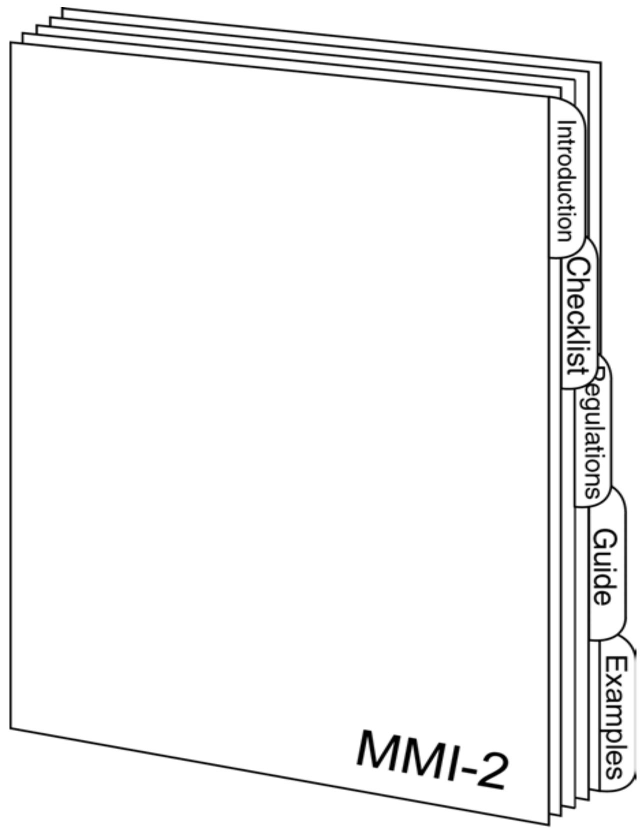
- Involve industry: (Ref. group)
- Overview & detailed workshops

PRELIMINARY CONCEPTS

ORGANISATION

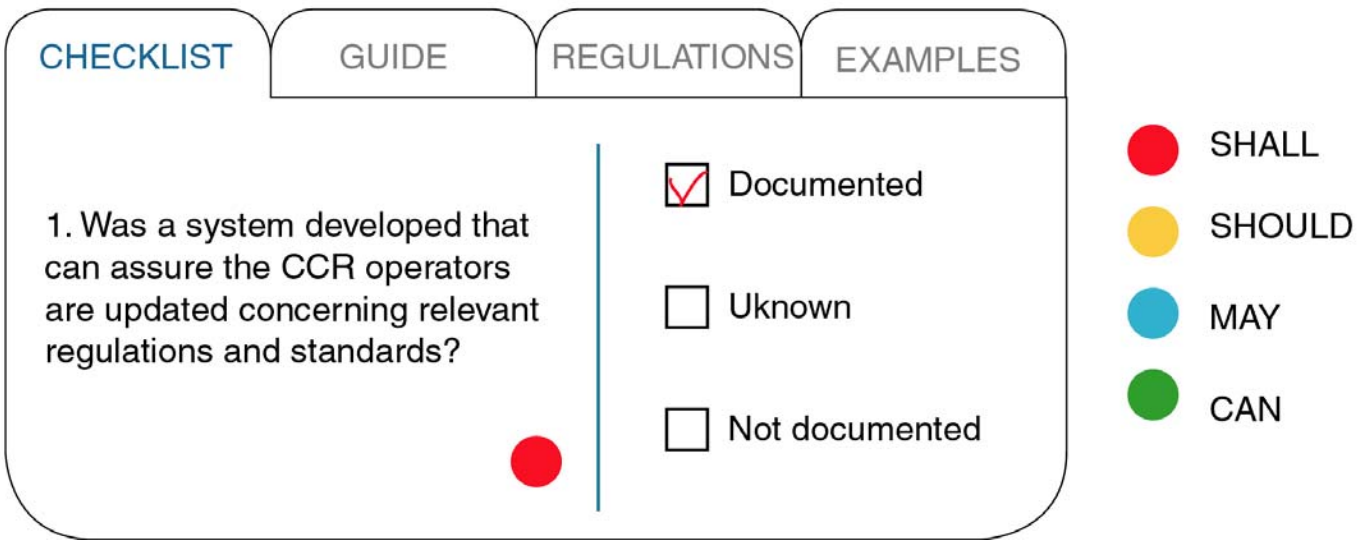
- Requirements
- Regulations
- Topic
- Design prosess
- Users
- Examples

Combinations Etc.



Picture book / Designguide / Revision tool

DATABASE


CHECKLIST
GUIDE
REGULATIONS
EXAMPLES
1. Was a system developed that can assure the CCR operators are updated concerning relevant regulations and standards?
Documented
Uknown
Not documented
SHALL
SHOULD
MAY
CAN

ISSUES

- Who should ”own” HF / MMI -2 ?
- How should HF requirements be presented? (process, performance criteria, detailed specs.)
- Your experience with ISO 11064 ?
- Your experience reviewing Human Factors in CCR design prosess?

HFW2002

Workshop On Human Factors In Offshore Operations

Capitalizing On Behavior Based Safety To Address Human Resource Development Needs

Ron Newton

Peak, Inc.

www.peaksbest.com

“ . . . Recruitment and retention problems are barriers to quality improvement initiatives, a driving factor in personal injuries and accidents, and a drain on crew performance.”

American Waterway Operators Task Force

All areas of human resource development and management are now interlinked more than ever—safety, personnel recruitment and retention, quality, fatigue, teamwork—all.

How Can We Capitalize on the Behavior Based Safety Process to Improve Total Human Resource Development?

A Model For Examination

Peak's 10-Year Experience With Offshore Service Companies

- Offshore Marine Industry: 1992-Present
- 8 Offshore Service Providers & 3 E&P Companies
- 1992-1995 Extensive Research Into Safety Behavior Culture:

Inland—US Offshore—World Offshore

- To Date:

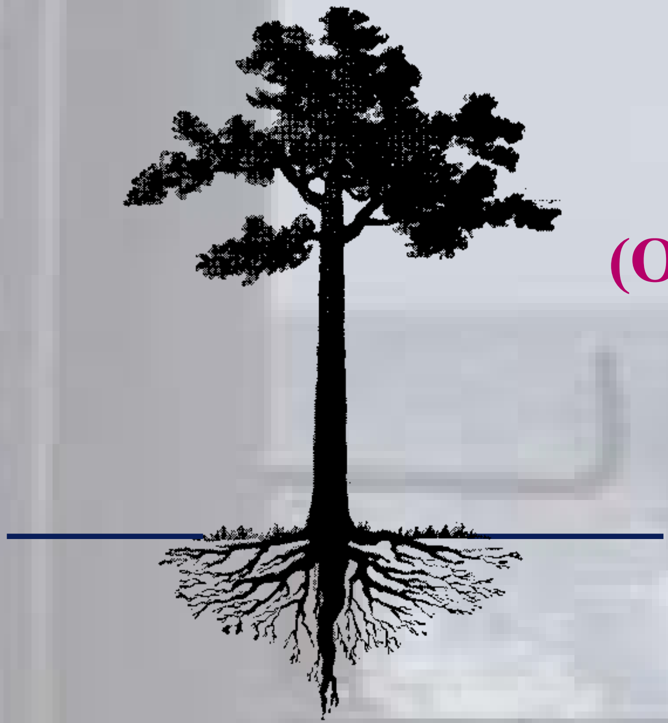
Personality and Behavior Data From +6,000 Vessel Officers, Deck Ratings & Shore Staff Serving In The Offshore Marine Industry

Task #1

Define Behavioral Tendencies Of Mariners.

Personality and Behavioral Measures

What Is Personality And Behavior?



BEHAVIOR

(OBSERVABLE SURFACE TRAITS)

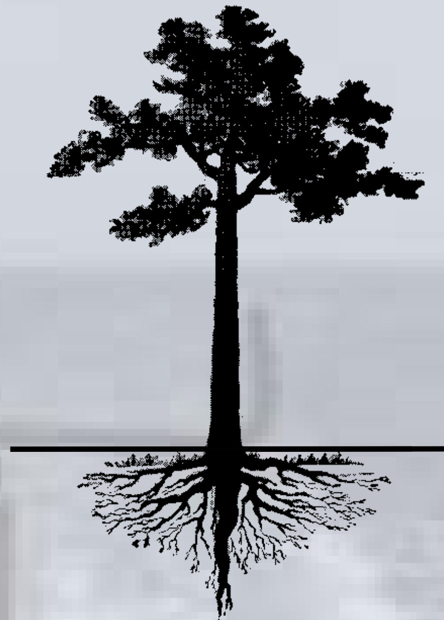
PERSONALITY

(HIDDEN ROOT TRAITS)

Socio-Economics, Parenting, Culture, Etc.

BEHAVIOR
(SURFACE TRAITS)

→ **DiSC® Personal Development Profile**



Sample Population: 437

PERSONALITY
(ROOT TRAITS)

→ **Taylor-Johnson Temperament Analysis**

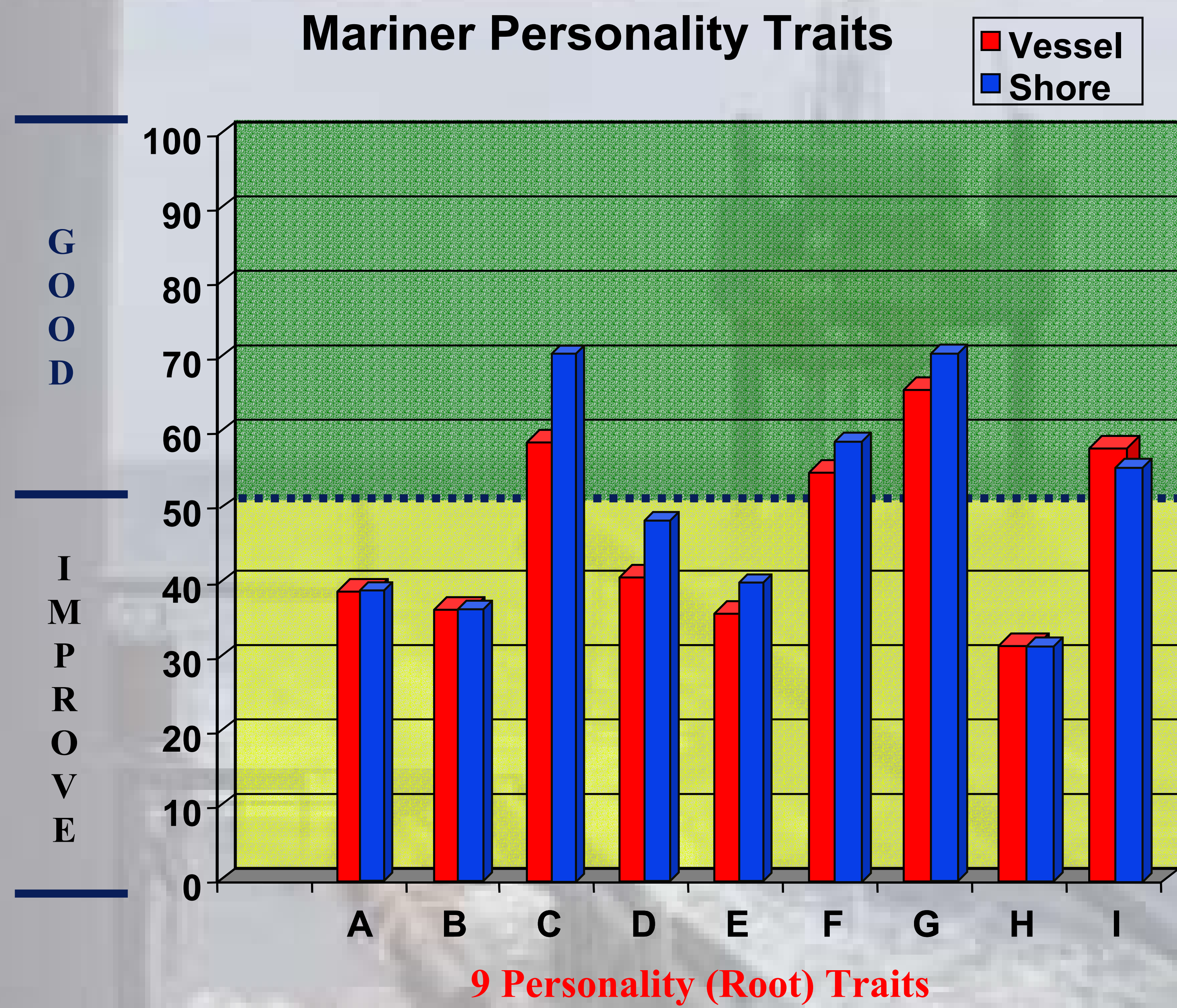
Population

103 Shore Staff
334 Vessel Officers

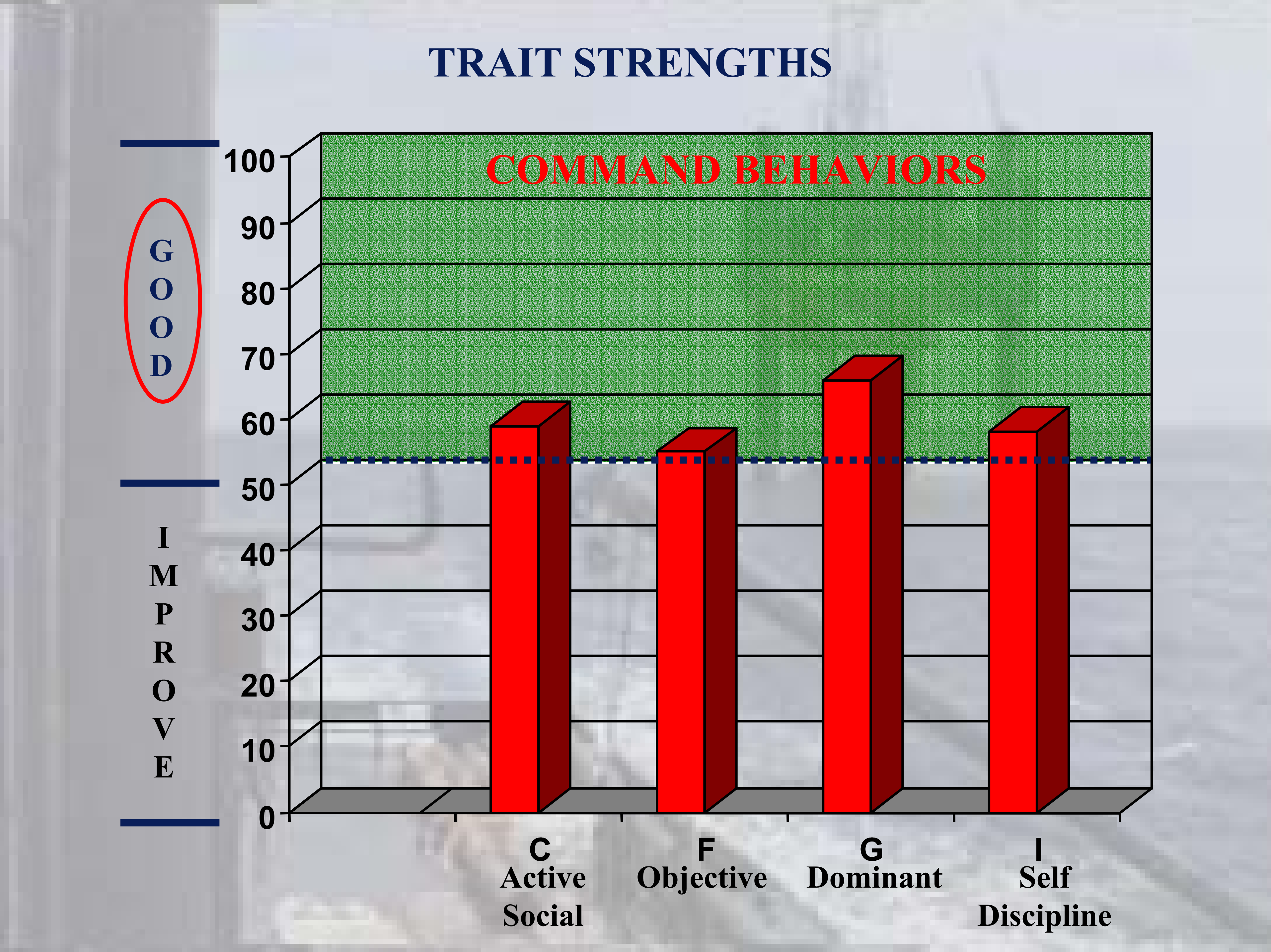
52.7% – Captains, or first officers

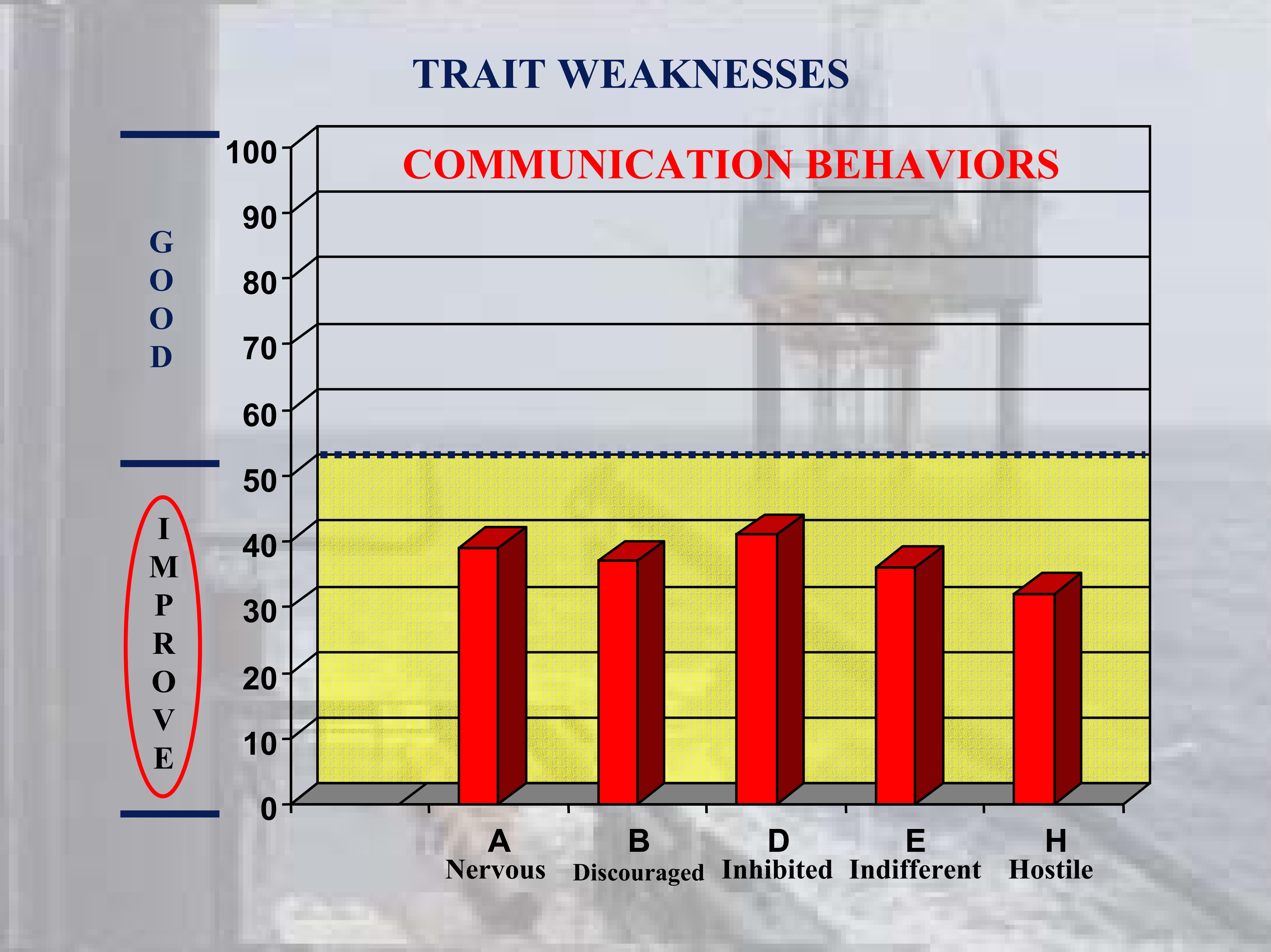
27.2% – 2nd Captain/Mate, or second officers

20.1% – Engineers

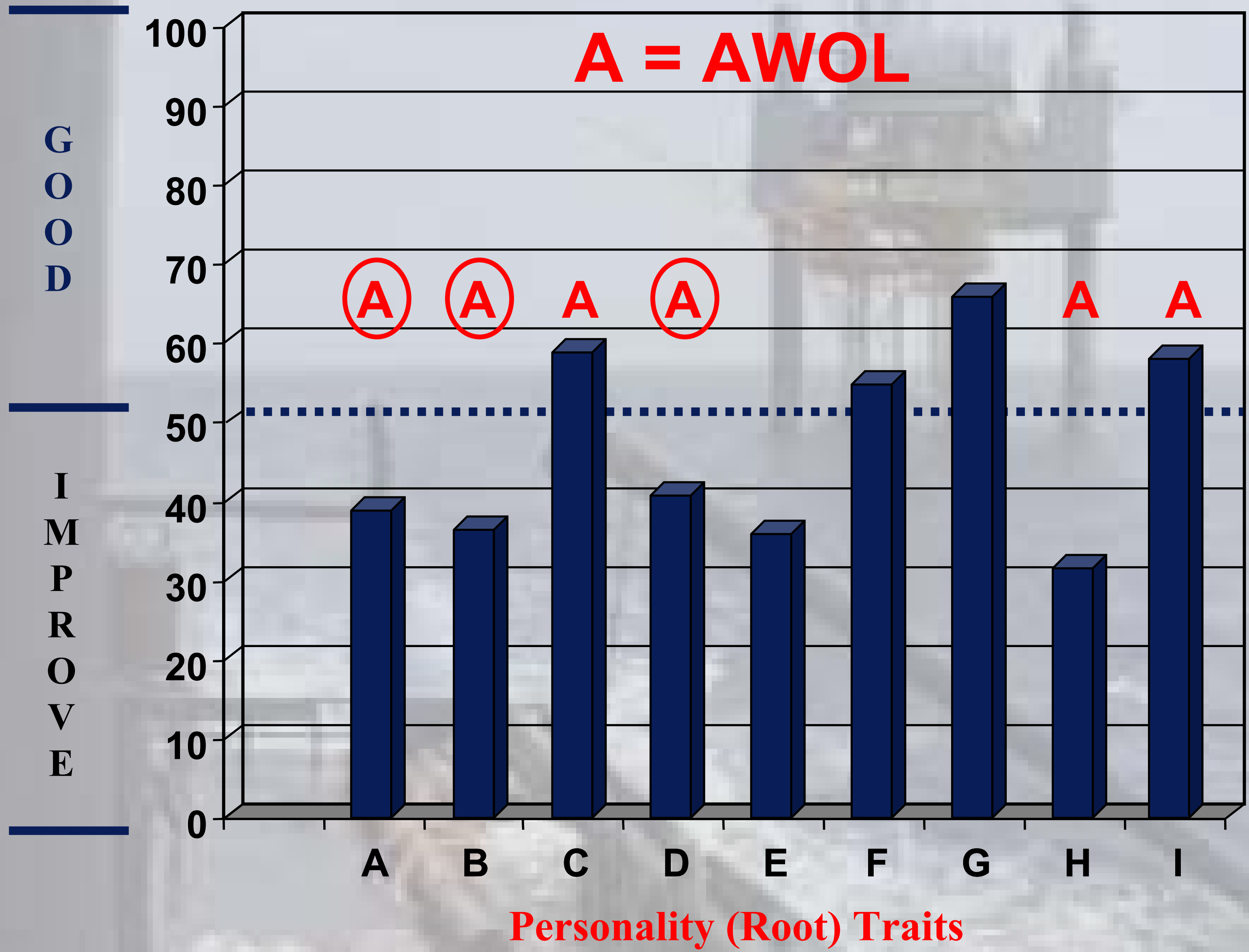


Mariner Personality Traits
Vessel
Shore
GOOD
IMPROVE
100
90
80
70
60
50
40
30
20
10
0
A
B
C
D
E
F
G
H
I
9 Personality (Root) Traits


TRAIT STRENGTHS
COMMAND BEHAVIORS
G O O D
I M P R O V E
100
90
80
70
60
50
40
30
20
10
0
C
Active Social
F
Objective
G
Dominant
I
Self Discipline


TRAIT WEAKNESSES
COMMUNICATION BEHAVIORS
GOOD
IMPROVE
100
90
80
70
60
50
40
30
20
10
0
A Nervous
B Discouraged
D Inhibited
E Indifferent
H Hostile

What Else Does It Tell Us?



Marine Offshore Temperament = High Turnover

DiSC™

D = Dominance: **Fast-Paced & Task-Oriented**

Motive = Get Results Done

i = Influence: **Fast-Paced & People-Oriented**

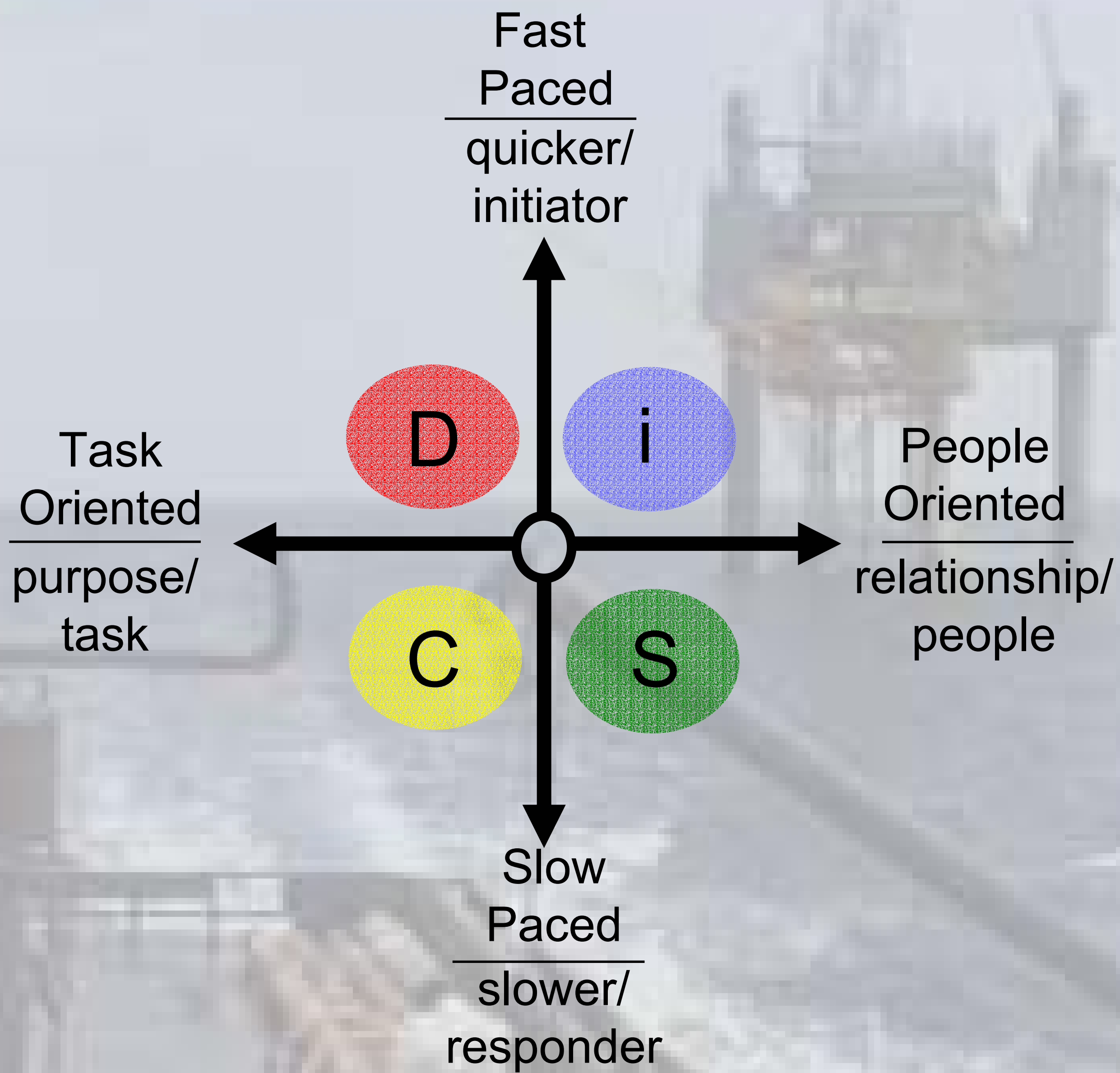
Motive = Influence Others

S = Steady: **Slow-Paced & People-Oriented**

Motive = Create Teamwork

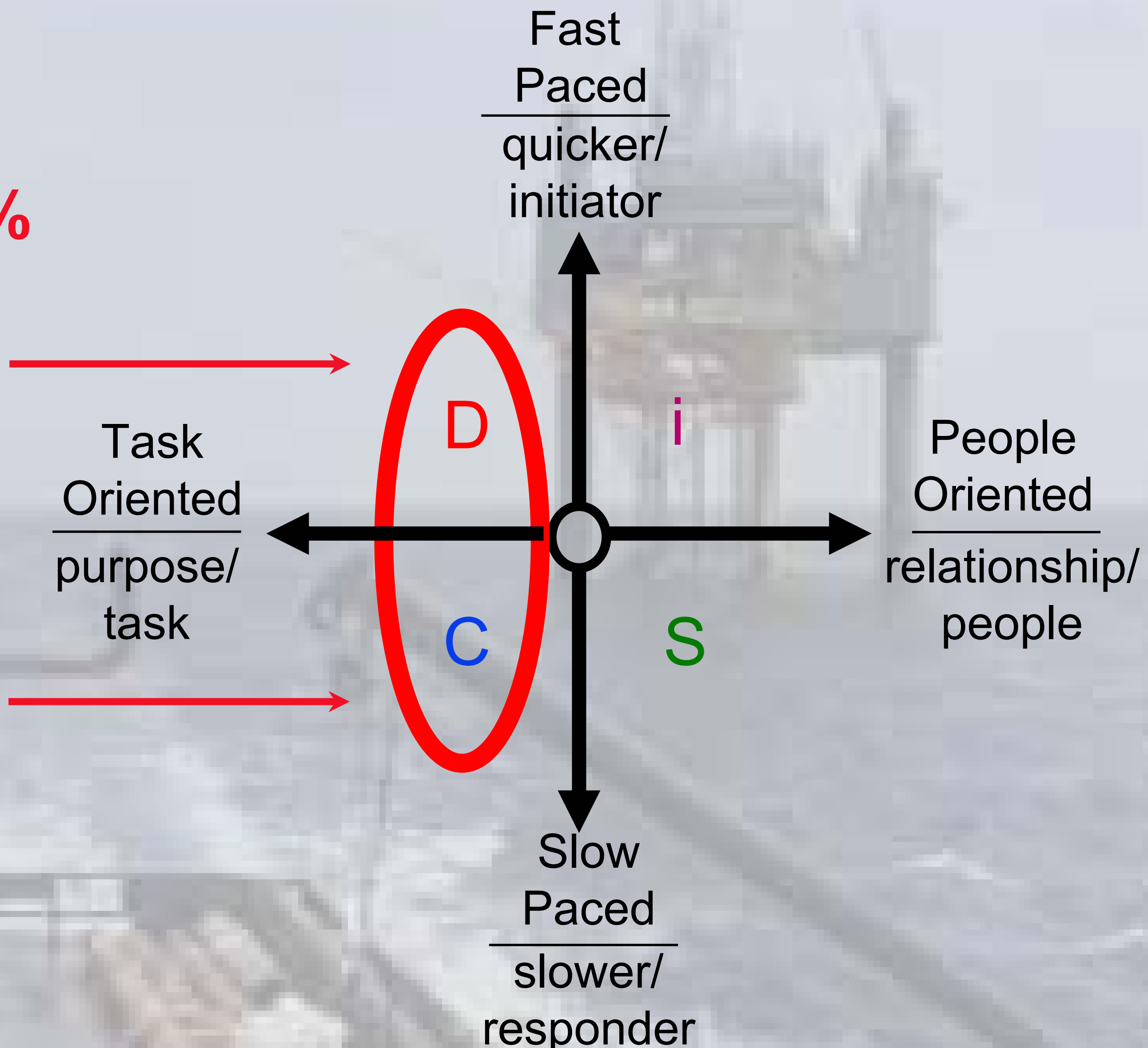
C = Correct: **Slow-Paced & Task-Oriented**

Motive = Insure Quality & Accuracy


Fast
Paced
quicker/
initiator
Task
Oriented
purpose/
task
D
i
C
S
People
Oriented
relationship/
people
Slow
Paced
slower/
responder

Almost 73% Of Work Force: D or C Behavior

Task Before People



1st Officer - 72%

2nd Officer - 68%

Engineer - 75%

Shore -74%

Mariner Behavioral Tendencies

- Repetition Of Traits In Retention
- Strong Command Behaviors
- Poor Interpersonal Communication Behaviors
- Non-verbalization Of True Emotions, Thoughts
- Self-centered, Prejudiced Behavior Affecting Teamwork
- Passive-Aggressive Tendencies: “us vs them”
  – Misery Loves Company

Mariner Behaviors

What Do They Look Like In The Workplace?

- Lack of conflict resolution
- Toleration of ongoing conflict
- Lack of verbal sympathy/empathy
- Over reliance on authoritarian leadership
- Reliance on hard-core skills for competency
- Pervasive “us vs them” verbalization
- Little interpersonal relationship guidelines
- Consistent turnover or desire to leave job
- Hesitancy to listen to personal insights/needs
- Hesitancy to share personal insights/needs

Task #2

Turn Behavioral Conclusions Into Effective Behavior Based Training Measures

But Not Without First Defining The Larger Picture Of HR (or Human Factor) Needs That Could Be Impacted

Ask

Is not resolving interpersonal conflicts a safety behavior?

What else does it affect?

Is over reliance on authoritative leadership a safety behavior concern?

What else does it affect?

Need

A behavior based process which will work hand-in-glove with a strategic human resource development model.

A Comprehensive Viewpoint.

Strategic Human Resource Development

Provide Accountability, Assessment, And Rewards

Enhance Stability In The Individual And The Team

Develop Employees Personally And Professionally

Communicate The Company's Mission, System, And Culture

Match The Team To The Mission

Step One:
Match The Team To The Mission

Strategy: Select The Best For Employment And Retention

Vehicle: Pre-Employment Analysis, Targeted Selection

The behavior based safety process should have the capability of producing data and identifying behavioral tendencies which can be used in a pre-employment analysis process.

Strategic Human Resource Development

Provide Accountability, Assessment, And Rewards

Enhance Stability In The Individual And The Team

Develop Employees Personally And Professionally

Communicate The Company's Mission, System, And Culture

Match The Team To The Mission

Step Two:

Communicate The Company's Mission, System, And Culture

Strategy: Prepare Individuals For Their Jobs, The Culture, And The Systems That Support It

Vehicle: Basic Course, New Hire Training In Human Factors

The behavior based safety process should have the capability of producing data and identifying behavioral tendencies which clearly define (and reflect) the company's system, mission and culture.

Strategic Human Resource Development

Provide Accountability, Assessment, And Rewards

Enhance Stability In The Individual And The Team

Develop Employees Personally And Professionally

Communicate The Company's Mission, System, And Culture

Match The Team To The Mission

Step Three:
Develop Employees Personally And Professionally

Strategy: Provide The Individual With Personal Developmental "Tools" And Programs

Vehicle: Systematic Training In Human Factors For Professional Development

The behavior based safety process should have the capability of producing data and identifying behavioral tendencies which can easily translated into teaching, training and coaching measures that not only improve hard-skill competencies but also soft-skill interpersonal needs.

Strategic Human Resource Development

Provide Accountability, Assessment, And Rewards

Enhance Stability In The Individual And The Team

Develop Employees Personally And Professionally

Communicate The Company's Mission, System, And Culture

Match The Team To The Mission

Step Four:

Enhance Stability In The Individual And The Team

Strategy: **Provide A Balance Between Work And Home**

Vehicle: **Emphasize Human Factors Applicability Through Employee Assistance And Training**

The behavior based safety process should have the capability of producing data and identifying behavioral tendencies which can be used to give guidance to the worker and his/her personal support structure.

Strategic Human Resource Development

Provide Accountability, Assessment, And Rewards

Enhance Stability In The Individual And The Team

Develop Employees Personally And Professionally

Communicate The Company's Mission, System, And Culture

Match The Team To The Mission

Step Five:
Provide Accountability, Assessment, And Rewards

Strategy: **Create An Ethical Environment Of Accountability, Assessment, And Rewards**

Vehicle: **Systems Of Accountability, Assessment, And Rewards**

The behavior based safety process should have the capability of producing data and identifying behavioral tendencies which can be used to give practical guidance to those whose job duties include performance evaluation and reward/award assessment.

The Capital Of Capitalization

- **Viewing the behavior based safety process as a means, not an end**
- **Coordinating behavior based safety with a well designed strategic human resource development plan**
- **Emphasis in behavioral science more upon the *behavioral* rather than the *science*, at least in the initial stages of implementation**

Thank You!

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OFFSHORE EMPLOYMENT:

ITS EFFECTS AND THEIR MANAGEMENT

Mark Shrimpton

Community Resource Services Ltd.

Newfoundland, Canada

PRESENTATION STRUCTURE

- Overview of MMS study
- Major findings:
  - Effects
  - Responses
- Conclusions:
  - Research gaps
  - Research issues

‘The Effects of Offshore Employment in the Petroleum Industry: A Cross-national Perspective’

OCS STUDY MMS 2001- 41

RATIONALE, SCOPE AND METHODOLOGY

- Respon... ...ter operations
- Focus... ...workers, families... ...ities
- Secondary... ...n:
  - Literature rev... (o... and mining)
  - International workshop
  - Key informant interviews

EFFECTS OF OFFSHORE EMPLOYMENT

- Health and safety
- Employment of:
  - Women
  - Minorities
  - Older Workers
- Family life
- Worker attraction and retention

EFFECTS OF OFFSHORE EMPLOYMENT

- Reside…
- Expen…
- Seconda… …ent
- Communit…
- Community s…ial and recreational services

RESPONSES

- Work schedules
- Accommodations
- Transportation
- Communications
- Hiring and orientation
- Counseling
- Family policies and services

RESPONSES

- Need for greater consideration of non-workplace issues:
  - Family and personal life effects
  - Commute dangers

RESEARCH GAPS

- US and developing countries
- Study of:
  - Small operations
  - Post-CRINE/NORSOK
  - Non-nuclear families
  - Minorities
- Longitudinal studies
- Best practices

RESEARCH ISSUES

- Exceptionalism:
  - Normal work
  - Normal families
- Problematization:
  - Family effects (separation and divorce)
  - Sleep disturbance

RESEARCH ISSUES

- The ideal s[illegible] a false grail?
- Need to [illegible]erences
- Ambi[illegible] cons that change w[illegible]
  - Famil[illegible] families)
  - Family, w[illegible]rk [illegible]d s[illegible]cial circumstances
  - Generations ([illegible]ld school' vs 'new outlookers')
- Ongoing adjustment and coping

RESEARCH ISSUES

- Exogenous ... .
  - Problen ...
  - Diffi ... cts
  - Need fo ... ponse
  - Consulta ... beneficial
- Uncertainty:
  - Highly problematic
  - Threat or reality

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Accident Investigation Trends - A Safety Management Perspective

International Workshop on Human Factors in Offshore Operations

April 8 - 10, 2002

Accident Investigation - Critical Element of MMS Safety

- Types of Investigations
- Root Cause Oriented
- Identifies Trends
- Identifies Potential Problems

MMS Reaction to Trends

- Safety Alerts
- Regulatory Review
- Inspection Modification
- Actions Specific to Operator

Trends Revealed in Recent Fatal Accident Investigations

- Human Factors
- Coincidental Injuries
- Day-to-Day Tasks
- Lack of Procedural Guidelines/Communications
- Management System Failures

Lack of Procedural Guidelines in Routine Tasks - Why?

- Complacency - Success
- Reliance on:
  - Pre-Job Safety Meetings
  - Safety Handbooks/Work Practices
  - General Training - T2
  - Corporate Safety Plan
- Non-uniformity of Task Steps
- No Systematic Management Policy on Hazardous Task Identification

Best Procedures Result from JHA/JSA

- JSA - Systematic Way of Dealing with Hazards
  - List Task Elements/Steps
  - Identify Hazards in Each Step
  - Precautions Taken to Deal with Hazards
- Types of JSA
  - Produced at Pre-Job Safety Meeting
  - Produced at Management Level
- Problem - No Systematic Way of Identifying Tasks to Subject to JSA

Management Responsibility

- Provide the Safest Environment
- Identifying Hazards
  - Reactively
  - Proactively
- Contractors
  - Review Safety Plan
  - Monitor Performance
  - Force a JSA Mentality

Contact Information

- Safety Alerts & Panel Reports
  - www.mms.gov/offshoresafety/
- Accident Stats
  - www.mms.gov/stats/OCSincident.htm
- Public Information Office (2010 reports)
  - 1-800-200-GULF
  - 504-736-2519

Contact Information Cont'd

- Frank Pausina - Accident Investigation Coordinator, MMS, GOMR
  - 504-736-2560
  - frank.pausina@mms.gov

- Joe Gordon - Chief, Office of Safety Management, MMS, GOMR
  - 504-736-2923
  - joe.gordon@mms.gov

Contact Information Cont'd

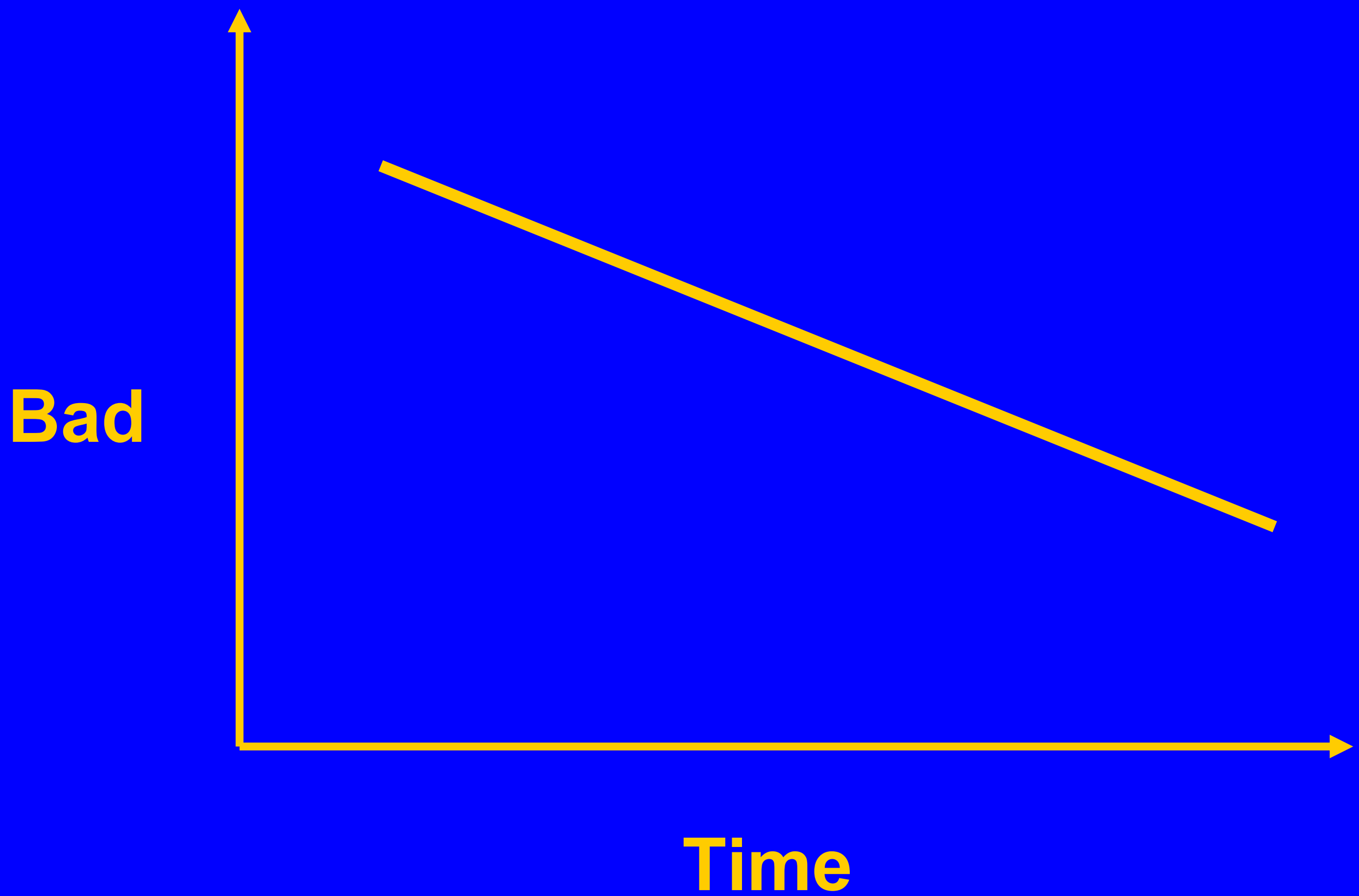
- MMS Article in Oil & Gas Journal - October 23, 2000 - *MMS investigation provides insights*

Thank You

HFW 2002

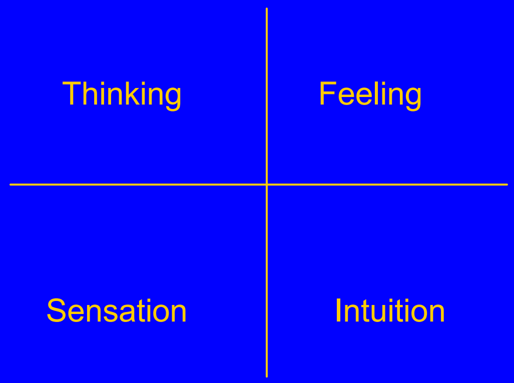
- Where we were in 1996
- Where we are today
- Great progress
- Great success of HFW 2002
- Thanks to all involved
- Outstanding way forward
- Clarify doubts
- Conclusions

Shape of the 20th Century

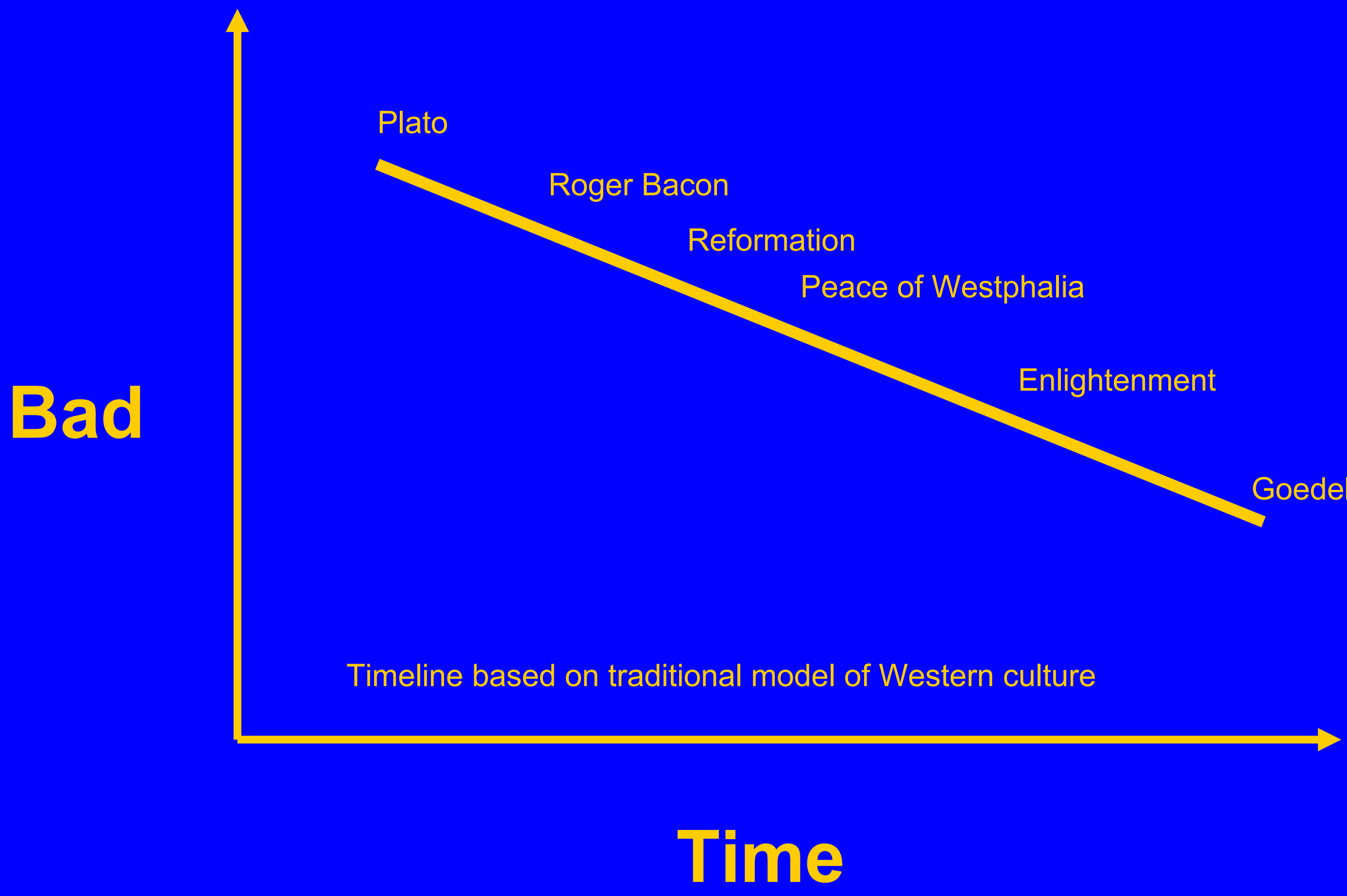


Carl Jung (1875-1961)

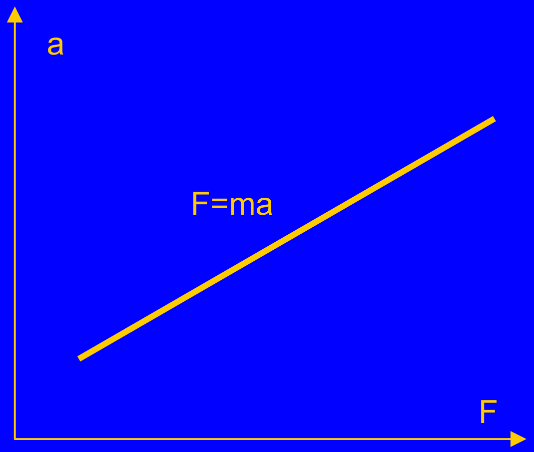
- Swiss psychologist
- Shadow
- Collective unconscious
- Psychological types (basis of MBTI)



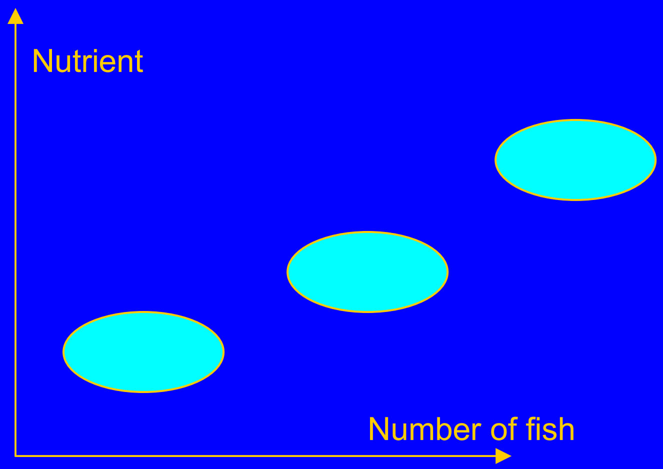
Shape of human progress



What is correct HFE model?



Newtonian physics



Chaos theory

The problem redefined

- 38 years and one month
- Engineering deficiency disorder” (DSM)
- Support group
- Process of continuous improvement
- The ‘trip’ to Austin
- Transcendance or Immanence?

Behavioral Science

- Behavioral Science: any of various disciplines dealing with human actions, usually including the fields of sociology,, social and cultural anthropology, psychology, and behavioral aspects of biology, economics, geography, law, psychiatry and physical science. (Britannica)

Behaviorism

- Watson: psychology was to become a purely objective, experimental branch of natural science (~1924)
- Skinner:
  - Professor of Psychology at U.of Indiana
  - Skinner's box
  - Central concept of reinforcement, or reward
  - Great influence but controversial today

Human behavior is complex

- “We assumed we would start to make computers understand simple children’s stories and work our way to the complex fields like physics and astronomy. It turned out that the understanding of physics and astronomy is extremely simple compared to the problem of understanding children’s stories”. Bill Wood, a scientist who had struggled to make computers understand ordinary language.(quoted in ‘Wittgenstein’s Ghost’, article by Paul Trachtman, Smithsonian, April, 2002).

The Conclusions (1)

- There is an enormous potential to apply our work in HFE to broader issues of the day.
- Provide an introduction to the proceedings, which puts the subject and papers in context
- Provide a synopsis (executive summary) at the beginning of every paper
- Agree on a single definition of HFE

The Conclusions (2)

- Resolve the status and qualifications required of an “HFE Professional”
- Develop the appropriate relationship between HFE, and industry regulations and standards
- Try and offer a way forward for those people who want immediate tools

The Conclusions (3)

- Thank you for an outstanding job exceptionally well done
- Start planning for HFW2005

Work Group Papers

Dr. Anita Rothblum U.S. Coast Guard	***1. Improving Incident Investigation through Inclusion of Human Factors***
Dr. Johan Hendrikse Paragon	***2. Effectively Including Human Factors in the Design of New Facilities***
Jeffrey Thomas ExxonMobil, USA	***3. Application of Human Factors in Reducing Human Error in Existing Offshore Facilities***
Bob Miles HSE, UK	***4. Solving Human Factor Issues as Applied to the Work Force***
Denise McCafferty American Bureau of Shipping	***5. Effective Integration of Human Factors into HSE Management Systems***
Jim Spigener BST	***6. Effective Application of Behavioral Based Processes in Offshore Operations***

WORKING GROUP 1

2ND INTERNATIONAL WORKSHOP ON HUMAN FACTORS IN OFFSHORE OPERATIONS (HFW2002)

HUMAN FACTORS IN INCIDENT INVESTIGATION AND ANALYSIS

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April 8 – 10, 2002
Houston, Texas

ABSTRACT

Studies of offshore and maritime incidents (accidents and near-misses) show that 80% or more involve human error. By investigating incidents, we can identify safety problems and take corrective actions to prevent future such events. While many offshore and maritime companies have incident investigation programs in place, most fall short in identifying and dealing with human errors. This paper discusses how to incorporate human factors into an incident investigation program. Topics include data collection and analysis and how to determine the types of safety interventions appropriate to safeguard against the identified risks. Examples are provided from three organizations that have established their own human factors investigation programs.

DISCLAIMER

ACKNOWLEDGEMENTS

The authors wish to thank their organizations for granting the permission both to contribute their time to the development of this paper and to share their organization's data and lessons learned so that others may profit from our experiences. Thanks to Rodger Holdsworth and Christy Franklyn of Risk, Reliability and Safety Engineering for providing guidance and reviews of this paper and for supplying information, references, and a figure used herein. Thanks to Gerry Miller (G.E. Miller and Associates) for the clarifying discussion of his Triangle of Effectiveness, help with locating references, and for his editing suggestions. Rachael Gordon contributed material on error detection and recovery, as well as information about her Human Factors Investigation Tool (HFIT). Jan Erik Vinnem shared a presentation on Norway's offshore near-miss database. This paper benefited from lively discussions at the April workshop and from amplifying information contributed by Scott Bergeron (McDermott), Melissa Roberts (ChevronTexaco), Sally Caruana (BOMEL Ltd.), and Cyril Arney (ExxonMobil). Thanks also to the following people who kindly took the time to critique a draft of this document: Capt. Dan Maurino (International Civil Aviation Organization), Trond S. Eskedal (Norwegian Petroleum Directorate), Jeffery Thomas (ExxonMobil), and James Reason (University of Manchester).

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HUMAN FACTORS IN INCIDENT INVESTIGATION AND ANALYSIS

1.0 INTRODUCTION

Traditionally, incident investigation has focused on hardware issues, such as material failures and equipment malfunctions. In the last fifteen years or so, it has become increasingly evident that human factors, rather than hardware factors, are responsible for most of the precursors to incidents. While many offshore and maritime companies have incident investigation programs in place, most consider human contributions to incidents only in a superficial way, if at all. The purpose of this paper is to help offshore and maritime companies incorporate human factors into their incident investigation programs so that they can identify human causes of incidents and determine effective safety interventions to prevent such incidents in the future.

1.1 Why Study Incidents?

An “accident” is defined as “an unplanned event or sequence of events that results in undesirable consequences” (Center for Chemical Process Safety, 1992, p.327). Accidents represent the proverbial “tip of the iceberg”. It has been estimated that for every accident, there are about *600 near-misses*[1] (Det Norske Veritas, 1995; Ferguson & Landsburg, 1998; Bea, Holdsworth, & Smith, 1997). Essentially, a near-miss is an accident that almost happened. Near-misses and accidents have the same causes, so studying near-misses can help us understand safety problems and make corrective changes *before* an accident takes place. In addition, since near-misses do not result in full-blown casualties, studying near-misses can help us learn how to develop early-warning systems to detect when conditions have become “non-normal” and also show us what steps were taken that *avoided the accident.*

Incident[2] investigation and analysis – that is, the study of accidents and near-misses – is squarely in line with the intent of the *International Safety Management (ISM) Code.* ISM requires that a company provide for a safe work environment and safe practices in maritime operations and establish safeguards against all identified risks. Incident investigation helps the company to identify its risks and to understand the underlying causes of incidents. This in turn helps the company develop safe work practices.

[1] A “near-miss” is defined as “an extraordinary event that could reasonably have resulted in a negative consequence under slightly different circumstances, but actually did not” (Center for Chemical Process Safety, 1992, p. 329).

[2] An “incident” is defined as including “all accidents and all near-miss events that did or could cause injury, or loss of or damage to property or the environment" (Center for Chemical Process Safety, 1992, p. 1).

This paper will help you to learn about human error and how it contributes to virtually every incident. This paper will also show you how to establish a human factors incident investigation program in your company and how to analyze the data collected so that you can learn from incidents and identify how to improve your policies and work practices to achieve a higher level of safety. Examples are provided from three different organizations that have established their own human factors investigation programs, sharing "lessons learned" and how the program has benefited them.

1.2 Background from the 1996 International Workshop on Human Factors in Offshore Operations

Studies of accidents and other incidents on offshore platforms have indicated that the vast majority of these accidents involve human error. In fact, about 80% do, and a further 80% of these occur during operations (Bea, Holdsworth, & Smith, 1997). The need to understand and control these human errors led to the assemblage of the 1996 International Workshop on Human Factors in Offshore Operations. The 1996 Workshop took a broad look at how Human Factors – often called Human and Organizational Factors to underscore the fact that most of these errors occur *not* within the span of control of the frontline operator, but are caused instead by decisions, policies, and operating procedures handed down by higher levels of the organization – affect every aspect of the offshore industry, from the design and fabrication of offshore production facilities, to field operations and maintenance, to management systems for improving safety and productivity. That Workshop laid the groundwork for the current workshop, which is delving into more detail on a number of human factors issues, including incident investigation and analysis.

The 1996 Workshop provided some good background material on human error (Bea, Holdsworth, & Smith, 1997; Card, 1997; Wenk, 1997), and even provided some tools that can be employed for incident investigation (Bea, 1997; Howard, et al., 1997; Kirwan, 1997; Moore, et al., 1997; Scient, Gordon, et al., 1997); these papers are heartily commended to the interested reader. The present paper goes into more detail on these topics and focuses the discussions on: the understanding of how human errors arise and contribute to incidents; a specific set of tools for representing the events and causes of an incident; dissecting out the different levels of human error; analyzing incident data; and using the human error model to select the most effective safety interventions. In short, this paper attempts to provide the reader with a "soup to nuts" examination of how to build a successful human factors incident investigation program.

1.3 The Typical Offshore Incident System and How Human Factors Data Can Enrich It

Thanks, in part, to OSHA and EPA regulations on Process Safety and Risk Management (e.g., 29 CFR 1910.119 and 40 CFR Part 68) and to the International Safety Management Code, many offshore and maritime companies already have an incident investigation program in place. These programs often follow well-grounded investigative practices, providing investigation team members with training in the basics of incident investigation, gathering and documenting evidence, and interviewing techniques. Many of these companies also keep an incident database and may do frequency and trending analysis. In short, they have many of the elements of a good incident investigation program already in place. However, where most of these programs fall short is in the areas of identifying human factors causes and determining how best to correct these problems.

While a number of companies attempt to consider "operator errors" during incident investigations, these operator errors represent only the tip of the human factors iceberg. As described in more detail in Section 2, most human factors causes originate further up the organizational chain, taking the form of poor management decisions, inadequate staffing, inadequate training, poor workplace design, etc. Simply identifying the "mistake" an operator made, and not "drilling down" to identify the underlying, organizational causes of that mistake, will not help to prevent reoccurrences of the incident. Because most offshore incident investigation programs do not have a thorough process for identifying the many types of human error, and the various levels of the organizations from which such errors originate, they lack the tools with which to make effective, human error-reducing, and thus incident-reducing, changes.

The remainder of this paper will provide the tools to understand, investigate for, and productively solve human error causes of incidents:

- Section 2 will describe what human error is and how it causes incidents; it will also discuss some of the most pervasive types of human error in the maritime and offshore industries.
- Section 3 outlines the keys to building a successful human factors incident investigation and analysis program. It will describe in detail the concept of an organization's "layers of system defenses" against catastrophic events, and how a weakening of these system defenses can result in incidents.
- Section 4 presents the Human Factors Analysis and Classification System (HFACS) – a simple to understand and use system for categorizing the types of human errors at each layer of system defense. HFACS has been used successfully in military and other industrial applications, and is compatible with maritime and offshore needs.
- Section 5 walks you through the analysis of an incident. It introduces Events and Causal Factors Charting, a method which first determines the events which occurred in the evolving incident (similar to a timeline analysis), and then considers the contributing causes to each event. The combination of Events and Causal Factors Charting, followed by an HFACS analysis of the causes, provides a powerful tools for ferreting out the underlying human error contributions to an incident.
- Data analysis is the topic of Section 6. Several different approaches are introduced, allowing companies to go well beyond the simple frequency and trend analysis in common usage today. Proactive, thoughtful data analysis is key to a company's awareness of safety issues and their probable underlying causes.
- Finding effective safety solutions is discussed in Section 7. This section takes you from the results of your HFACS and data analyses, through focused information-gathering on safety problems, to crafting effective interventions. The "triangle of effectiveness" is a

tool that will help you to find the most effective human factors interventions and safety solutions.

- Section 8 presents the “lessons learned” and “success stories” from three organizations now involved in human factors incident investigation and analysis. Their experiences can give you a head start with your own program.
- Section 9 wraps up the paper with a summary of the most important points discussed.
- The Appendices provide you with sample human factors-related questions to ask during an investigation, additional examples of human factors incident investigation classification schemes, database elements to capture the non-human factors relevant to an investigation, and specific data elements that can help to identify and understand three of the most prevalent types of human error in maritime/offshore accidents: fatigue, inadequate communications, and limitations in skill and knowledge.

When a focus on human error is incorporated into your existing incident investigation, analysis, and intervention program (as in Fig. 1), it can produce great benefits for your company, including fewer incidents, fewer lost-time accidents, improved employee morale, greater productivity, and an overall improvement to the bottom line.

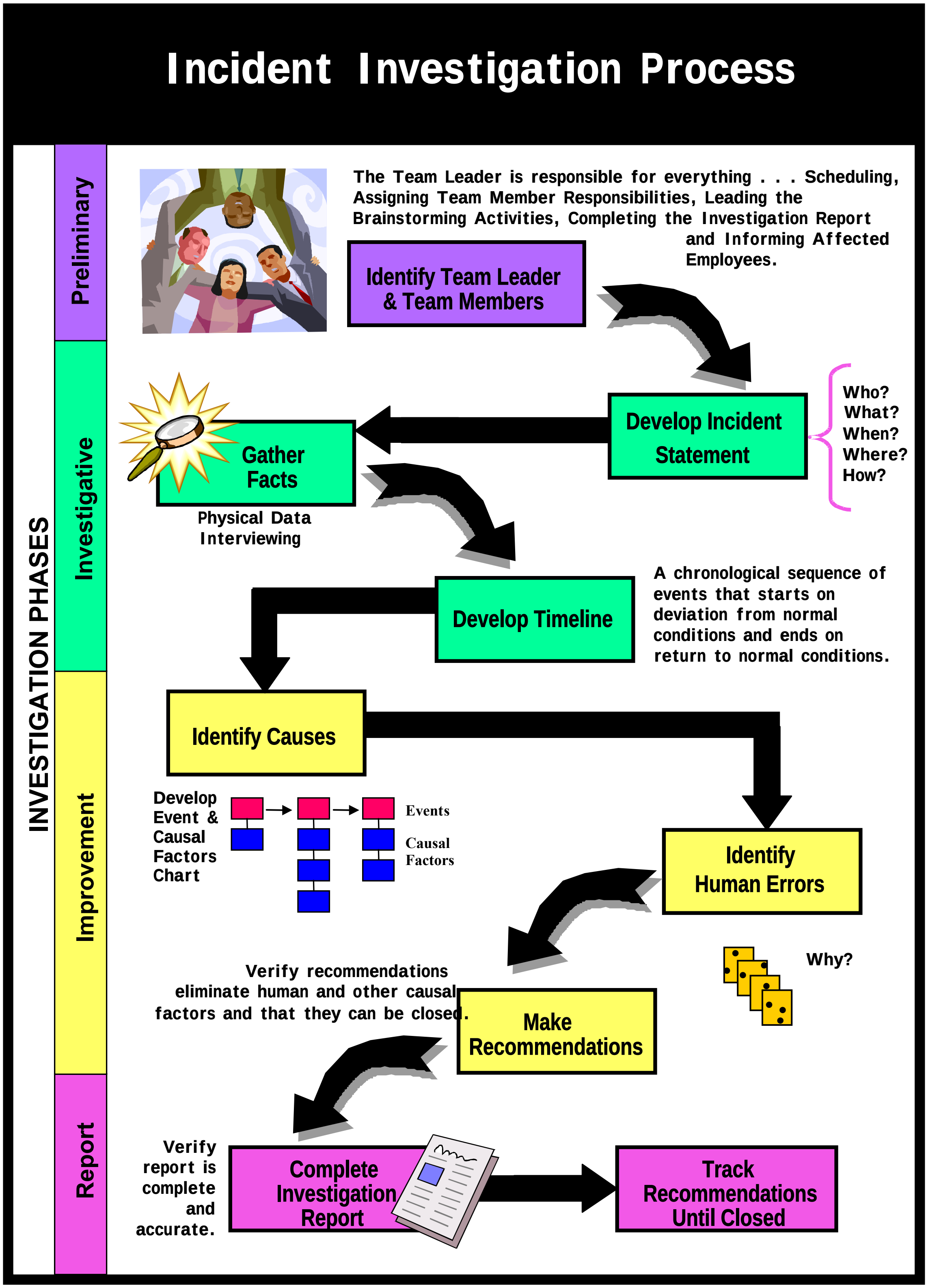

Figure 1. Incident Investigation Process.
(modified from Franklyn, 2000)

2.0 HUMAN ERROR[3]

Over the last 40 years or so, the shipping industry has focused on improving the structure of ships and platforms and improving the reliability of equipment systems in order to reduce casualties and increase efficiency and productivity. Today's maritime and offshore systems are technologically advanced and highly reliable. Yet, the maritime casualty rate is still high. The reason for this is because ship/offshore structure and system reliability are a relatively small part of the safety equation. The maritime system is a *people* system, and human errors figure prominently in casualty situations. About 75-96% of marine casualties are caused, at least in part, by some form of human error. Studies have shown that human error contributes to:

- 84-88% of tanker accidents (Transportation Safety Board of Canada, 1994)
- 79% of towing vessel groundings (Cormier, 1994)
- 89-96% of collisions (Bryant, 1991; U.K. P&I Club, 1992)
- 75% of allisions (Bryant, 1991)
- 75% of fires and explosions (Bryant, 1991)

Therefore, if we want to make greater strides towards reducing marine casualties, we must begin to focus on the types of human errors that cause casualties.

One way to identify the types of human errors relevant to the maritime and offshore industries is to study incidents and determine how they happen. Chairman Jim Hall of the National Transportation Safety Board (NTSB) has said that accidents can be viewed as very successful events. What Chairman Hall means by "successful" is that it is actually difficult to create an accident (thank goodness!). Accidents are not usually caused by a single failure or mistake, but by the confluence of a whole series, or chain, of errors. In looking at how accidents happen, it is usually possible to trace the development of an accident through a number of discrete events.

A Dutch study of 100 marine casualties (Wagenaar & Groeneweg, 1987) found that the number of causes per accident ranged from 7 to 58, with a median of 23[4]. Minor things go wrong or little mistakes are made which, in and of themselves, may seem innocuous. However, sometimes when these seemingly minor events converge, the result is a casualty. In the study, human error was found to contribute to 96 of the 100 accidents. In 93 of the accidents, multiple human errors were made, usually by two or more people, each of whom made about two errors apiece. But here is the most important point: *every human error* that was made was determined to be a *necessary condition* for the accident. That means that if just one of those human errors had *not* occurred, the chain of events would have been broken, and *the accident would not have happened*. Therefore, if we can find ways to prevent some of these human errors, or at least increase the probability that such errors will be noticed and corrected, we can achieve greater marine safety and fewer casualties.

[3] This section is taken from Rothblum (2000).

[4] This means that half the accidents had 7-23 causes and the other half of the accidents had 23-58 causes.

2.1 Types of Human Error

What do we mean by "human error"? Human error is sometimes described as being one of the following: an incorrect decision, an improperly performed action, or an improper lack of action (inaction). Probably a better way to explain human error is to provide examples from two real marine casualties.

The first example is the collision of the *M/V SANTA CRUZ II* and the USCG Cutter *CUYAHOGA*, which occurred on a clear, calm night on the Chesapeake Bay (Perrow, 1984). Both vessels saw each other visually and on radar. So what could possibly go wrong? Well, the *CUYAHOGA* turned in front of the *SANTA CRUZ II*. In the collision that ensued, 11 Coast Guardsmen lost their lives. What could have caused such a tragedy? Equipment malfunctions? Severe currents? A buoy off-station? No, the sole cause was human error.

There were two primary errors that were made. The first was on the part of the *CUYAHOGA*'s captain: he misinterpreted the configuration of the running lights on the *SANTA CRUZ II*, and thus misperceived its size and heading. When he ordered that fateful turn, he thought he was well clear of the other vessel. The second error was on the part of the crew: they realized what was happening, but failed to inform or question the captain. They figured the captain's perception of the situation was the same as their own, and that the captain must have had a good reason to order the turn. So they just stood there and let it happen. Another type of human error that may have contributed to the casualty was insufficient manning (notice that this is not an error on the part of the captain or crew; rather, it is an error on the part of a "management" decision-maker who determined the cutter's minimum crew size). The vessel was undermanned, and the crew was overworked. Fatigue and excessive workload may have contributed to the captain's perceptual error and the crew's unresponsiveness.

The second example is the grounding of the *TORREY CANYON* (Perrow, 1984). Again we have clear, calm weather--this time it was a daylight transit of the English Channel. While proceeding through the Scilly Islands, the ship ran aground, spilling 100,000 tons of oil.

At least four different human errors contributed to this incident. The first was economic pressure, that is, the pressure to keep to schedule (pressure exerted on the master by management). The *TORREY CANYON* was loaded with cargo and headed for its deep-water terminal in Wales. The shipping agent had contacted the captain to warn him of decreasing tides at Milford Haven, the entrance to the terminal. The captain knew that if he didn't make the next high tide, he might have to wait as much as five days before the water depth would be sufficient for the ship to enter.

This pressure to keep to schedule was exacerbated by a second factor: the captain's vanity about his ship's appearance. He needed to transfer cargo in order to even out the ship's draft. He could have performed the transfer while underway, but that would have increased the probability that he might spill a little oil on the decks and come into port with a "sloppy" ship. So instead, he opted to rush to get past the Scillies and into Milford Haven in order to make the transfer, thus increasing the pressure to make good time.

The third human error in this chain was another poor decision by the master. He decided, in order to save time, to go *through* the Scilly Islands, instead of *around* them as originally planned. He made this decision even though he did not have a copy of the *Channel Pilot* for that area, and even though he was not very familiar with the area.

The final human error was an equipment design error (made by the equipment manufacturer). The steering selector switch was in the wrong position: it had been left on autopilot. Unfortunately, the design of the steering selector unit did not give any indication of its setting at the helm. So when the captain ordered a turn into the western channel through the Scillies, the helmsman dutifully turned the wheel, but nothing happened. By the time they figured out the problem and got the steering selector back on "manual", it was too late to make the turn, and the *TORREY CANYON* ran aground.

As these two examples show, there are many different kinds of human error. It is important to recognize that "human error" encompasses much more than what is commonly called "operator error". In order to understand what causes human error, we need to consider how humans work within the maritime system.

2.2 The Maritime System: People, Technology, Environment, and Organizational Factors

As was stated earlier, the maritime system is a *people* system (Fig. 2). People interact with technology, the environment, and organizational factors. Sometimes the weak link is with the people themselves; but more often the weak link is the way that technological, environmental, or organizational factors influence the way people perform. Let's look at each of these factors.

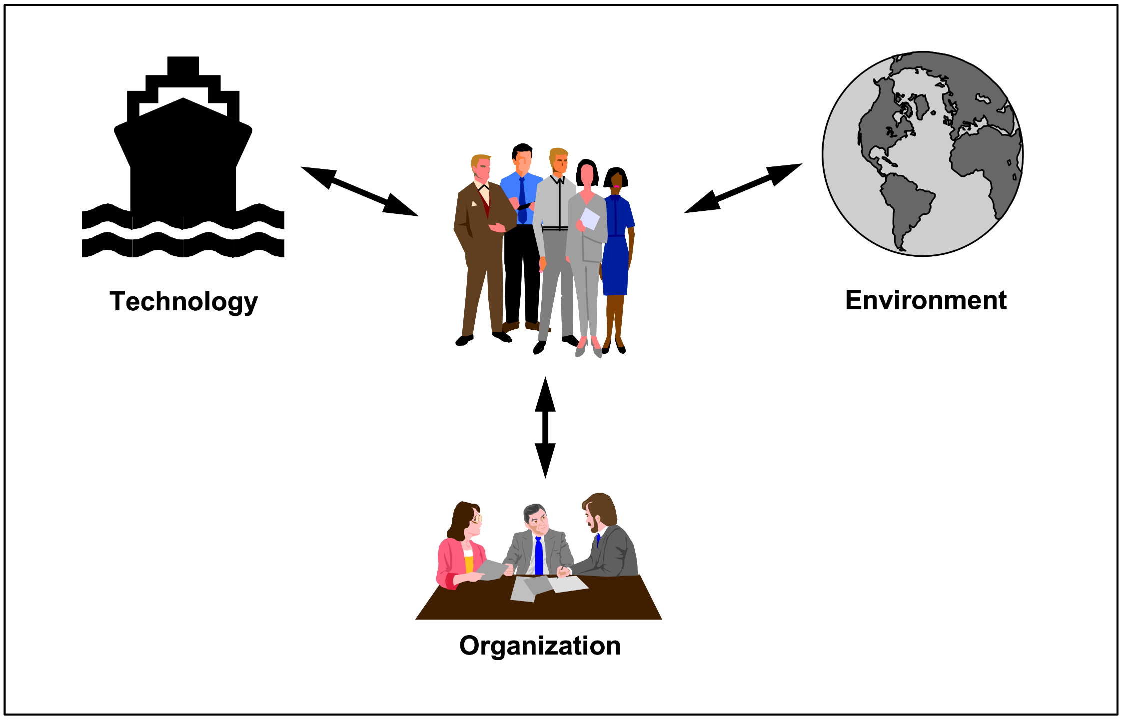

Figure 2. The Maritime System Is A *People* System

First, the people. In the maritime system this could include the ship's crew, pilots, dock workers, Vessel Traffic Service operators, and others. The performance of these people will be dependent on many traits, both innate and learned (Fig. 3). As human beings, we all have certain abilities and limitations. For example, human beings are great at pattern discrimination and recognition. There isn't a machine in the world that can interpret a radar screen as well as a trained human being can. On the other hand, we are fairly limited in our memory capacity and in our ability to calculate numbers quickly and accurately--machines can do a much better job. In addition to these inborn characteristics, human performance is also influenced by the knowledge and skills we have acquired, as well as by internal regulators such as motivation and alertness.

- **Knowledge**
- **Skills**
- **Abilities**
- **Memory**
- **Motivation**
- **Alertness**

Figure 3. The Maritime System: People

The design of technology can have a big impact on how people perform (Fig. 4). For example, people come in certain sizes and have limited strength. So when a piece of equipment meant to be used outdoors is designed with data entry keys that are too small and too close together to be operated by a gloved hand, or if a cutoff valve is positioned out of easy reach, these designs will have a detrimental effect on performance. Automation is often designed without much thought to the information that the user needs to access. Critical information is sometimes either not displayed at all or else displayed in a manner which is not easy to interpret. Such designs can lead to inadequate comprehension of the state of the system and to poor decision making.

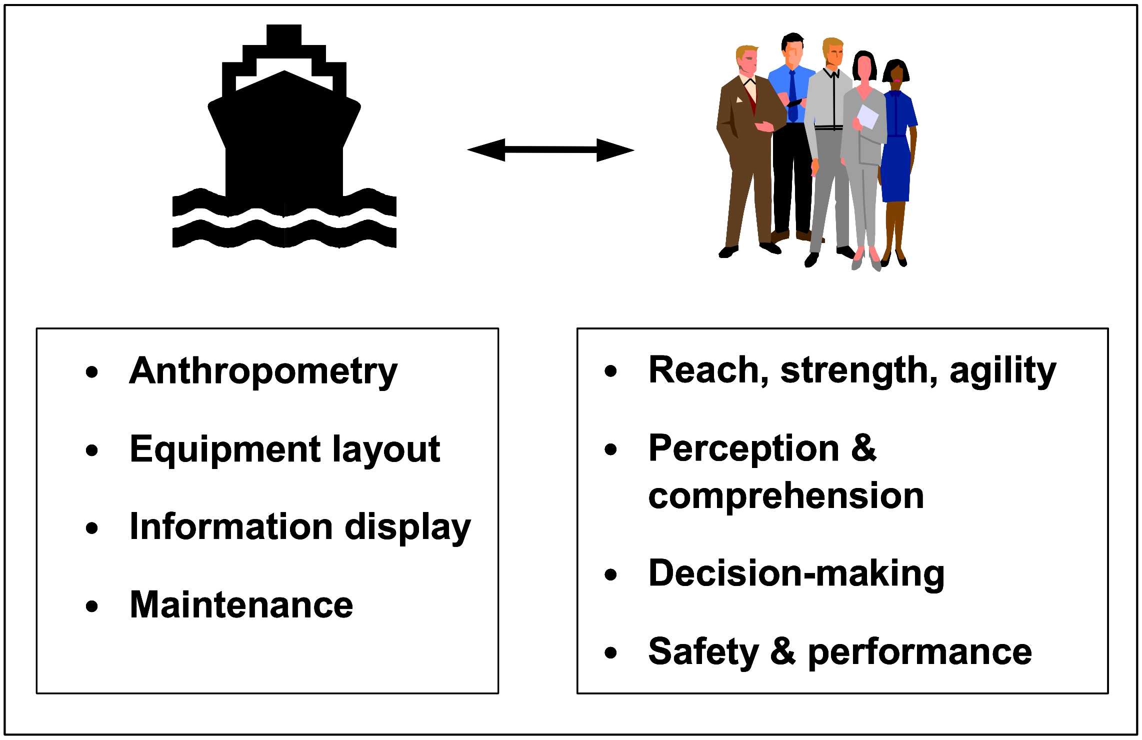

Figure 4. The Maritime System: Effect of Technology on People

The environment affects performance, too (Fig. 5). By "environment" we are including not only weather and other aspects of the physical work environment (such as lighting, noise, and temperature), but also the regulatory and economic climates. The physical work environment directly affects one's ability to perform. For example, the human body performs best within a fairly restricted temperature range. Performance will be degraded at temperatures outside that range, and fail altogether in extreme temperatures. High sea states and ship vibrations can affect locomotion and manual dexterity, as well as cause stress and fatigue. Tight economic conditions can increase the probability of risk-taking (e.g., making schedule at all costs).

Finally, organizational factors, both crew organization and company policies, affect human performance (Fig. 6). Crew size and training decisions directly affect crew workload and their capabilities to perform safely and effectively. A strict hierarchical command structure can inhibit effective teamwork, whereas free, interactive communications can enhance it. Work schedules which do not provide the individual with regular and sufficient sleep time produce fatigue. Company policies with respect to meeting schedules and working safely will directly influence the degree of risk-taking behavior and operational safety.

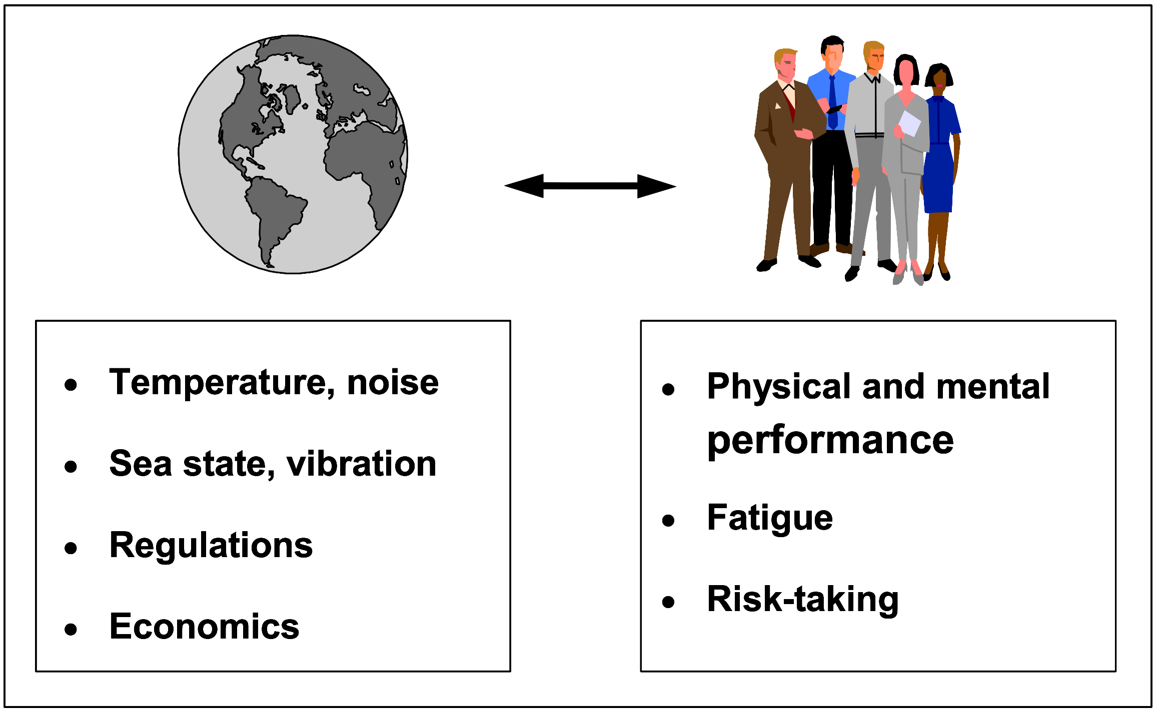

Figure 5. The Maritime System: Effect of Environment on People

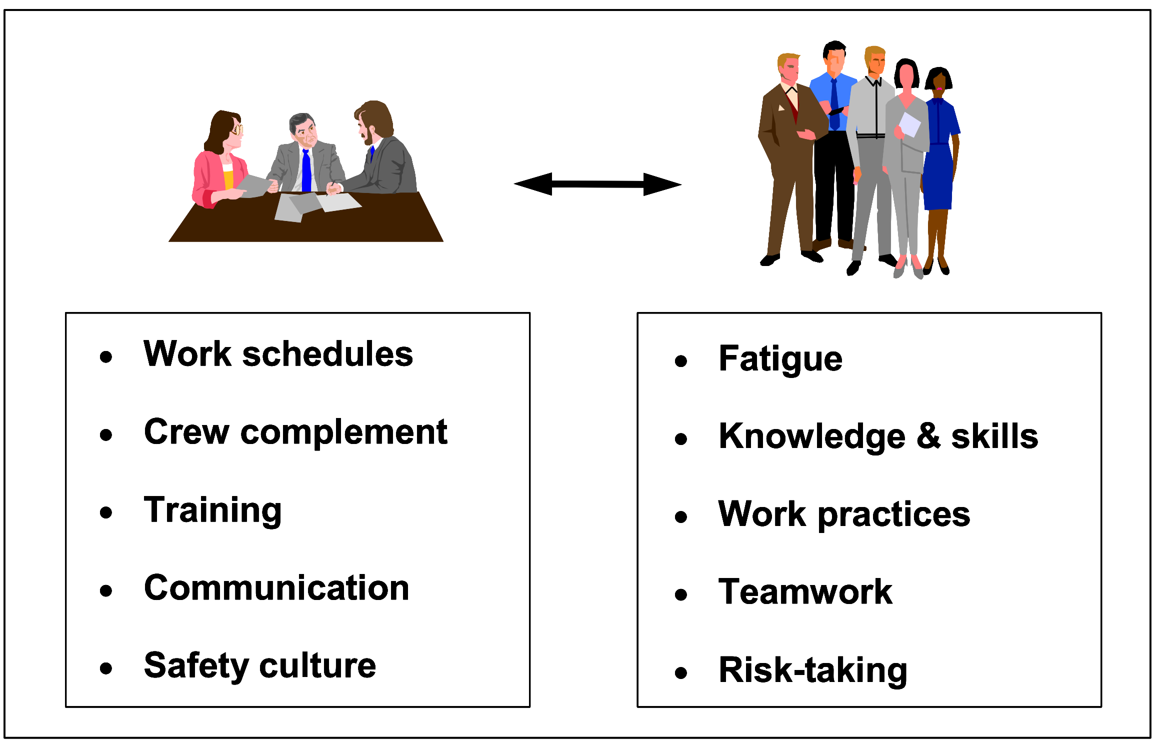

Figure 6. The Maritime System: Effect of Organization on People

As you can see, while human errors are all too often blamed on "inattention" or "mistakes" on the part of the operator, more often than not they are symptomatic of deeper and more complicated problems in the total maritime system. Human errors are generally caused by technologies, environments, and organizations which are incompatible in some way with optimal human performance. These incompatible factors "set up" the human operator to make mistakes. So what is to be done to solve this problem? Traditionally, management has tried either to cajole or threaten its personnel into not making errors, as though proper motivation could somehow overcome poorly designed management and equipment systems and inborn human limitations. In other words, the human has been expected to adapt to the system. *This does not work*. Instead, what needs to be done is to *adapt the system to the human*.

The discipline of human factors is devoted to understanding human capabilities and limitations, and to applying this information to design equipment, work environments, procedures, and policies that are compatible with human abilities. In this way we can design technology, environments, and organizations which will work *with* people to enhance their performance, instead of working *against* people and degrading their performance. This kind of *human-centered* approach (that is, adapting the system to the human) has many benefits, including increased efficiency and effectiveness, decreased errors and incidents, decreased training costs, decreased personnel injuries and lost time, and increased morale.

2.3 Human Factors Issues in the Maritime Industry

What are some of the most important human factors challenges facing the maritime industry today? A study by the U.S. Coast Guard (1995) found many areas where the industry can improve safety and performance through the application of human factors principles. Below are summaries of the "top ten" human factors areas that need to be improved in order to prevent casualties.

2.3.1 Fatigue

The NTSB has identified fatigue to be an important cross-modal issue, being just as pertinent and in need of improvement in the maritime industry as it is in the aviation, rail, and automotive industries. Fatigue has been cited as the "number one" concern of mariners in two different studies (Marine Transportation Research Board, 1976; National Research Council, 1990). It was also the most frequently mentioned problem in a recent Coast Guard survey (U.S. Coast Guard, 1995). A recent study has objectively substantiated these anecdotal fears: in a study of critical vessel casualties[5] and personnel injuries, it was found that fatigue contributed to 16% of the vessel casualties and to 33% of the injuries (McCallum, Raby, & Rothblum, 1996).

[5] A "critical" vessel casualty was defined as a vessel casualty in which there was significant damage to the vessel or property, or in which the safety of the crew was at risk.

2.3.2 Inadequate Communications

Another area for improvement is communications--between shipmates, between masters and pilots, ship-to-ship, and ship-to-VTS. An NTSB report (National Transportation Safety Board, 1981) stated that 70% of major marine collisions and allisions occurred while a State or federal pilot was directing one or both vessels. Better procedures and training can be designed to promote better communications and coordination on and between vessels. Bridge Resource Management (BRM) is a first step towards improvement.

2.3.3 Inadequate General Technical Knowledge

In one study, this problem was responsible for 35% of casualties (Wagenaar & Groeneweg, 1987). The main contributor to this category was a lack of knowledge of the proper use of technology, such as radar. Mariners often do not understand how the automation works or under what set of operating conditions it was designed to work effectively. The unfortunate result is that mariners sometimes make errors in using the equipment or depend on a piece of equipment when they should be getting information from alternate sources.

2.3.4 Inadequate Knowledge of Own Ship Systems

A frequent contributing factor to marine casualties is inadequate knowledge of own ship operations and equipment. Several studies and casualty reports have warned of the difficulties encountered by crews and pilots who are constantly working on ships of different sizes, with different equipment, and carrying different cargoes. The lack of ship-specific knowledge was cited as a problem by 78% of the mariners surveyed (National Research Council, 1990). A combination of better training, standardized equipment design, and an overhaul of the present method of assigning crew to ships can help solve this problem.

2.3.5 Poor Design of Automation

One challenge is to improve the design of shipboard automation. Poor design pervades almost all shipboard automation, leading to collisions from misinterpretation of radar displays, oil spills from poorly designed overfill devices, and allisions due to poor design of bow thrusters. Poor equipment design was cited as a causal factor in one-third of major marine casualties (Wagenaar & Groeneweg, 1987). The “fix” is relatively simple: equipment designers need to consider how a given piece of equipment will support the mariner’s task and how that piece of equipment will fit into the entire equipment “suite” used by the mariner. Human factors engineering methods and principles are in routine use in other industries to ensure human-centered equipment design and evaluation. The maritime industry needs to follow suit.

2.3.6 Decisions Based on Inadequate Information

Mariners are charged with making navigation decisions based on all available information. Too often, we have a tendency to rely on either a favored piece of equipment or our memory. Many casualties result from the failure to consult available information (such as that from a radar or an echo-sounder). In other cases, critical information may be lacking or incorrect, leading to navigation errors (for example, bridge supports often are not marked, or buoys may be off-station).

2.3.7 Poor Judgement

Risky decisions can lead to accidents. This category contained actions that were not consistent with prudent seamanship, such as passing too closely, excessive speed, and ignoring potential risks.

2.3.8 Faulty Standards, Policies, or Practices

This is an oft-cited category and covers a variety of problems. Included in this category is the lack of available, precise, written, and comprehensible operational procedures aboard ship (if something goes wrong, and if a well-written manual is not immediately available, a correct and timely response is much less likely). Other problems in this category include management policies which encourage risk-taking (like pressure to meet schedules at all costs) and the lack of consistent traffic rules from port to port.

2.3.9 Poor Maintenance

Published reports (Bryant, 1991; National Research Council, 1990) and survey results (US Coast Guard, 1995) expressed concern regarding the poor maintenance of ships. Poor maintenance can result in a dangerous work environment, lack of working backup systems, and crew fatigue from the need to make emergency repairs. Poor maintenance is also a leading cause of fires and explosions (Bryant, 1991).

2.3.10 Hazardous Natural Environment

The marine environment is not a forgiving one. Currents, winds, ice, and fog make for treacherous working conditions. When we fail to incorporate these factors into the design of our ships, platforms, and equipment, and when we fail to adjust our operations based on hazardous environmental conditions, we are at greater risk for casualties.

These and other human errors underlie almost every maritime incident. By studying incidents to understand their contributing causes, we can learn how to redesign our policies, procedures, work environments, and equipment to be more compatible with our human users and, thus, bring about improved safety and productivity. In the next sections we will discuss how to develop a human factors incident investigation program for your company.

3.0 BUILDING A HUMAN FACTORS INCIDENT INVESTIGATION PROGRAM

A well-designed company safety program is multi-faceted. Health, Safety, and Environment (HSE) management, risk assessment and management, behavior based safety management (BBSM), quality programs, and project management all play a role in improving safety. A careful Job Hazards Analysis (JHA) or Job Safety Analysis (JSA) can identify work hazards and recommend redesigns of equipment and work procedures, as well as associated precautions that can prevent accidents.

Behavior based safety management and other related processes work hand-in-hand with incident investigation to identify potential problems. Behavior based safety management is a *proactive* process which examines the workplace to identify problems *before* an incident occurs, while incident investigation is a *reactive* process which identifies workplace and procedural hazards that caused an accident or near-miss. The data from both types of processes should be used together to gain the most complete understanding of potential hazards. The fact that both these processes can be used to prevent incidents was underscored by a fatal fall that occurred at a construction site. Just prior to the accident, the company's BBSM data had shown that personnel were not hooking up or using fall protection properly. The data also identified several barriers to the safe behavior, including: lack of available hook up points; lack of available fall protection in high hazard areas; lack of training on proper use of protective equipment; unclear procedures; and discomfort associated with wearing harnesses. By collecting these kinds of upstream indicators, a company can correct the situation before an incident happens.

Unfortunately, we're not always able to foresee and prevent every type of incident that might occur. This is what makes incident investigation an important part of the company's overall safety strategy. An incident investigation and analysis program is essential to understanding the underlying, and sometimes hidden, causes of workplace incidents. Proper identification of the true contributors to accidents allows a company to establish workable preventive measures. This section discusses how to build a human factors incident investigation program.

Additional information and publications on human factors and incident investigation in the offshore industry are offered on several web sites. The American Institute of Chemical Engineers (http://www.aiche.org) offers two documents, "Guidelines for Investigating Chemical Process Incidents" and "International Conference and Workshop of Process Industry Incidents". The U.K.'s Health and Safety Executive (http://www.open.gov.uk/hse/hsehome.htm) has the publication "Human and Organisation Factors in Offshore Safety". The International Association of Oil and Gas Producers (http://www.ogp.org.uk) has a safety incident reporting system and incident statistics.

3.1 Keys to a Successful Human Factors Incident Investigation Program

Before we jump into the details of how to investigate for human factors causes of incidents, it is important to mention a few key factors which will encourage cooperation in incident investigations and will promote good data quality. These key factors are: an open, fair, improvement-seeking culture; an understanding of the purpose and scope of the incident investigation program; training for investigators on human factors; a database classification scheme (taxonomy) that supports the goals of the incident investigation program; a simple, user-friendly way of entering incident data; and feedback to show how incident data have been used to improve safety (Hill, Byers, & Rothblum, 1994).

3.1.1 <u>An Open, Fair, Improvement-Seeking Culture</u>

The fundamental purpose of an incident investigation is to understand the circumstances and causes of the incident with the aim of improving safety. We want to understand: what happened; how it happened; why it happened; and, most importantly, what steps can be taken to prevent it from happening again. Only by dispassionately analyzing the incident evolution in detail and determining its underlying contributing factors can we design and implement effective remedial actions. It is important to remember that we are *not* out to attribute blame: actions taken solely to "blame and shame" generally do little to prevent similar incidents from occurring in the future. This is because, as discussed in the previous section, most incidents are not the "fault" of a given person; rather, they are indicative of deficiencies within the system. Companies whose incident investigations focus on "finger-pointing" (i.e., identifying the person who is supposedly "to blame" for the incident) short-circuit their ability to find and understand the *real* causes of the incident. Only by analyzing and addressing the contributing factors – the system deficiencies – that underpin the actions of those directly involved, can we make real progress in reducing the frequency of incidents. Therefore, it is necessary to foster an open and trusting environment where personnel feel free to discuss the evolution of an incident without fear of unjust reprisal. If personnel know that the purpose of the investigation is to identify how to improve safety, and that the investigation will lead to a fair and objective analysis of the incident, they will be much more likely to participate in a candid interview. Without such a supportive environment, involved individuals will be reluctant to cooperate in a full disclosure of the events leading to an incident.

3.1.2 <u>Common Understanding of the Purpose and Scope of the Incident Investigation Program</u>

The incident investigation program, and the database which supports it, should be constructed to accomplish a well-defined purpose. Program managers need to agree on specific questions the program – and, therefore, the incident database – will be expected to answer. For example, a company might wish to focus on reducing maintenance incidents which result in lost time for the employee. Such a program, and its database, would need information on the type of maintenance activity being performed, the type of injury sustained (accident) or narrowly avoided (near-miss), damage to equipment or workplace, lost time and money due to injury (or potential loss, in the case of a near-miss), and causes of the of the (near-) injury (such as poor standard operating procedures, insufficient lighting, undermanning, equipment defects, inadequate task design, lack of safety policies, etc.). In contrast, a program focused on preventing hazardous material spills/emissions could have a significantly different set of factors of interest (such as type of hazmat, regulations violated, location and size of spill, fines and clean-up costs; operational activities at time of spill; events and underlying causes leading to the spill). The point here is that the goals of your incident investigation program must drive the types of questions you will want to answer, which in turn dictate the types of data you will collect during the investigations.

A knowledge of the purpose of the database will guide the form the investigation takes and will help in determining the appropriate resources to devote to the investigation. If certain causal areas are known to be particularly important, effort will be concentrated in those areas. Conversely, if the investigators do not understand the purpose of the program, they will shape their investigations around their own biases and areas of expertise, rather than around the goals of the program.

Clear guidance is needed for investigators to know what level of detail is sufficient, and what resources are needed to properly fulfill the purpose of their investigations and thoroughly report their findings. In the offshore industry this is often formalized through a "charter" which is developed at the beginning of an incident investigation. The charter identifies the investigation team, states the responsibilities of the team, its goals (e.g., to identify causes or to develop recommendations), and a timeline for the investigation. The incident investigators, and *all* personnel, must understand the program goals and how their input will help promote safety improvements. Only then will the investigators know what types of data are important to collect, and only then will employees understand why their active cooperation is important.

3.1.3 Appropriate Training for Incident Investigators

An incident investigation program rests on the abilities of its investigators. Incident investigation does not come naturally: it must be trained. Investigators need background on how incidents evolve and the myriad events and attributes which can cause or contribute to the severity of an incident. They need to know how to ask appropriate questions, how to work with uncooperative witnesses, how to build an events and causal tree (or other tool to help guide the investigation). And, of course, they need to understand the specific goals of the company's incident investigation program.

Human factors-related information is often overlooked even by seasoned investigators if they have not been specifically trained to identify such data. While it is both natural and expected that investigators will use their individual experiences and unique areas of expertise (e.g., engineering, navigation, drilling) when conducting investigations, some individuals may not have an adequate perspective to search for or recognize human-related causes. A related problem is that if a human factors element is not overlooked entirely, it is often oversimplified. A single "obvious" human-related contributing factor may be identified, such as "inattention", without looking for the root cause (perhaps information overload, as a result of a poor display design). As described earlier, many external factors (technology, organization, environment) affect human performance, and it takes training for investigators to understand and recognize these underlying contributors.

In the offshore industry, it is fairly common for a company to "charter" an incident investigation team when an incident occurs. These *ad hoc* team members may include a combination of workers, line supervisors, and managers. It is important to choose a team that will be fair, unbiased, and objective. While team members are usually chosen because of their experience in the area where the incident occurred, they may have little or no background in either incident investigation or human factors. If the team is going to be successful at identifying the underlying causes of the incident, then at least some of the team members must have training and experience in human factors incident investigation.

3.1.4 Incident Database Classification Scheme

The database classification scheme (taxonomy) must be directly linked to the purpose and scope of the incident investigation program. The database elements must match the level of detail that is needed to answer the safety-related questions upon which the program goals are based. Too often an incident database is constructed in a haphazard way, with the program managers trying to think up data elements without first determining the questions the database is meant to answer. The sad result is a database of little value, which falls far short of supporting safety improvements.

When it comes to human factors information, the database must be compatible with both the program goals and the level of knowledge of the investigators. The terminology used in the classification scheme must be well-defined and understood by the investigators. In some cases, tools may be needed to help the investigator determine whether a given human factor is related to the incident.

For example, the term “fatigue” is very hard to define – many of us carry our own beliefs (correct or incorrect) as to what fatigue is and how it relates to safety. In order to obtain reliable and valid data on fatigue, it may be useful to determine specific pieces of data the investigator would collect and to provide an algorithm that would use these data to determine whether “fatigue” played a role in the incident. An example of this is the Fatigue Index Score being used by the U.S. Coast Guard (McCallum, Raby, & Rothblum, 1996; see App. G): investigators collect the number of hours worked and slept in the twenty-four hours preceding the casualty and also collect information on fatigue symptoms (e.g., difficulty concentrating, heavy eyelids, desire to sit down). These data are put into an equation which tells the investigator whether fatigue is a likely cause, and therefore whether a more extensive investigation needs to be done to determine what contributed to the fatigue. When the classification scheme is based on well-defined, quantifiable data, it increases the reliability and validity of the human factors causes identified (e.g., fatigue), and, more importantly, it keeps the investigator focused on *why* the human factors cause was present (e.g., insufficient sleep due to extended port operations).

A good database should also be adaptable to the changing needs of the organization. As the organization learns lessons from the incident data, it is probable that additional items or levels of detail will be desired from investigations, requiring a modification of the classification scheme and database. One final note: while a classification scheme is extremely helpful for data analysis, it can never capture the flavor of the incident. Narrative sections are crucial for a full understanding of the evolution of the incidents and for capturing important information that just does not fit into the taxonomy.

3.1.5 Simple Data Entry

An incident database should reside on a computer system so that data analyses can be performed. It is best to have the investigators enter their own incident data, as a clerk may easily misread or misunderstand the investigator's notes. The user interface of the database needs to be efficient and user-friendly in order to promote data validity and completeness. Unfortunately, examples of poor user interfaces abound. Just as the classification scheme will determine the data collected and reported, the computer interface will determine the quality of the data entered. If a certain data field is required to be filled out, it will always be filled out, even if the data entered are of questionable quality. When the computer interface is poorly designed the system becomes an obstacle to be overcome, and effort will be focused on just getting "something" into the system, rather than spending effort on the veracity and completeness of the data entered (Hill, Byers, & Rothblum, 1994). A good incident database must be simple to use, allowing investigators to enter all relevant data easily and completely, and allowing them to skip data fields that do not pertain to the case.

3.1.6 Feedback on Results of the Incident Investigation Program

Nothing dulls an investigator's enthusiasm more than to be working hard to capture useful data, only to get the feeling that it's all going down some deep, dark hole. Feedback is crucial to a successful incident investigation program. Investigators need to see the results of their work. And all personnel need to know that the program is not just another "flash in the pan", but something to which management has an on-going commitment. Publish results of incident analyses, make specific incidents the topic of safety meetings, use the results to start discussions on how to improve safety, and let personnel know that the new policies going into effect were based on lessons learned from incident investigations. When the use of the incident database is made public, investigators will redouble their efforts to collect complete data, and personnel will be more likely to cooperate in investigations.

3.2 Investigating for Human Factors Causes

Historically, companies and agencies that investigate incidents have overlooked human factors causes almost entirely. Material deficiencies in incidents (for example, equipment malfunction or a deficiency in the structural integrity of the vessel or platform) can normally be readily identified (e.g., a shaft is broken or there's a hole in the hull). However, the real difficulty in incident investigation is to answer *why* these deficiencies occurred, and the answer is usually related to human behavior. For instance, the shaft may have broken because of company management decisions, such as cutting back on maintenance, purchasing a less costly (and less well-made) piece of equipment, or selecting less-experienced engineers. Or, the shaft may have broken due to poor supervision of operations or maintenance, or due to an error made during maintenance, or to someone who used the equipment outside its safe operating range. Each of these underlying factors needs to be probed for *why* it happened, as well (e.g., did the company cut back on maintenance to save money or to offload its minimally-manned crew? was the equipment operated outside its range due to inexperience or willful violation by the operator?). Only after the investigator understands the true underlying cause(s) can meaningful solutions be developed. In typical investigations, however, the *why* is often ignored.

Another problem with the way most investigations unfold is that individuals are usually targeted for either "incompetence" or for "criminal negligence". This is particularly true when the investigator discovers that a given individual appeared to be responsible for the incident because the individual: had fallen asleep on duty; was under the influence of alcohol or drugs on duty; violated a regulation or standard operating procedure; appeared to be inattentive; or made an inappropriate decision. While it is sometimes the case that an individual *is* incompetent or negligent, the investigator should always look for contributing causes or other factors underpinning such behavior. It is often the case that work policies, standard operating procedures, and poorly designed jobs or equipment are at the core of the problem. Sanctioning the individual will not solve the problem and only creates a culture of fear and secrecy. Discovering the real reasons which underlie a given incident and working to solve the core issues will engender trust and openness in the work culture and lead to real improvements in safety.

3.3 How an Incident Evolves

There are usually multiple causes of an incident, with multiple people and events contributing to its evolution. As mentioned in the Introduction, the accidents studied in detail by Wagenaar and Groeneweg (1987) had anywhere from 7 to 58 distinct causes, with 50% of the cases having at least 23 causes. We are often very good at identifying the error most immediately linked to an incident. This is usually an error made by one of the people at the scene of the incident, such as that made by the helmsman of the *TORREY CANYON* when he failed to take the ship off automatic pilot in time to make the turn. We call these "active failures" because they represent an action, inaction, or decision that is directly related to the incident. However, we are often not as good at identifying other contributing causes, because many of these contributing causes may have occurred days, months, or even years before the incident in question. We call these "latent conditions", because they are error-inducing states or situations that are lying dormant until the proper set of conditions arise which expose their unsafe attributes. One of the latent conditions in the *TORREY CANYON* incident was the poor design of the steering selector switch: it gave no indication at the helm as to whether steering was set to "manual" or "automatic". An even more important latent error was management pressure on the master to keep to schedule, for that sense of urgency underlay his poor decisions. In this way the human operator is "set up" to make errors because the latent conditions make the system in which he works error-inducing rather than error-avoiding.

James Reason (1990) offered a useful paradigm, often referred to as the "Swiss cheese model," that explains how the many types of contributing factors can converge, resulting in an incident[6]

[6] Reason's work underscores the fact that "human errors" and "human factors" relate to the *entire system*, not just to an individual operator. The International Ergonomics Association defines human factors as being "concerned with the understanding of interactions among humans and other elements of a system." Further, it states that the area of human factors considers the design of "tasks, jobs, products,

(Fig. 7). A company tries to promote safety and prevent catastrophic accidents by putting into place layers of system defenses, depicted in the figure below as slices of Swiss cheese. Essentially, "system defenses" refers to the safety-related decisions and actions of the entire company: top management, the line supervisors, and the workers. The Organizational Factors layer (slice) represents the defenses put into place by top management. This level of system defenses might include a company culture which puts safety first, and management decisions which reinforce safety by providing well-trained employees and well-designed equipment to do the job. The second layer of defenses is the "Supervision" layer. This refers to the first-line supervisor and his or her safety-consciousness as displayed by the operational decisions he or she makes.

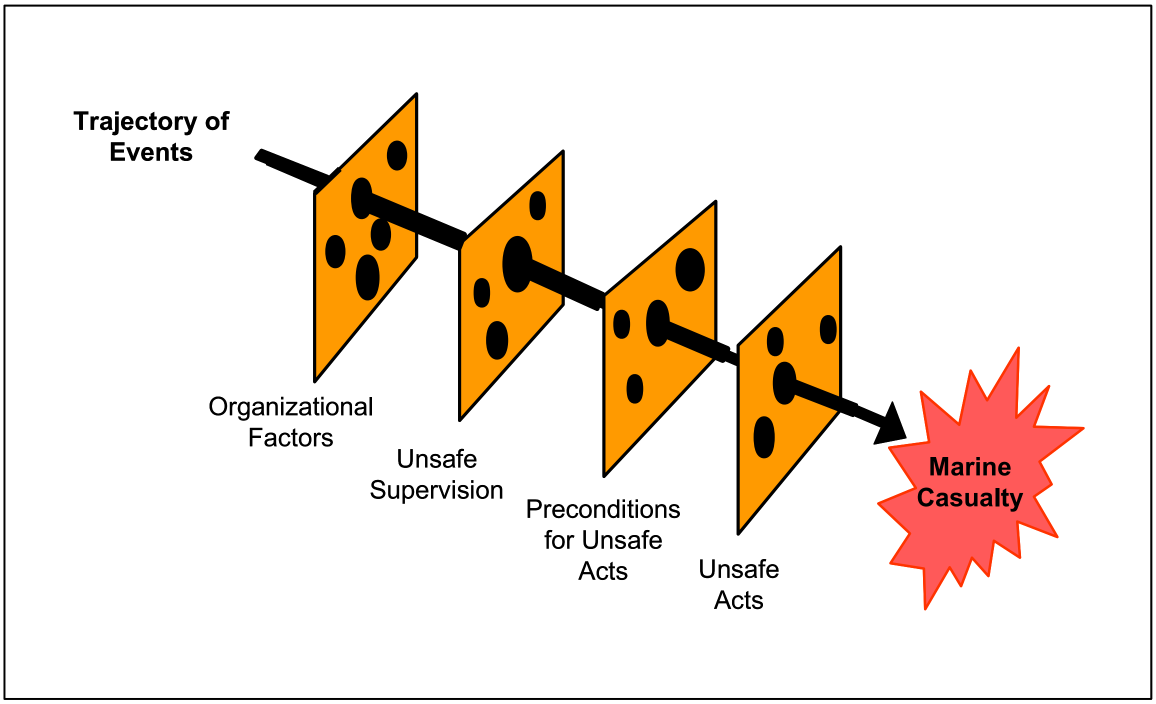

Figure 7. An Accident in the Making
(after Reason, 1990, as adapted by Wiegmann & Shappell, 1999)

For example, a good supervisor will ensure that personnel receive the proper training and mentoring, that work crews have the necessary skills and work well together, and that safety-related procedures are used routinely. The actions and "fitness for duty" of the worker make up the third layer of system defenses. In a safe system, the operator is physically and mentally ready to perform and routinely adheres to safe operating practices and procedures.

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environments and systems in order to make them compatible with the needs, abilities and limitations of people." It is crucial to understand that in a human factors incident investigation we are *not* looking to identify a person "at fault"; instead, we are looking primarily for weaknesses in the links between the human workers and other parts of the system, such as management policies, equipment design, and work environment.

These system defenses can slowly erode over time in response to economic pressures, increasing demand for products and services, diminishing attention to promoting a safety culture, and others. Each time safety is sacrificed (e.g., by cutting back on preventive maintenance or by taking unsafe "shortcuts" in operational tasks), it puts another hole into that slice of cheese. If synergistic reductions in safety occur at all three levels of the system (that is, when the "holes" in the Swiss cheese line up), then the system no longer has any inherent protections, and it becomes an accident waiting to happen. All it takes is one mistake (unsafe act).

Here's an example of how chipping away at system defenses can result in a casualty. Let's say as a cost-cutting measure, a company decides to decrease the inventory of spare parts on its ships (hole in the Organizational Factors slice). One day the ship develops engine problems from clogged fuel injectors and doesn't have sufficient spare parts (this would be analogous to an equipment "precondition"). The captain, knowing that the company would penalize him if he spent money to be towed into port (hole in Supervision, since the captain reports to the company), decides to take a risk and transit on only one engine (Unsafe Act). That engine fails, and the vessel drifts and grounds.

3.4 Improving Safety through Incident Investigation and Analysis

Maritime and offshore operations are inherently risky. Company managers have to weigh often-competing interests in safety, productivity, profitability, and customer expectations in order to be viable. Sometimes, well-meaning decisions back-fire and cause unanticipated safety problems. One way management can keep its finger on the safety pulse of the company is through incident investigation and analysis. As Fig. 8 shows, by thoroughly investigating incidents and the human errors that cause them, one can identify the holes in the system defenses and develop workable solutions.

An incident investigation program consists of five components (Fig. 8). First, the company must support the investigation of incidents. This requires objective investigators with at least a minimal amount of training in investigation techniques and a firm understanding of the purpose of the investigation and the types of data which must be collected to support the company's objectives. Second, the company must develop and maintain an incident database. As mentioned earlier, such a database should be computerized for easier analysis. The database must be composed of a set of taxonomies (classification schemes) which will capture the incident elements of interest to the company. The database should also incorporate narrative fields so that investigators can explain events and causes in more detail. Third, the company must then support regular analysis of the incidents in the database. As will be discussed in more detail later, analysis allows the company to find patterns common to a group of incidents, and allows the determination of how frequently different types of incidents occur and, in the case of near-misses, the potential severity of the accident that was avoided. Such data are very helpful in targeting the types of safety problems that the company will want to spend time and money to solve.

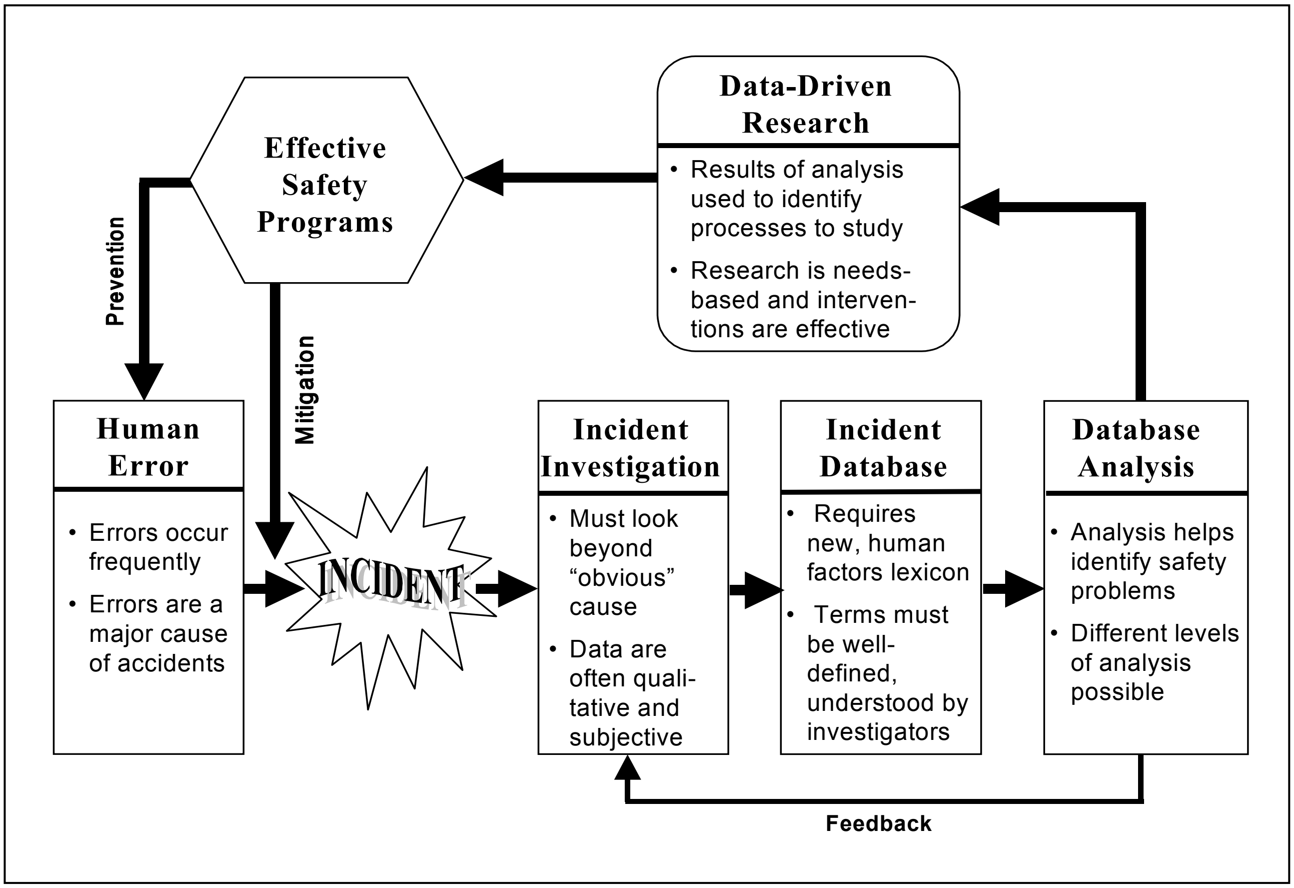

Figure 8. How An Effective Human Factors Incident Investigation Program Can Improve Safety
(Modified from Wiegmann and Shappell, 1999)

The fourth component of a successful incident investigation program is data-driven research. Incident investigation will frequently just "skim the surface" of a safety problem. The value of incident investigation and analysis is that it *identifies areas of concern.* In most cases, incident investigation and analysis will *not* be sufficient to "solve" the problem. Solving the problem will require getting more information on the policies, standard operating procedures, common work practices, equipment and job design, and employee attributes (like training, preparedness, physical and mental condition) linked to the activities or situations in which the incidents have occurred. The "research" might take the form of a risk assessment, or it may require the collection of additional, detailed information in subsequent investigations of related incidents, or perhaps a comparison of current company policies and practices with those employed by other companies ("benchmarking"). Through research, the company gains a more complete understanding of all the various contributing factors which drive the incidents of interest. The research might then extend to a comparison of the effectiveness of different prevention methods.

Finally, the result of the research step is an addition to or a revision of the company's safety program. Using the concept of "barrier analysis" (Hollnagel, 2000), the company wants to understand how safety failures arise and implement "barriers" (such as equipment "shields" to protect workers from exposure to potential harm, or procedures which prevent activities known to be hazardous) to prevent incidents. Successful *prevention* can eliminate certain hazards. Other incident causes may not be easily prevented, but there may be ways to *mitigate* (reduce) their consequences. When a safety program acts on the incident data which contains underlying causes, it will be effective.

3.5 Error Recovery

Error recovery is an important supplementary safety goal, and will be mentioned briefly here. Many offshore companies have a "zero accidents" policy which, while the ultimate safety goal, may be difficult to fully attain (Kontogiannis, 1999). In some industries, systems are being developed which focus on preventing the consequences of human error by providing opportunities for error recovery (Helmreich, et al., 2000; Sasou & Reason, 1999).

A framework developed by Kontogiannis (1999) categorizes error recovery according to the process used, the outcome, and the stage of performance. The process is usually either detection, explanation, or correction. For example, if you are using a word processor and misspell a word, one option for the spell check function is to merely *detect* the misspelled word and allow the user to decide what, if anything, to do about it. A different option has the spell checker both detect and *explain* or suggest options for correcting the word. Some word processors are even capable of *correction*, by automatically detecting and correcting misspellings as you type. Similar detection, explanation, and correction features can be built into offshore and maritime systems, either through automation or through procedures.

Outcomes of the recovery process refer to the state of the system after recovery. For example, an error-detecting system might block the error from happening and return the system to its original state prior to the error (this is called backward recovery). The stage of performance relates to the stage in which the error detection was made. For example, the outcome stage would be where an error is detected based on a mismatch between the expected outcomes of a process and the outcomes actually observed. For instance, if there is a low pressure reading and the operator erroneously turns the valve in the wrong direction, the outcome will be an even lower pressure. An error detector in the outcome stage would note the discrepancy between the present pressure reading and the higher pressure that was intended, and signal the error.

A simplified version of this framework is being used in a U.K. oil industry research project developing a human factors investigation tool (HFIT – see App. C; Gordon, Flin & Mearns, 2001). Investigators are asked three questions regarding the possible recovery process of the error: was the error detected (realized or suspected), was it understood why the error occurred, and was it corrected (e.g., by modifying an existing plan or developing a new plan)? How the error was detected (e.g., via system feedback, external communications, etc.) is also discussed. By including these types of questions into an incident investigation, it may illuminate changes to equipment or procedures which may act to prevent such errors in the future.

4.0 AN EXAMPLE OF A HUMAN FACTORS TAXONOMY: HFACS[7]

An effective incident database has at its heart a set of classification schemes or taxonomies: schemes to classify the type of incident, the type of people involved in the incident, the type of platform or vessel involved, the geographical area and weather conditions, the type of equipment that failed, the activities occurring at the time of the incident, and of course, the human factors causes. A maritime example with all these components and more is the International Maritime Incident Safety System (IMISS; Rothblum, Chaderjian, & Mercier, 2000; see App. B). It is important to understand *all* of the different types of factors (equipment, human, weather, etc.) involved in an incident. Since the offshore and maritime industries already have adequate ways of identifying equipment and other non-human contributions to incidents, this section will focus only on the identification and classification of human factors causes.

There are many, many human factors taxonomies that are in use by NASA, the Nuclear Regulatory Commission, the Transportation Safety Board of Canada, the U.K. Marine Accident Investigation Branch, and others. Some of these are listed in Appendix C; they are all useful taxonomies. These taxonomies vary with respect to how they chose to group human factors elements, the level of detail they provide, and the level of expertise required on the part of the investigator.

In order to provide an example of a human factors taxonomy and to show how it would be used during an investigation, we selected the Human Factors Analysis and Classification System (HFACS; Shappell & Wiegmann, 1997a, 2000; Wiegmann & Shappell, 1999) because it is relatively easy to learn and use, and because its effectiveness has been demonstrated through its use by the U.S. Navy and U.S. Marine Corps for aviation accident investigation and analysis. This classification scheme, as well as several of the others mentioned, is based on the well-established human error frameworks of the SHEL model (Software-Hardware-Environment-Liveware; Edwards (1972) and Hawkins (1984, 1987) as cited in TSB, 1998), Rasmussen's taxonomy of errors (1987, as cited in TSB, 1998), and Reason's (1990) "Swiss cheese" model of accident causation.

HFACS seeks to understand all the human-related contributing causes to an incident by considering the "holes" in the four layers of system defenses: unsafe acts, preconditions for unsafe acts (unsafe conditions), unsafe supervision, and organizational factors (see Fig. 9). The discussion below summarizes some of the types of latent conditions and active failures associated with these layers of system defenses. For more information, please see Shappell & Wiegmann (1997a, 2000) or Wiegmann & Shappell (1999).

[7] The majority of this section has been taken from Shappell & Wiegmann (2000). For additional information about HFACS, or to take a seminar on HFACS, please contact either Dr. Scott Shappell at scott_shappell@mmacmail.jccbi.gov and (405) 954-4082, or Dr. Doug Wiegmann at dwiegman@uiuc.edu and (217) 244-8637.

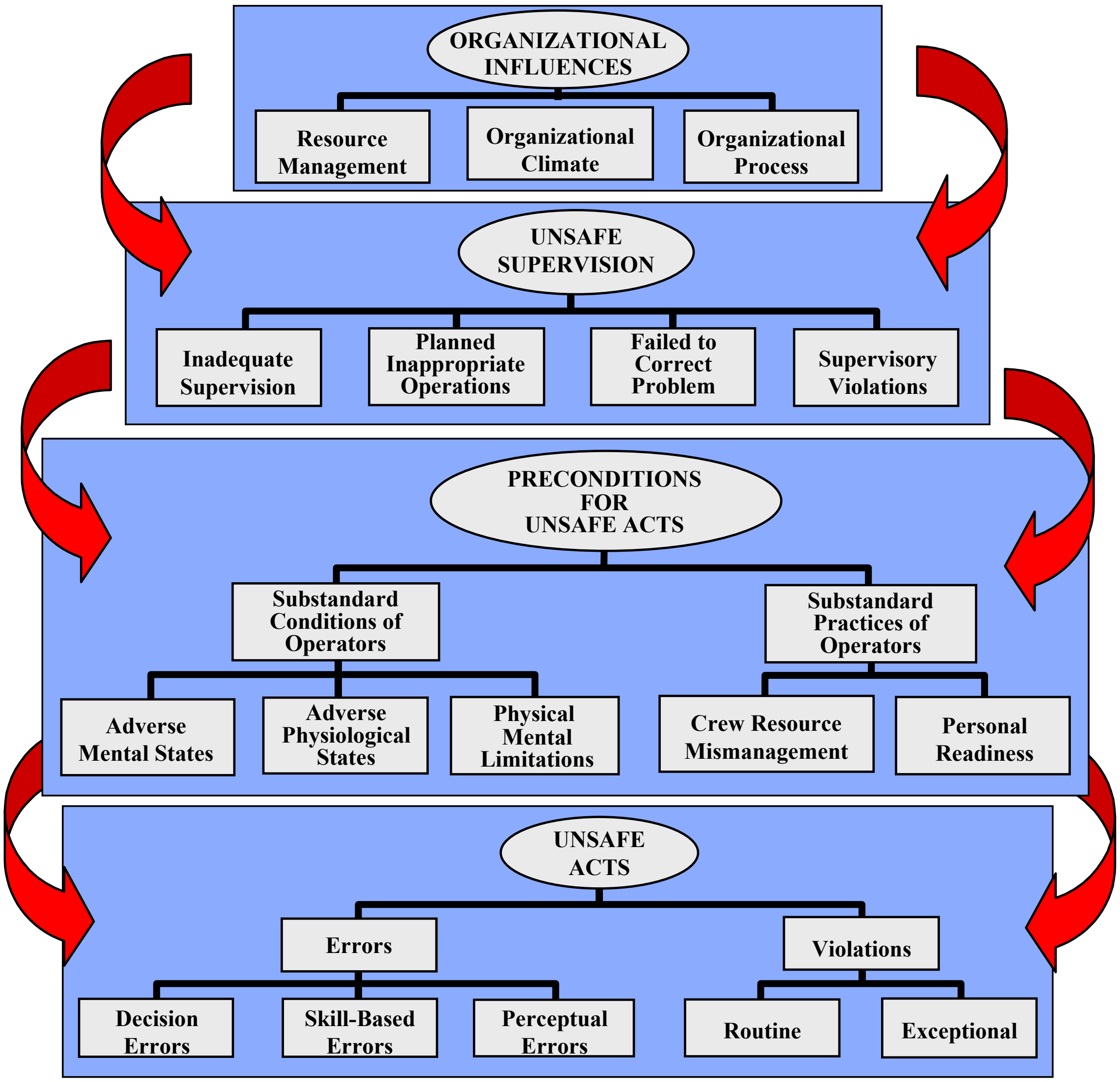

Figure 9. The Human Factors Classification and Analysis System (HFACS)

4.1 HFACS: Unsafe Acts

In an incident investigation, the investigator starts with the immediate actions and events surrounding the incident and then works backwards to uncover contributing causes. In terms of human errors, those immediately linked to the incident are typically “unsafe acts”. There are two types of unsafe acts: errors and violations.

Errors represent the mental and physical activities of individuals that fail to achieve their intended outcome; that is, the result of the person’s action was not as expected. For example, if the captain orders “right 20 degrees” when he meant to order “left 20 degrees”, that would be an error. A violation, on the other hand, is when the person’s action reflects a willful disregard for standard operating procedures or regulations (even though they probably did *not* intend to cause an incident). For example, an engineer doing maintenance might decide to “cut corners” and not perform a maintenance procedure the way it should be done. His performance is an intentional violation of the correct procedure. Errors and violations can be further subdivided, as shown in Figure 10. Errors can be decision errors, skill-based errors, or perceptual errors. Violations can be routine or exceptional.

4.1.1 Decision Errors

The decision error represents an activity or behavior that proceeds as intended, yet the plan proves inadequate or inappropriate for the situation. Often referred to as “honest mistakes,” these unsafe acts represent the actions or inactions of individuals whose “hearts are in the right place,” but they either did not have the appropriate knowledge or just simply made a poor choice. These types of knowledge-based and rule-based errors have been referred to in Reason’s taxonomy as “mistakes” (TSB, 1998).

Decision errors can result from multiple causes. For example, a wrong decision can be made if the person does not fully understand the situation at hand, misdiagnoses the problem, and proceeds to apply the wrong “solution” (because he’s solving the wrong problem). Troubleshooting an electrical fault could lead to this type of procedural decision error. Decision errors can also occur if the person does not have sufficient experience to guide his decision, or if there is not enough time to fully work through the problem properly before a choice must be made (called a choice decision error). Problem-solving errors can occur when the problem is a novel one, requiring the person to reason through it.

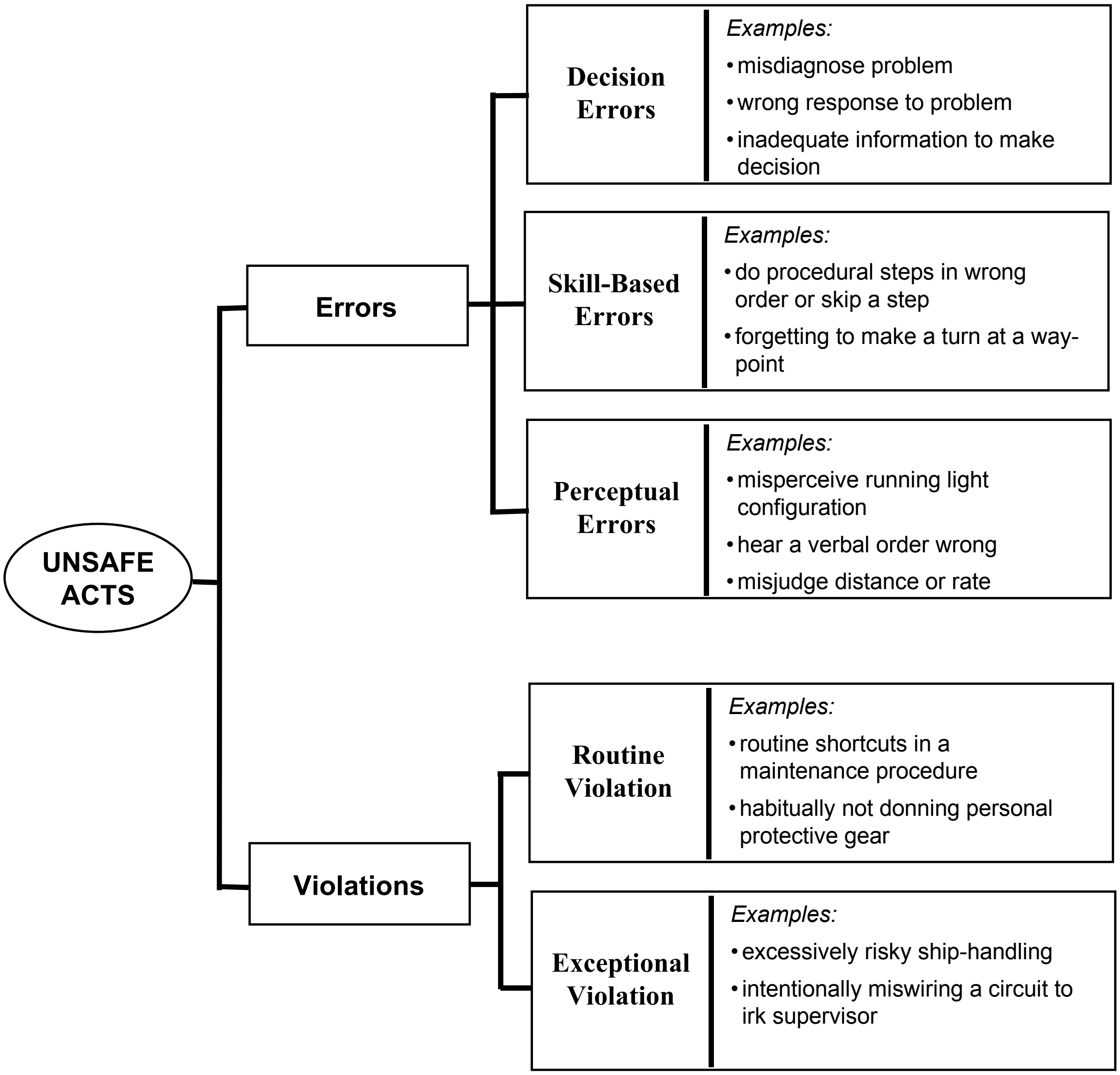

Figure 10. Classification of Unsafe Acts
(modified from Shappell & Wiegmann, 2000, and TSB, 1998)

4.1.2 Skill-based Errors

Skill-based errors can occur in the execution of skills or procedures that have become so well-learned that they are performed almost automatically. Routine maintenance tasks, taking navigational bearings, monitoring equipment displays, and other repetitive operations would be considered skill-based tasks. These types of tasks are sometimes performed improperly due to a failure of attention or memory. Consider the hapless soul who locks himself out of the car or misses his exit because he was either distracted, in a hurry, or daydreaming. These are both examples of attention failures that commonly occur during highly automatized behavior. Types of attention failures include omitting a step in a procedure, reversing the order of two steps, or doing the right thing at the wrong time. Attentional deficits can also result in failing to detect a problem while monitoring equipment.

In contrast to attention failures, memory failures often appear as omitted items in a checklist, place losing, or forgotten intentions. Failures in memory can result in forgetting to do a planned activity or losing one's place in a series of tasks. For example, most of us have experienced going to the refrigerator only to forget what we went for. Likewise, it is not difficult to imagine that when under stress during an operational emergency, critical steps in the emergency procedures can be missed. Even when not particularly stressed, individuals can forget to complete certain steps within a procedure.

If one of these types of errors is found during an incident investigation, it is a signal to look deeper. Merely telling an operator to "pay better attention next time" will not solve the problem. These types of errors are symptoms of underlying system failures. Take, for example, the fatal accident aboard the *RIX HARRIER* (MAIB, 1997). On a July afternoon, the vessel was being moored to a jetty on the River Humber. A mooring rope had been led around a fairlead, which was situated on top of the aft bulwark rail. As the rope tightened, it sprang over the top of the fairlead, striking the officer on his right arm and throwing him against the accommodation bulkhead. Neither the officer nor the crew member helping him noticed that the mooring rope had been passed inadvertently around the fairlead. This was an error resulting from lack of attention. The investigation determined that the design of the aft mooring arrangement increased the likelihood that such an error would be made. The investigation also determined that, due to the ship's work schedules, it was likely that the officer and crew member had endured days of fragmented sleep and were suffering from chronic fatigue, a state that increases the probability of attentional deficits. So in this case, both a ship design flaw and a problem with the ship's work schedules appeared to contribute to the attentional errors that caused the death of the officer.

4.1.3 <u>Perceptual Errors</u>

Not unexpectedly, when one's perception of the world differs from reality, errors can, and often do, occur. Typically, perceptual errors occur when sensory input is degraded, such as navigating at night. Visual illusions, for example, occur when the brain tries to "fill in the gaps" and make sense out of sparse information. In the earlier example of the *CGC CUYAHOGA*, the captain made a perceptual error in his interpretation of the configuration of the running lights on the *SANTA CRUZ II.* Had he seen the vessel in daylight, there would have been many visual cues available to determine the type and heading of the vessel; but at night, with little visual information available, it is all too easy to misinterpret.

Another common type of perceptual error occurs when trying to communicate in a noisy environment. Static over the radio or noise from engines and generators can muffle or degrade spoken words and commands. Again, the brain will attempt to "fill in" what wasn't heard – often based on the listener's expectations, be they correct or incorrect. As an example, a ship was transiting restricted waters when the Third Engineer noticed that the lube oil pressure was low. He shouted (across a noisy engine room) to a cadet to adjust the pressure. The cadet misunderstood (perception error) and closed the valve, causing the engine to go to dead slow and creating a dangerous situation by greatly reducing the ship's maneuverability in the high-traffic waterway (McCallum, Raby, Rothblum, Forsythe, Slavich, & Smith, 2000, unpublished).

4.1.4 Routine Violations

As discussed above, errors occur when someone is trying to follow the rules and do the right thing, but gets an unexpected result. By contrast, a violation is when someone intentionally ignores or "bends" a rule. Routine violations tend to be habitual by nature and are often tolerated by supervision (in the case of not following a standard operating procedure) or by the governing authority (in the case of not following a regulation) (Reason, 1990). Consider, for example, the individual who routinely drives 5-10 mph faster than the posted speed limit (a routine violation). Since the police will rarely pull someone over for such a minor infraction, they are tolerating the violation and implicitly reinforcing the unsafe behavior. If the police were to crack down on minor speeding, people would be less likely to violate the speed limit. Therefore, if a routine violation is identified during an incident investigation, the investigator must look further up the supervisory chain to identify those individuals in authority who are not enforcing the rules.

4.1.5 Exceptional Violations

Unlike routine violations, exceptional violations appear as isolated departures from authority, not necessarily indicative of the individual's typical behavior pattern nor condoned by management (Reason, 1990). For example, an isolated instance of driving 105 mph in a 55 mph zone is considered an exceptional violation. Note that the violation is not considered "exceptional" because of its extreme nature. Rather, it is considered exceptional because it is neither typical of the individual nor condoned by authority. The fact that such behavior is *not* typical of the individual makes it difficult to predict and deal with exceptional violations.

4.2 HFACS: Preconditions for Unsafe Acts

Although unsafe acts can be linked to the vast majority of incidents, simply focusing on unsafe acts is like focusing on a fever without understanding the underlying disease causing it. Thus, investigators must dig deeper into why the unsafe acts took place. As a first step, it is useful to consider any preconditions for unsafe acts. There are two major subdivisions of unsafe conditions (preconditions): substandard conditions of the operators and the substandard practices they commit (Fig. 11). Substandard conditions are broken down into Adverse Mental States, Adverse Physiological States, and Physical/Mental Limitations. Types of Substandard Practices include Crew Resource Mismanagement and Personal Readiness. Each of these subcategories is discussed below.

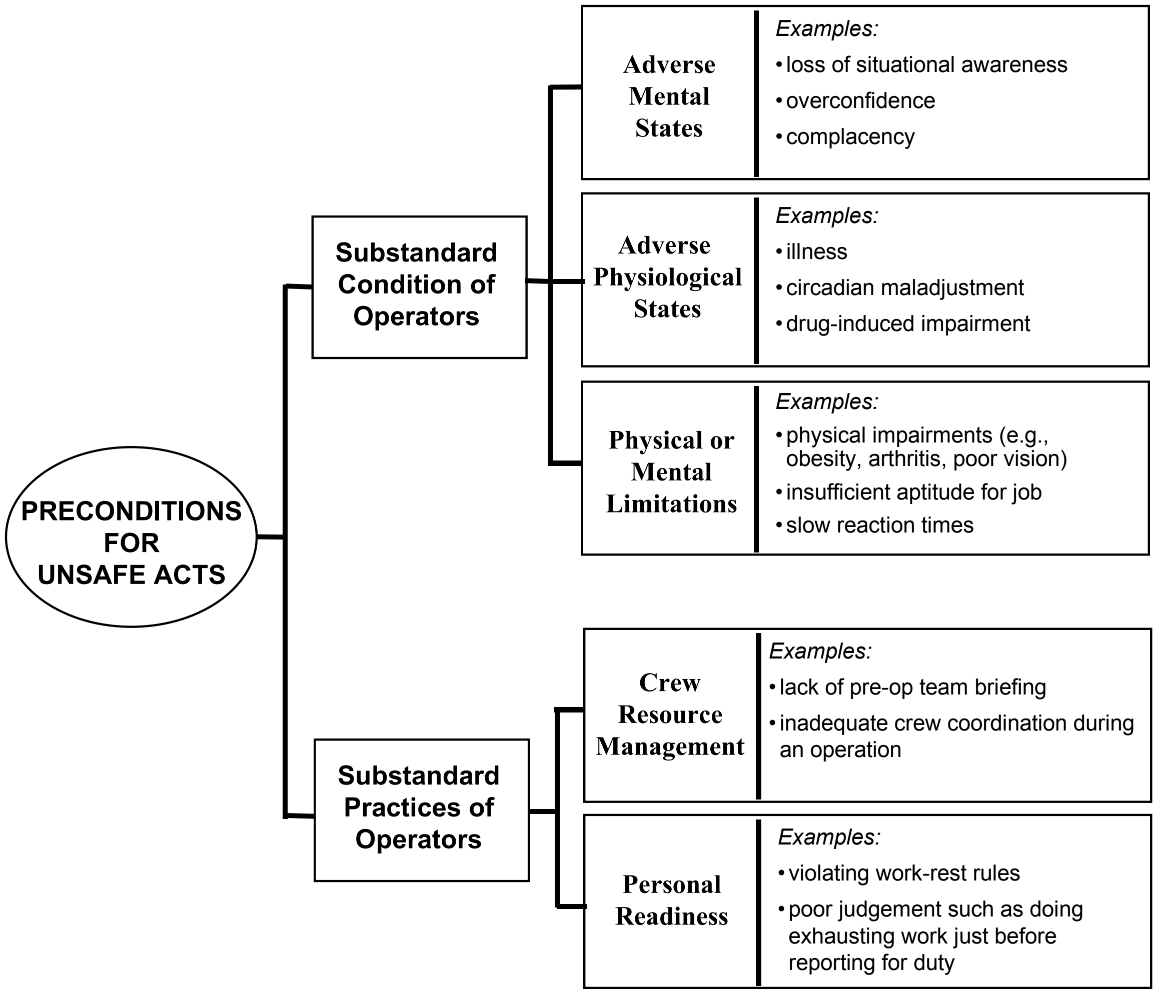

Figure 11. Classification of Preconditions for Unsafe Acts
(modified from Shappell & Wiegmann, 2000, and TSB, 1998)

4.2.1 Adverse Mental States (Substandard Conditions of Operators)

Being prepared mentally is critical in nearly every endeavor. As such, the category of Adverse Mental States was created to account for those mental conditions that affect performance. Key examples in the maritime and off-shore industries are loss of situational awareness, overconfidence, and complacency. Predictably, if an individual loses situational awareness, the likelihood increases that an error will occur. In a similar fashion, pernicious attitudes such as overconfidence and complacency increase the likelihood that a violation will be committed. Clearly then, any framework of human error must account for pre-existing adverse mental states in the causal chain of events.

4.2.2 Adverse Physiological States (Substandard Conditions of Operators)

This category refers to those medical or physiological conditions that preclude safe operations. For example, illness can have a negative impact on our performance. Nearly all of us have gone to work ill, dosed with over-the-counter medications, and have generally performed sufficiently well. However, the side-effects of antihistamines, and the fatigue and sleep loss that often accompany an illness can be detrimental to decision-making. For example, over-the-counter antihistamines decrease vigilance, performance on divided attention tasks, and short-term memory, resulting in a 14% loss of productivity and an increase in errors (Kay, 2000). Sleep loss, even in healthy individuals, increases the risk of accidents. Every April when the U.S. “springs ahead” to daylight savings time, there is a significant increase in automobile accidents: and this is from a mere *one hour decrease* in sleep time (Coren, 1998; Monk, 1980). Therefore, it is incumbent upon any safety professional to account for these sometimes subtle medical and physiological conditions within the causal chain of events.

4.2.3 Physical/Mental Limitations (Substandard Conditions of Operators)

The final substandard condition involves individual physical and mental limitations. Specifically, this category refers to those instances when task or situational requirements exceed the capabilities of the operator. For example, the human visual system is severely limited at night. Yet, most people do not take this into account when driving a car at night, and do not slow down or take other precautions. Similarly, there are occasions when the time required to complete a task exceeds an individual’s capacity. Individuals vary widely in their abilities to process and respond to information. It is well documented that if individuals are required to respond quickly (i.e., less time is available to consider all the options thoroughly), the probability of making an error goes up markedly. Consequently, it should be no surprise that when faced with the need for rapid processing and reaction times, as is the case in emergencies, all forms of errors would be exacerbated.

In addition to the basic sensory and information processing limitations described above, there are at least two additional instances of physical and mental limitations that need to be addressed, albeit they are often overlooked by most safety professionals. These limitations involve individuals who simply are not compatible with a given job, because they are either unsuited physically or they do not possess the aptitude to do it. For example, some individuals simply do not have the physical strength required to operate manual valves or haul heavy equipment. Likewise, not everyone has the mental ability or aptitude for every job. The difficult task for the safety professional is identifying whether physical or mental aptitude might have contributed to the incident causal sequence.

Clearly then, numerous substandard conditions of operators can, and do, lead to the commission of unsafe acts. Nevertheless, there are a number of things that we do to ourselves that set up these substandard conditions. Generally speaking, the substandard practices of operators can be summed up in two categories: crew resource mismanagement and personal readiness.

4.2.4 Crew Resource Mismanagement (Substandard Practices of Operators)

Operations in the off-shore and maritime industries depend on good communications and teamwork. Communication and coordination is essential, not just between workers on a given task, but between teams working on complementary or coordinated tasks. On a ship, communications may be important between members of the same department (e.g., two engineers repairing a piece of equipment, or passing information during a watch relief), between departments (the deck officer may need to notify engineering of an upcoming maneuver), between ships (for meeting and passing arrangements), and between the ship and other groups or authorities such as Vessel Traffic Service, bridge tenders, dock workers, and the vessel agent. The need for communication and coordination is often overlooked, leading to incidents. One study of maritime casualties found that a lack of communication contributed to 18% of vessel casualties and 28% of personnel injuries (McCallum, Raby, Rothblum, Forsythe, Slavich, & Smith, 2000).

Here's an example of how such crew resource mismanagement can result in a serious incident. A barge was moored to a quarry loading facility by a pull cable that was controlled from the facility. The deckhand on the barge noticed that the pull cable was caught under a deck fitting, and walked over to free it. Before he reached it, a dock worker started the winch to take the slack out of the mooring line. As the cable tightened, it snapped off the fitting and struck the deckhand with such force that he required surgery. In this case, both the deckhand and the dock worker should have – but didn't – alert the other to their plans: an obvious failure of crew coordination. A serious injury was the unhappy consequence of this lack of crew resource management (Rothblum, 2000).

4.2.5 Personal Readiness (Substandard Practices of Operators)

In every occupation, people are expected to show up for work ready to perform at optimal levels. Nevertheless, personal readiness failures occur when individuals fail to prepare physically, mentally, or physiologically for duty. For instance, violations of work-rest rules, use of intoxicants and certain medications, and participating in exhausting domestic or recreational activities prior to reporting for duty can impair performance on the job and can be preconditions for unsafe acts. While some of these maladaptive behaviors may be addressed by rules and regulations, most are left up to the judgement of the individual. It is necessary for the individual to understand that some "off-time" activities can be detrimental to subsequent job performance. The incident investigator needs to probe for personal readiness and activities that may have degraded it.

4.3 HFACS: Unsafe Supervision

In addition to investigating those causal factors associated directly with the operator, it is necessary to trace the possible causal chain of events up the supervisory chain of command (Reason, 1990). It has been estimated that 80% of offshore platform accidents have their predominant roots in supervisory and organizational factors (Bea, Holdsworth, & Smith, 1997). There are four categories of unsafe supervision: inadequate supervision, planned inappropriate operations, failure to correct a known problem, and supervisory violations (Fig. 12). Each is described briefly below.

4.3.1 Inadequate Supervision

The role of any supervisor is to provide the opportunity to succeed. To do this, the supervisor, no matter at what level of operations, must provide guidance, training opportunities, leadership, and motivation, as well as the proper role model to be emulated. Unfortunately, this is not always the case. For example, it is not difficult to conceive of a situation where adequate crew resource management training was either not provided, or the opportunity to attend such training was not afforded to a particular crew member. Conceivably, coordinated teamwork would be compromised, and if an emergency situation arose, the risk of an error being committed would be exacerbated and the potential for an incident would increase markedly.

In a similar vein, sound professional guidance and oversight is an essential ingredient of any successful organization. While empowering individuals to make decisions and function independently is certainly essential, this does not divorce the supervisor from accountability. The lack of guidance and oversight has proven to be the breeding ground for many of the violations that have crept into the cockpit. As such, any thorough investigation of incident causal factors must consider the role supervision plays (i.e., whether the supervision was inappropriate or did not occur at all) in the genesis of human error.

4.3.2 Planned Inappropriate Operations

Occasionally, the operational tempo and/or the scheduling of personnel is such that individuals are put at unacceptable risk, crew rest is jeopardized, and ultimately performance is adversely affected. Such operations, though arguably unavoidable during emergencies, are unacceptable during normal operations. Therefore, the second category of unsafe supervision, planned inappropriate operations, was created to account for these failures.

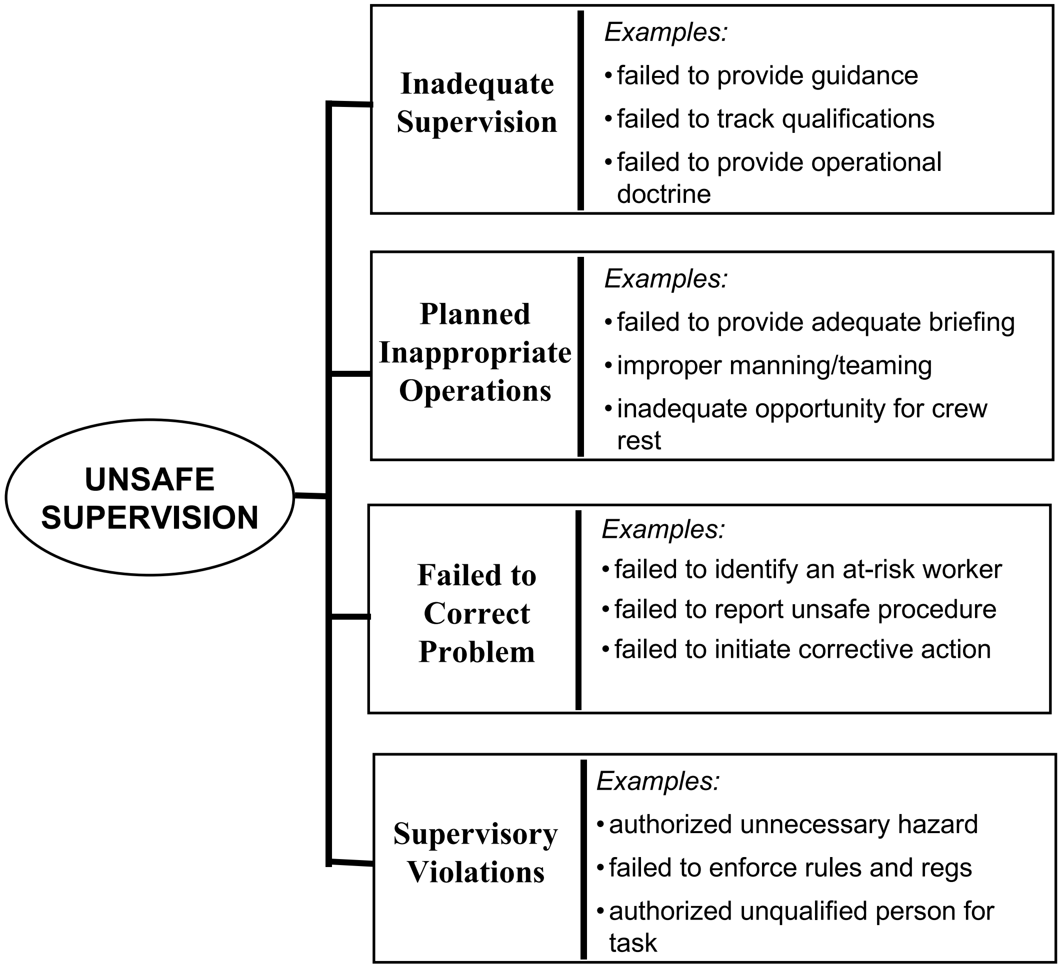

Figure 12. Categories of Unsafe Supervision.
(modified from Shappell & Wiegmann, 2000)

Take, for example, the issue of improper team complements. In aviation it is well known that when very senior, dictatorial captains are paired with very junior, weak co-pilots, communication and coordination problems are likely to occur. This type of personality mismatch is apt to happen in any team environment, and can (and do) contribute to tragic accidents (such as the crash of a commercial airliner into the Potomac River shortly after takeoff in 1982). When team member selection is not taken into account, gross perceived differences in authority and experience can cause more junior team members to be ignored, effectively eliminating an important input to the team as a whole.

4.3.3 Failure to Correct a Known Problem

The third category of known unsafe supervision, Failed to Correct a Known Problem, refers to those instances when deficiencies among individuals, equipment, training or other related safety areas are "known" to the supervisor, yet are allowed to continue unabated. For example, a given worker might have a reputation for risky behavior or cutting safety margins too closely. If the supervisor knows this and allows the behavior to continue, an incident may be the unsurprising consequence. The failure to correct the behavior, either through remedial training or, if necessary, removal from the job, can put the entire operation at risk. Likewise, the failure to consistently correct or discipline inappropriate behavior fosters an unsafe atmosphere and promotes the violation of rules.

4.3.4 Supervisory Violations

Supervisory violations, on the other hand, are reserved for those instances when existing rules and regulations are willfully disregarded by supervisors. Although relatively rare, supervisors have been known occasionally to violate the rules and doctrine when managing their assets. For instance, sometimes individuals are assigned to do a task for which they are unqualified, either through the lack of sufficient training, or even lacking the appropriate license. The failure to enforce existing rules and regulations or flaunting authority are also violations at the supervisory level. While rare and possibly difficult to identify, such practices are a flagrant violation of the rules and invariably set the stage for the tragic sequence of events that predictably follow.

4.4 HFACS: Organizational Influences

As noted previously, fallible decisions of upper-level management directly affect supervisory practices, as well as the conditions and actions of operators. Unfortunately, these organizational errors often go unnoticed by safety professionals, due in large part to the lack of a clear framework from which to investigate them. Generally speaking, the most elusive of latent failures revolve around issues related to resource management, organizational climate, and operational processes, as detailed in Figure 13.

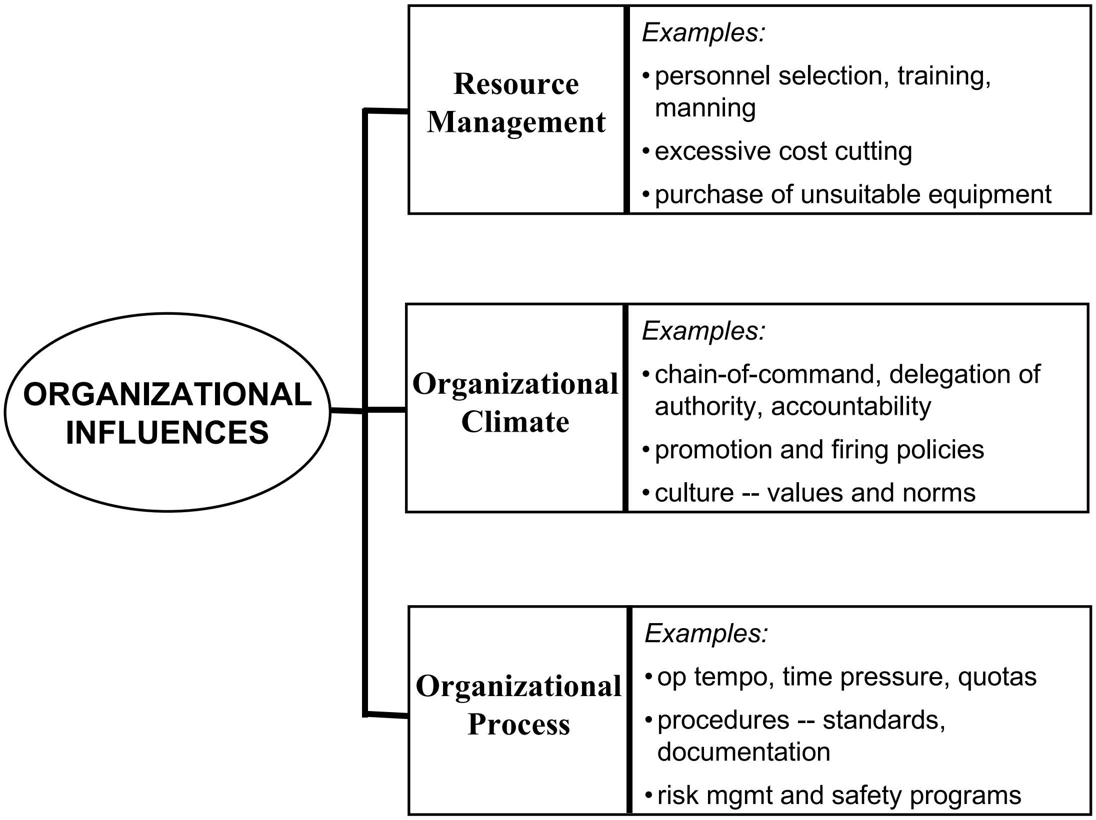

Figure 13. Organizational Factors Which Contribute to Incidents
(modified from Shappell & Wiegmann, 2000)

4.4.1 Resource Management

This category encompasses the realm of corporate-level decision making regarding the allocation and maintenance of organizational assets such as human resources (personnel), monetary assets, and equipment and facilities. Generally, corporate decisions about how such resources should be managed center around two distinct objectives – the goal of safety and the goal of on-time, cost-effective operation. In times of prosperity, both objectives can be easily balanced and satisfied in full. However, there may also be times of fiscal austerity that demand some give and take between the two. Unfortunately, accident reports show us time and again that safety is often the loser in such battles and, as some can attest to very well, safety and training are often the first to be cut in organizations having financial difficulties. If cutbacks in such areas are too severe, worker proficiency may suffer, leading to errors and incidents.

Excessive cost-cutting could also result in reduced funding for new equipment or may lead to the purchase of equipment that is sub-optimal and inadequately designed for the task. Other trickle-down effects include poorly maintained equipment and workspaces, and the failure to correct known design flaws in existing equipment. The result is a scenario involving unseasoned, less-skilled workers using poorly maintained equipment under less than desirable conditions and schedules. The ramifications for safety are not hard to imagine.

4.4.2 Organizational Climate

Climate refers to a broad class of organizational variables that influence worker performance. In general, organizational climate can be viewed as the working atmosphere within the organization. One telltale sign of an organization's climate is its structure, as reflected in the chain-of-command, delegation of authority and responsibility, communication channels, and formal accountability for actions. Just like in the operational arena, communication and coordination are vital within an organization. If management and staff within an organization are not communicating, or if no one knows who is in charge, organizational safety clearly suffers and incidents do happen (Muchinsky, 1997).

An organization's policies and culture are also good indicators of its climate. Policies are official guidelines that direct management's decisions about such things as hiring and firing, promotion, retention, raises, sick leave, drugs and alcohol, overtime, incident investigations, and the use of safety equipment. Culture, on the other hand, refers to the unofficial or unspoken rules, values, attitudes, beliefs, and customs of an organization. Culture is "the way things *really* get done around here."

When policies are ill-defined, adversarial, or conflicting, or when they are supplanted by unofficial rules and values, confusion abounds within the organization. Indeed, there are some corporate managers who are quick to give "lip service" to official safety policies while in a public forum, but then overlook such policies when operating behind the scenes. Safety is bound to suffer under such conditions.

4.4.3 Organizational Process

This category refers to corporate decisions and rules that govern the everyday activities within an organization, including the establishment and use of standardized operating procedures and formal methods for maintaining checks and balances (oversight) between the workforce and management. For example, such factors as operational tempo, time pressures, incentive systems, and work schedules are all factors that can adversely affect safety (Fig. 13). There may be instances when those within the upper echelon of an organization determine that it is necessary to increase the operational tempo to a point that overextends a supervisor's staffing capabilities. Therefore, a supervisor may resort to the use of inadequate scheduling procedures that jeopardize crew rest and produce sub-optimal crew complements, putting the operation and its workers at an increased risk of a mishap. Organizations should have official procedures in place to address such contingencies as well as oversight programs to monitor such risks.

Regrettably, not all organizations have these procedures nor do they engage in an active process of monitoring operator errors and human factors problems via anonymous reporting systems and safety audits. As such, supervisors and managers are often unaware of the problems before an incident occurs. It is incumbent upon any organization to fervently seek out the “holes in the cheese” and plug them up, before they create a window of opportunity for catastrophe to strike.

4.5 The Benefits of Using HFACS

The Human Factors Analysis and Classification System (HFACS) framework bridges the gap between theory and practice by providing investigators with a comprehensive, user-friendly tool for identifying and classifying the human causes of incidents. The system, which is based upon Reason’s (1990) model of latent and active failures (Shappell & Wiegmann, 1997a), encompasses all aspects of human error, including the conditions of operators and organizational failure. Still, HFACS and any other framework only contribute to an already burgeoning list of human error taxonomies (see, for example, Appendix C) if it does not prove useful in the operational setting. In this regard, HACS has recently been employed by the U.S. Navy, Marine Corps, Army, Air Force, and Coast Guard for use in aviation accident investigation and analysis. To date, HFACS has been applied to the analysis of human factors data from approximately 1,000 military aviation accidents. Throughout this process, the reliability and content validity of HFACS has been repeatedly tested and demonstrated (Shappell & Wiegmann, 1997b). HFACS has also been implemented by other types of organizations; an example of its use by the Marine Facilities Division of the California State Lands Commission in the investigation of incidents at marine terminals is provided in Section 8 and Appendix E.

Given that accident/incident databases can be reliably analyzed using HFACS, the next logical question is whether anything unique will be identified. Early indications within the military suggest that the HFACS framework has been instrumental in the identification and analysis of global human factors safety issues, such as trends in operator proficiency, causes of specific accident types, and problems such as failures of crew resource management (Shappell & Wiegmann, 2000). Consequently, the systematic application of HFACS to the analysis of human factors accident data has afforded the U.S. Navy and Marine Corps (for which the original classification system was developed) the ability to develop objective, data-driven intervention strategies.

Additionally, the HFACS framework and the insights gleaned from database analyses have been used to develop innovative incident investigation methods that have enhanced both the quantity and quality of the human factors information gathered during incident investigations. However, not only are safety professionals better suited to examine human error in the field, but using HFACS, they can now track those areas (the “holes in the cheese”) responsible for the incidents as well. Only now is it possible to track the success or failure of specific intervention programs designed to reduce specific types of human error and subsequent incidents. In so doing, research investments and safety programs can be either readjusted or reinforced to meet the changing needs of safety.

5.0 PUTTING IT ALL TOGETHER: INVESTIGATING AN INCIDENT FOR HUMAN FACTORS CAUSES

5.1 Introduction

As stated earlier, in an incident investigation, the investigator starts with the immediate actions and events surrounding the incident and then works backwards to uncover contributing causes. *Who, where, when, what,* and *how* are all useful questions to get information relevant to the incident; but asking *why* is what will help the investigator "drill down" into the contributing, latent conditions that need to be identified and resolved in order to avoid similar incidents in the future. Remember from our introductory discussion that it's not just the people you want to concentrate on, but also the ways in which *technology, environment, and organizational factors influenced human performance.*

5.2 Incident Investigation: Going Beyond the Obvious

If we are to learn from an incident, it is very important to go beyond the "obvious" cause and ferret out the underlying, contributing causes. Here's an example. During the early hours of a November morning, the *DOLE AMERICA*, a Liberian-registered refrigerated cargo vessel, collided with the Nab Tower, a conspicuously-lit, man-made construction in the eastern approaches to The Solent off the Isle of Wight (MAIB, 1999). The ship had left her berth in Portsmouth and was proceeding seaward with the Norwegian captain, a Filipino officer, and a helmsman on the bridge. The captain was in charge, and he set a course to pass to the east of the tower. Suddenly, he saw on the starboard bow what he thought was the red portside light of a vessel at close range, crossing from starboard to port and presenting an imminent risk of collision. The captain ordered starboard helm before going to the front of the bridge to confirm what he thought he had seen. He then called the officer to join him, and the officer confirmed the presence of a red light and reported a second red light to starboard of the first. The captain then ordered hard to starboard helm. When no further lights were seen ahead, the captain ordered hard to port helm, still with the intention of passing to the east of the Nab Tower. The ship struck the tower shortly afterwards.

The immediate cause of the collision was the master's inappropriate and unquestioned helm order to port (unsafe act – decision error). However, the following contributing factors were important to this casualty:

- From his position at the front of the bridge, the captain was unaware of the ship's heading and her exact position in relation to the tower (precondition for unsafe act – substandard practice – crew resource mismanagement).
- No discussions took place between the captain and the officer concerning the ship's progress (precondition for unsafe act – substandard practice – crew resource mismanagement).

- The captain and the officer failed to work as an effective team, probably due, in part, to their differing nationality and social backgrounds, and to an autocratic management style (precondition for unsafe act – substandard practice – crew resource mismanagement *and* organizational factor – organizational climate).
- With no dedicated lookout to refer to, the captain called the officer to join him at the front of the bridge, thereby removing his only source of navigational information (unsafe act – decision error).
- The ship's manager provided no specific instructions to its officers regarding voluntarily offering relevant information to the captain (organizational factor – organizational climate).

While the immediate cause was the captain's poor decision making due to inadequate information, future avoidance of this type of incident depends on correcting the underlying unsafe conditions and organizational factors. Changing the autocratic management style that was in place in this company to one of crew resource management, and training the bridge team to operate more effectively by empowering the officer to actively contribute to navigational decisions (particularly relevant to a multi-national crew) are keys to preventing such a casualty. Had the investigation stopped with the "obvious" cause, the true precursors to this incident would have remained hidden, and remedial actions based only on the immediate cause would have been ineffective.

5.3 A Tool for Investigation: Events and Causal Factors Charting

Before one can begin identifying the human error causes of an incident, one needs a way to represent how an incident happened. There are a number of tools that can be used to get varying levels of detail surrounding the events of an incident and what might have contributed to it. Some of these include timeline analysis, link analysis, barrier analysis, work safety analysis, human error HAZOP, and human error analysis. Most of these can be used either during a safety audit (to understand the work conditions and identify risks *before* an incident occurs) or during an incident investigation. A good introduction to these methods may be found in Kirwan (1997).

Another method that is more directly related to understanding the progression and causes of an incident is Events and Causal Factors Charting (Hill & Byers, 1992a). This method was originally developed by the National Transportation Safety Board for the analysis of accident investigations. It highlights the major events in the progression of an incident and also associates contributing causes to each event. "Contributing causes" include not only active and latent human errors, but also equipment problems, weather, and anything else which may have influenced the events surrounding the incident. Events and causal factor charting can be helpful in organizing and understanding the sequence of events and also in identifying holes or inconsistencies in the incident information collected.

To illustrate how Events and Causal Factors Charting can be used, let's take a closer look at the *TORREY CANYON* incident that was introduced in Section 2 (Hill & Byers, 1992b).

5.3.1 *TORREY CANYON* Synopsis

The Captain of the *TORREY CANYON* was experienced, careful, and a stickler for details. The *TORREY CANYON* was traveling from Kuwait to Wales with a cargo of 100,000 tons of oil. They were heading for Angle Bay, British Petroleum's (BP) deep-water terminal on the western tip of Wales. The day before the *TORREY CANYON* was due to arrive at Angle Bay, the captain was contacted by BP's agent, who told him of impending decreases in the tide at Milford Haven, at the entrance to Angle Bay. He was told that if the *TORREY CANYON* did not catch high tide on the next evening, it would have to wait outside the harbor for most of a week for the next tide high enough to get the ship in. Now, to have a ship of that size sitting idle for five days is very expensive, and the captain was determined to reach Milford Haven on time. This didn't seem to present any problem at the time; to be ready to catch the high tide the next evening the *TORREY CANYON* had to get to Milford Haven and it had to transfer cargo from the midship tanks to the fore and aft tanks to even out the ship's draft. At sea, the tanker drew 52 feet 4 inches amidships, but that was too deep to make it into Angle Bay, so they had to shift cargo. The captain estimated the transfer would take about four hours and planned to make the transfer after they reached Milford Haven. Still, there seemed to be plenty of time.

The next morning, the captain asked to be called when the Scilly Islands were sighted. The Scillies are made up of 48 tiny islands and contains a number of submerged large rocks and sandbars. There were 257 shipwrecks there between 1679 and 1933. The captain was intending to sight the Scillies to starboard, pass them to the west and then go into Milford Haven. However, when the Scillies were sighted, and he was called, they were off the port bow. Rather than turn and go west around the islands, the captain decided he needed to save time and would pass between the Scilly Islands and Land's End, the southwesternmost tip of England. The passage between Land's End and the Scillies is divided into two parts by an island and each of those parts have further obstructions within them. The captain decided to take the western channel. He did not have a copy of the Channel Pilot for the region and he was not particularly familiar with the area. The *TORREY CANYON* was making full speed when it met some fishing boats in the channel, which delayed it making a turn. After taking a bearing from the unfamiliar landmarks, the captain realized that he had overshot his turn and the channel. When he ordered hard to port, and the helmsman turned the wheel, nothing happened. The captain realized that the steering selector switch was set incorrectly on autopilot, reset it to manual, and the turn to port was begun. The *TORREY CANYON* then ran into a granite reef so hard that it could not be pulled off. The Royal Air Force eventually bombed the wreck in an effort to burn some of the oil before it washed up on the beaches.

During the official inquiry which followed, it was pointed out that the captain had plenty of time to get to Milford Haven if he had transferred his cargo while underway[8]. The chairman of the board of inquiry reportedly stated after the hearing, "He [the captain] didn't want to dirty his deck, to come into port looking sloppy" (Hill & Byers, 1992b). Perrow (1984, p. 184) points out, that as most accidents do, this accident involves many "if only" statements:

- If only the captain had not forgotten to put the helm on manual, they might have turned in time;
- If only the fishing boats had not been out that day, he could have made his turn earlier;
- If only he had prudently slowed down once he saw the fishing boats, he could have turned more sharply;
- once deciding to risk going through the Scilly Islands he used a peculiar passage through them – if only he had used another passage, it might have been safer (even faster).

We'll never know precisely why the captain made the decisions he made.

5.3.2 An Event and Causal Factors Chart of the *TORREY CANYON* Incident

To do an Event and Causal Factors Chart, we begin by determining the major events that occurred. Working backwards from the accident, there are four major events:

- The *TORREY CANYON* fails to make its turn in time and runs aground;
- The captain takes the western channel between the Scilly Islands and Land's End;
- The *TORREY CANYON* goes east of the Scilly Islands;
- The Scilly Islands are sighted to the NW (port) rather than to the NE (starboard).

These four events would be placed in boxes (to denote that they are "events") across the top of the page, as shown below in Figure 14.

[8] This accident occurred years before the *Exxon Valdez* and the environmental protection legislation that followed. At the time of the *TORREY CANYON* incident, transferring oil while underway was standard operating procedure for many companies.

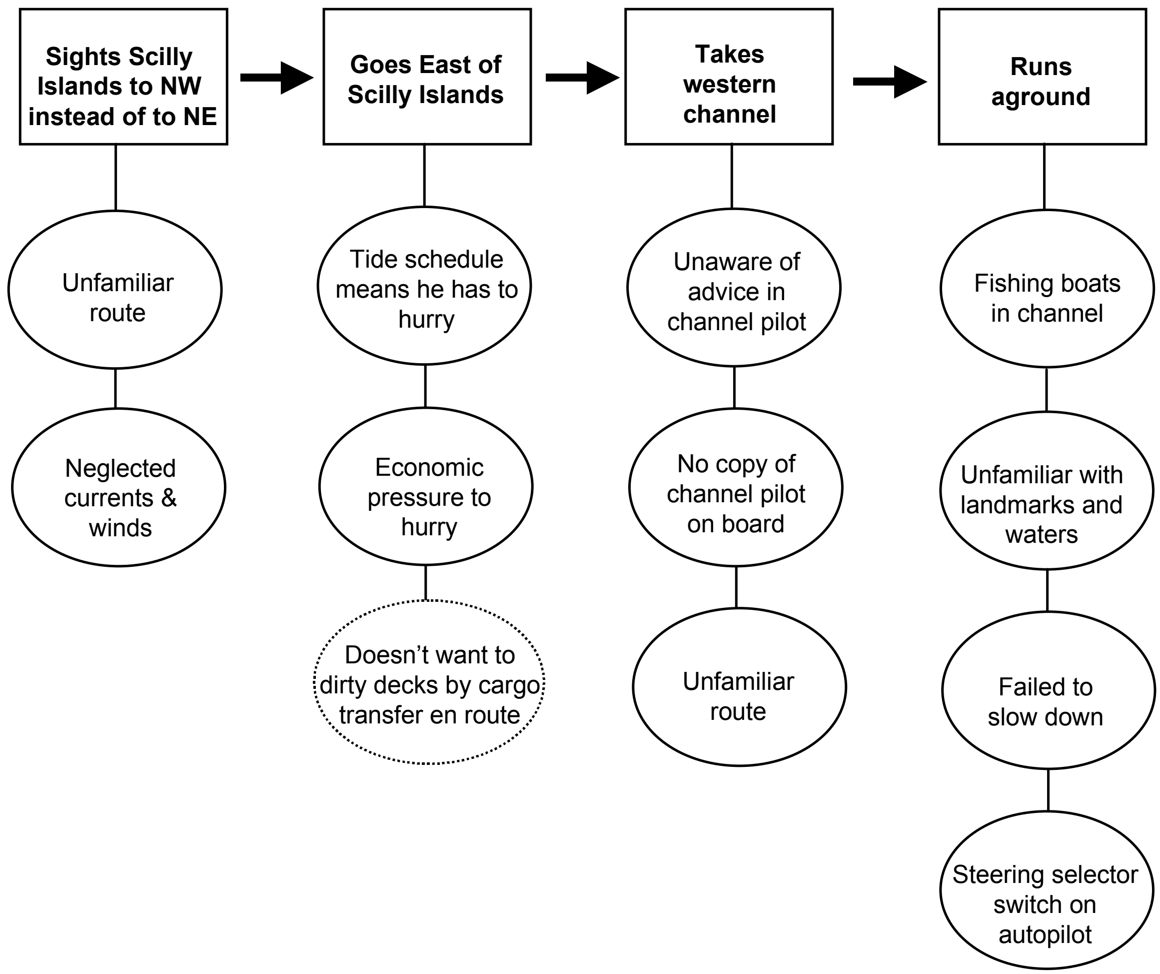

Figure 14. Events and Causal Factors Chart for *TORREY CANYON* Grounding
(after Hill & Byers, 1992)

Below each event box, we list the perceived causes of the event, depicted as ovals (solid ovals for established causes, and dotted ovals for assumed causes). We "drill down" into the causes by asking *why*. For example, when we ask *why* the *TORREY CANYON* failed to make the turn in time (thereby running aground), we find four different issues:

- The *TORREY CANYON* failed to begin its turn in time because there were fishing boats in the way;
- The captain was unfamiliar with the waterway and landmarks, making him late to recognize the turning point and initiate the turn;
- He failed to slow down and was going too fast to make the turn;

- The steering selector switch was in the wrong position (autopilot), and by the time it was corrected, it was too late to make the turn.

While the Events and Causal Factors Charting often ends at this point, we want to take it a step further for the purpose of determining active and latent human factors causes. To do this, it is helpful to remember the human-system approach discussed in Section 2 (refer to Fig. 2). Human errors result not only from errors made by a given person, but, more importantly, human errors usually result from suboptimal *interactions* between people and organizational, technological, or environmental factors. As you drill down seeking contributing causes, keep asking yourself the following questions to help you identify human errors:

- *Did some aspect of the involved person contribute to the incident?* (consider knowledge, skills, experience, motivation, alertness, physical and mental states, use of medicines or drugs, personal problems, etc.)
- *Did some aspect of interpersonal interactions contribute to the incident?* (consider communication, definition of roles and responsibilities, experience working as a team, autocratic vs. empowered style, etc.)
- *Did some aspect of the interactions between the people and the organization contribute to the incident?* (consider training and qualification requirements, crew/team complement, work schedules, safety culture, supervision, policies regarding economic pressure, etc.)
- *Did some aspect of the interactions between the people and the technology contribute to the incident?* (consider equipment layout, whether equipment is designed to do the job, how information is provided from the equipment to the user, whether controls can be easily operated, whether displays are legible, whether the design obstructs proper maintenance, etc.)
- *Did some aspect of the interactions between the people and the environment contribute to the incident?* (consider the workplace environment in terms of lighting, noise, temperature, vibration, ship motion, fog, snow, etc.; also consider the regulatory and economic environment and their impact on job behavior)

The human-system approach and HFACS are complementary ways of looking at human errors. In the human-system approach, we identify the *locus* of the error. That is, we determine whether the error resulted because of a deficiency in a given person's actions or decisions, or whether there was a poor interaction between multiple people or between people and technology, organization, or environment. HFACS identifies the parts of the company's organization that had the *responsibility* for preventing the error. That is, with HFACS we determine whether the individual (Preconditions for an Unsafe Act), the line supervisor (Unsafe Supervision), and-or management (Organizational Influences) had the responsibility for preventing the error. By identifying the level(s) of the organization that had the responsibility for preventing an incident, we identify the part(s) of the organization where changes must be made to solve the human error problems.

Now let us look again at the Events and Causal Factors Chart of the *TORREY CANYON* grounding and use the human-system approach and HFACS to identify the underlying human factors causes of the last event, "Runs aground." To do this, we would continue to ask *why*. To ask why there were fishermen in the way doesn't get us anywhere with this particular case[9]. Note that the presence of the fishermen is, in fact, an environmental factor that interacts with the captain; but since neither the captain nor the company have any control over the presence of fishermen, that aspect of the incident is ignored. The captain *did* have control over his *response* to the presence of the fishing vessels, and that will be discussed in the third causal factor.

"Drilling down" on the second causal factor, the fact that the captain was unfamiliar with the waterway, is more enlightening. The captain was unfamiliar with the route, because it was not the route he had planned to take. Furthermore, he did not have a copy of the Channel Pilot on board, and so could not avail himself of helpful information. *Why* did he not have a copy of the Channel Pilot, when he had planned to take a nearby route? While we don't have the answer to this question, it might have involved an error in HFACS Organizational Influences – Organizational Process if the company had not established that ships carry information about all routes it would transit. Or, perhaps the company had the policy, but the captain had failed to ensure that the document was onboard and available for use; this would be an example of Unsafe Supervision – Supervisory Violation. As you can readily see, depending on who was responsible (the company or the captain), the type of corrective action needed would be vastly different.

Asking *why* the captain failed to slow down when he saw the fishing vessels (which was determined by the board of inquiry to be the prudent action to have taken), the probable answer is that the captain felt pressured to make good time, and that pressure negatively influenced his judgement. While there's no question that the captain's unsafe act (going too fast) was based on a decision error, we need to continue to ask *why*. *Why* did the captain feel such a compulsion to make good time? As pointed out in the incident synopsis, had the captain missed the evening high tide at Milford Haven, the *TORREY CANYON* may have had to sit idly waiting for several days before the next tide of sufficient depth to allow her to pass. This spawns several issues for further investigation. Given that the tidal depths at Milford Haven were known, why did the company elect to send a tanker that could only get through Milford Haven on certain days (i.e., did the company consider lightening the *TORREY CANYON's* load or sending a different vessel(s) that had a draft more compatible with the tides at Milford

[9] Although this question is a good one in certain sections of the U.S. where fishing regulations limit fishing seasons to only a day or two, causing greatly congested waterways on those days. Asking *why* in these cases may point out a flaw in the regulations, showing that these regulations need to consider not only conservation but waterway mobility, as well.

Haven? – potential HFACS Organizational Influences – Resource Management issue)? If the *TORREY CANYON* had gotten into Milford Haven too late to make the high tide, how would that have affected the captain? Did the company have a policy which would have penalized the captain for missing the tide, thus encouraging him to take risks (HFACS: Organizational Influences – Organizational Climate)? Or, perhaps, was this a self-imposed pressure due to the captain's pride at making schedule and resulting in his taking unnecessary risks (Unsafe Supervision – Supervisory Violation)? There is an obvious tension between the pressure to make good time and safe navigation. Depending on how it evolved (organizational policy or supervisory deficiency), the appropriate correction will vary.

Finally, we have the causal factor of the steering selector switch being in the wrong position. When we ask *why*, we will find a procedural issue: why was the ship on autopilot in a hazardous navigating environment? The answer to this question could be a combination of factors such as: it was put there inadvertently (HFACS: Unsafe Act – Skill-based Error); it was put there intentionally to allow the helmsman to do another task (Unsafe Act – Routine Violation); or perhaps it was left on autopilot too long, due to inadequate bridge team coordination (Precondition – Substandard Practices – Crew Resource Mismanagement). Using the human-system approach, we might ask whether there was a suboptimal interaction between the people and the technology. Specifically, *why* didn't the helmsman know that the ship was on autopilot? The answer is that there was no indication of the steering selector setting at the helm! The steering selector control was located where it could not be seen when standing at the helm. Whereas the *locus* of this error is the interaction between the user and the technology, note that the *responsibility* for the error is at an entirely different level. On the one hand, this is a design error on the part of the equipment manufacturer; however, since the company most likely had no control over the manufacturer's design, this is not a useful avenue to pursue. But on the other hand, this might also be an error on the part of company management for selecting and purchasing unsuitable equipment and-or installing it in an unsuitable manner (HFACS: Organizational Influences – Resource Management).

By charting first the primary events that led to the incident, and then by asking *why* until the (many) contributing causes are found, one can establish the reasons why an incident happened and trace the layers of responsibility from the individual(s) to the preconditions, to supervisory errors, and to unsafe organizational influences. The combination of Events and Causal Factors Charting, the human-system approach, and the Human Factors Analysis and Classification System (HFACS) can be a powerful tool for ferreting out the true underlying causes of incidents and identifying parts of the system which need to be corrected in order to prevent recurrences of similar problems.

5.4 The Art of Incident Investigation

Incident investigation is somewhat of an art. It takes great skill to build a rapport with and interview people associated with the incident[10]. It also takes a great deal of knowledge about the technical and human factors aspects of the incident to ask the right questions and identify the important issues (this is the reason for having investigation *teams* – no one person is likely to have all the requisite skills and knowledge). Likewise, there is no one method or "best" set of questions to ask that will work for all investigations (Appendix H gives a sample of human factors questions that could be asked). It takes experience to spot potential issues and to know what avenues of questioning will be most fruitful in a particular incident. It takes experience and skill to hunt for underlying causes and to fit the pieces of the puzzle together.

Incident investigation is also not a serial endeavor: it is highly iterative. As Figure 15 depicts, there is a cyclical process of gathering information, organizing it into the sequence of events and causes that led up to the incident, and looking for the underlying human factors causes. Oftentimes after the initial round of interviews, it will become apparent that the sequence of events has missing pieces, or that some of the information appears contradictory. This necessitates additional interviews or re-interviews. As you begin to feel you understand the sequence of events, you may find that you still lack the information to identify the types of human errors that were made and the underlying causes of these errors. More questioning is needed. Sometimes an exploration of the human errors will bring to light that the sequence of events is still incomplete. And so it goes, back and forth, asking questions, organizing data, finding holes, and asking more questions, until you can finally produce a set of events, causes, and underlying human errors that "hang together" and make a sensible explanation for how the incident evolved. Patience and persistence are two traits of successful investigators!

In this section we have repeatedly stressed that the good investigator keeps asking "*why?*" It is useful to consider when to *stop* asking why. Asking *why* is a great tool for identifying underlying contributors to the errors that caused the incident. But if taken to extremes, it can become almost absurd. In general, we want to keep asking *why* as long as the answer is still something that has practical significance to the incident and is *under the company's control* to make changes[11]. In the *TORREY CANYON* incident, for example, we elected *not* to consider why

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[10] For a discussion of interviewing techniques, as well as other good material on the collection of evidence, see Center for Chemical Process Safety (in preparation).

[11] There are times when we *do* want to look for causes that are beyond the company's control. Some incident causes have ramifications for offshore or maritime safety in general and may necessitate changes to equipment, legislation, or codes of practice. For example, if a regulation appeared to be a cause of the incident, then that information needs to be brought to the attention of the appropriate authorities so that the regulation can be revised. In the *TORREY CANYON* example, the poor design of the steering selector mechanism, because it could easily cause similar problems for others, should have been discussed with the manufacturer, to prompt a redesign, and reported in industry publications to warn others of the hazard. While the main thrust of this paper is to help companies use human factors incident investigation to improve their own safety, we all have the responsibility to share this knowledge in order to improve the safety of the industry as a whole.

there were so many fishing vessels in the channel, because that was totally out of the control of the company. But we *did* elect to consider the captain's *response* to those fishing vessels (i.e., the fact that he did not slow down), because his response *is* within his (and the company's) control. There will always be extenuating circumstances. We need to focus on how the company *responds* to those circumstances in a way that gets the job done safely.

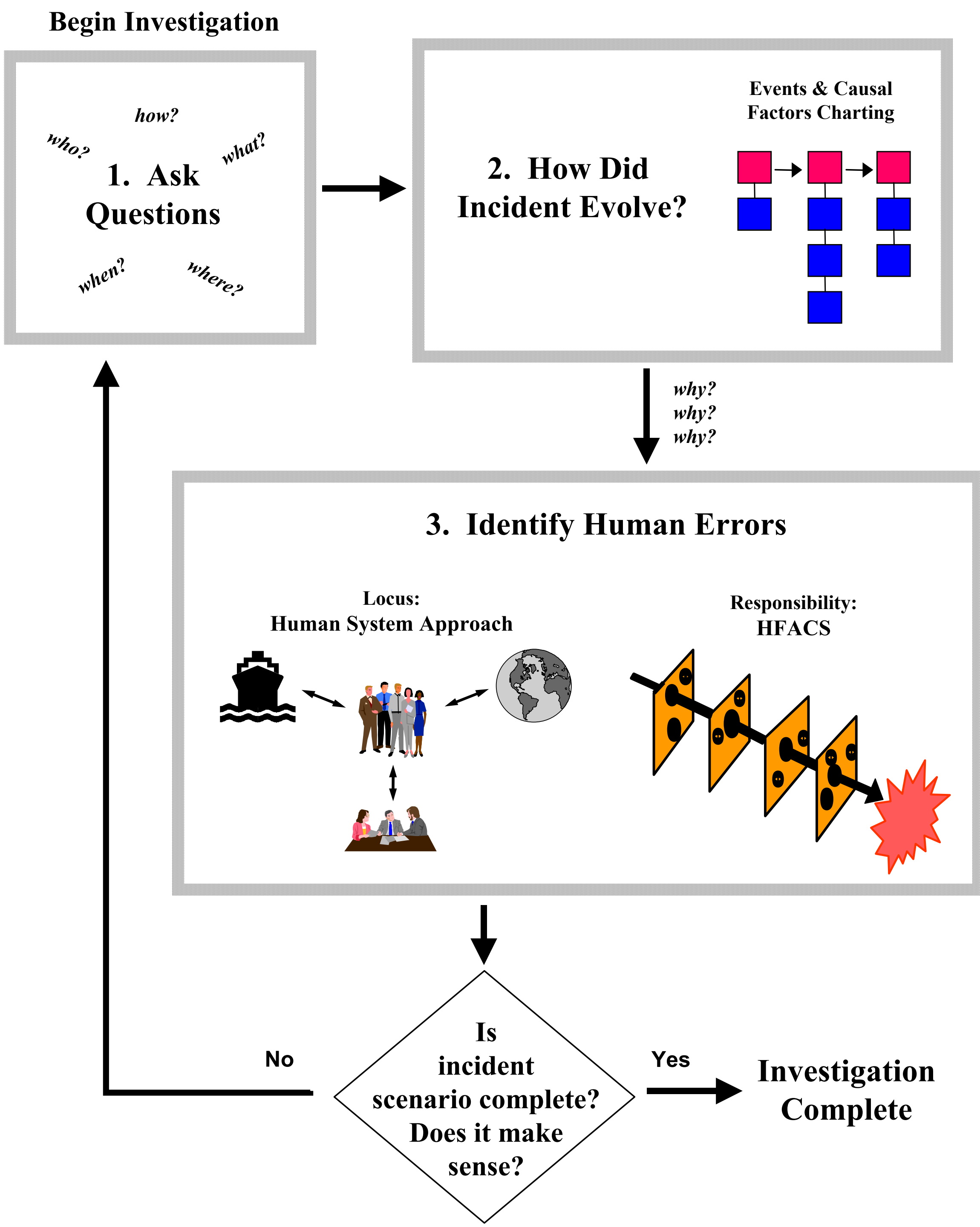

Figure 15. The Incident Investigation Process

6.0 ANALYZING INCIDENT DATA

Now that you've been running your incident investigation program for awhile, what do you do with all those data? There are many ways to make good use of the data collected from incident investigations. Here are a few ideas.

6.1 Learning from Individual Incidents

This is the simplest way to learn from your incident investigation program. Individual incidents can be discussed at safety meetings, allowing personnel to gain an understanding of how different incidents evolved and how an accident was avoided. This type of information sharing can stimulate discussion of similar occurrences and potential changes to procedures, policies, training, equipment usage, etc. that might help prevent future incidents.

While case-by-case studies can be beneficial, they have a drawback. By focusing on a single incident, there is no way to know what facets of that incident may represent general problems as opposed to things that were unique to that particular incident. Most companies would rather spend their money fixing frequently-occurring problems than smaller, once-in-a-lifetime problems. The way to get a feeling for the importance and the frequency of a problem is through data analysis, and several approaches to analysis are discussed below.

6.2 Identifying High-Risk Activities or Facilities Using Simple Frequency Analysis

Frequency analysis can be an effective way to identify problem areas on which you need to focus. For example, say an offshore drilling company has three rigs and wants to know whether all three have about the same number of incidents. A simple frequency analysis entails adding up the number of incidents reported over a given period of time (e.g., one year) by the crews of each rig (Fig. 16).

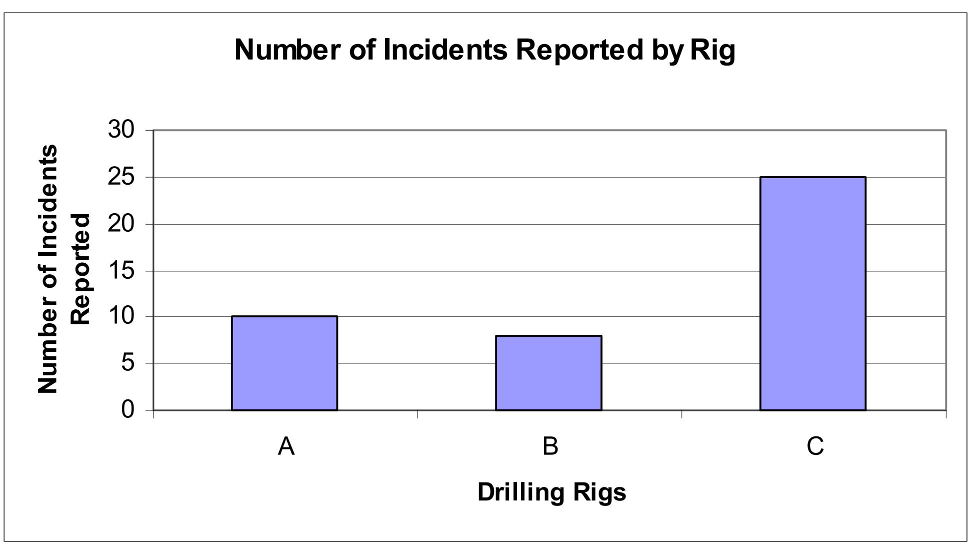

Figure 16. Example of a Frequency Analysis

In the example shown in Figure 16, it is obvious that Rig C has reported over twice as many incidents as has either Rig A or Rig B. Looks like Rig C has a problem, right? Well, not necessarily. You need to go deeper and find out *why* Rig C has reported more incidents. Maybe the crew members on Rig C are very excited about the new incident investigation program and are being vigilant for and reporting every incident that arises, while the crews on Rigs A and B are only reporting the incidents they consider to be "important" in some respect. Or maybe Rig C is larger, does more operations, and has more people working on it than either A or B – if Rig C is doing four times the work that is done by either Rig A or B, then C's true incident rate would actually be *lower* than that on A or B! This shows the necessity for considering how to make an "apples to apples" comparison. However, if Rigs A, B, and C are roughly equivalent in all respects, then C might truly have a safety problem that needs to be identified and solved. One way to look into this in more depth would be to do more frequency analyses by type of operation, or by type of equipment used, or by some other relevant factor. In this way you can isolate which operations or equipment appear to be related to the higher incident rates (for example, perhaps when looking just at Operation X, Rig C's incident rate is the same as that for A and B; but when looking just at Operation Y, Rig C's incident rate is much higher than that for A or B).

6.3 Looking for Trends

A simple extension of the frequency analysis discussed above is to compare frequencies over time to look for trends in the data. Perhaps you have made some changes to a standard operating procedure to reduce injuries. Is the new SOP helping? To find out, you could plot the number of injuries in the years prior to the new SOP and compare that to the number of injuries since the new SOP was put into place. Or maybe the SOP has been helpful in reducing certain types of injuries but not others. A plot, like that presented in Figure 17, could help the company spot areas of concern. In this example, most of the injury rates are fairly consistent over the four years shown. However, three injury categories show some interesting changes. "Struck By/Against" and "Slips/Trips/Falls" both show marked decreases. In this particular case, the company had built and put into service 18 new ships in 1996-1999. The learning curve for operating the new ships may have contributed to exaggerated "Struck By/Against" rates in 1998 and 1999, with the decrease in 2000 showing that the crews had become familiar with the new ships. The decreased rate of slips, trips, and falls is attributed to the company's purchase of new safety shoes (designed for the restaurant industry to keep traction on wet floors) – a successful safety intervention! The third item of interest is the relatively greater rate of injuries in the "Chemical Spray" category over the last two years. This appears to be due to the fact

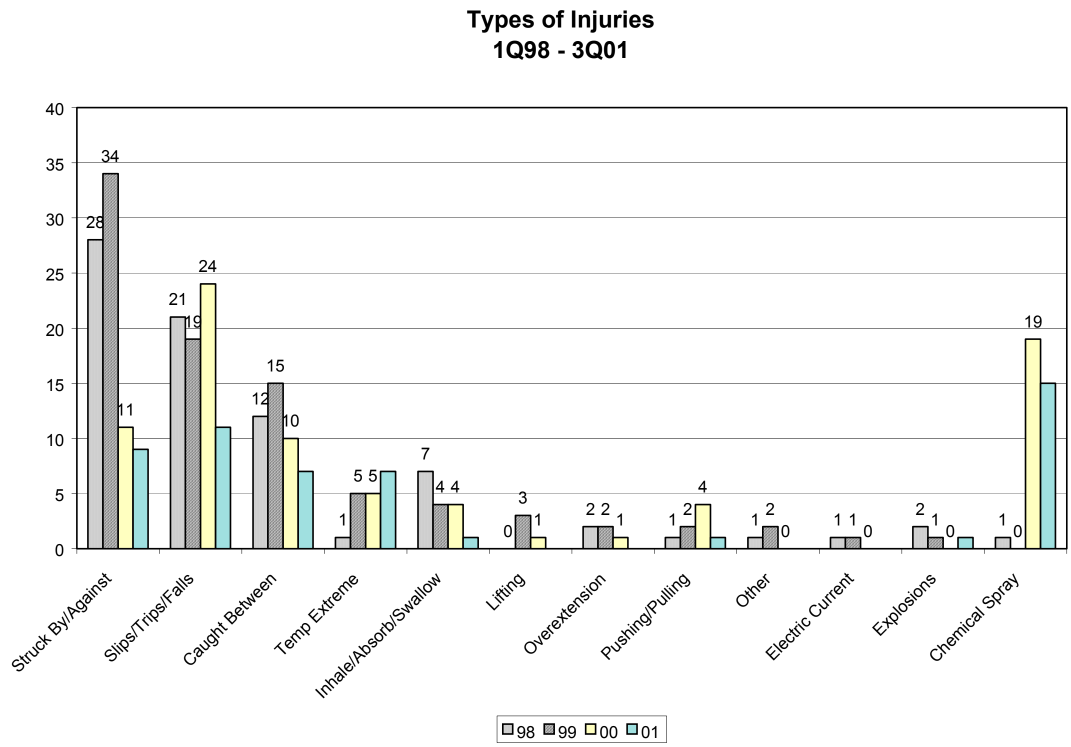

Figure 17. Example of a Trend Analysis
(Data courtesy of Stolt-Nielsen Transportation Group)

that new crews were hired to man some of the newer ships, and these crew members did not have previous experience on a chemical tanker. Stolt is addressing this problem with an intensive training course taught by experienced Captains and Chief Mates, a course which has proved very successful in the past. This type of finding alerts a company to the need for getting additional data to understand the contributing causes to such incidents so that productive safety interventions can be designed and implemented.

Frequency and trend analysis are often supplemented with cost data to help a company decide where to focus its next safety intervention. While frequency data tell you how often a given type of incident happens, it does not tell you the severity or consequence of the incident. Therefore, it is helpful to combine frequency data with cost (or some other measure of severity) to determine which types of incidents are most in need of controls. For example, Figure 17 shows a much higher frequency of slips, trips, and falls than injuries associated with temperature extremes. Going solely by the frequency data, one would assume the slips, trips, and falls are more important to control. However, if most of the slips, trips, and falls have a relatively minor consequence (that is, the injury caused is mild), then it may not warrant much attention. Let’s say that on the average, the injury caused to the workers in these slips, trips, and falls is so minor that nothing more than first aid is needed and the employee can return immediately to the job. However, let's say that the result of the average injury due to extreme temperatures (e.g., heat stroke or frostbite) requires hospitalization and one week of lost time. So even though the *frequency* of the temperature-related incidents is only about a quarter of that due to slips, trips, and falls, their *severity* is much worse. The "total cost" (frequency x average cost) of the temperature-related incidents is much greater than that for the slips, trips, and falls, making the reduction of temperature-related incidents a higher priority for the company.

A word of warning about trend analysis: just because the data appear to show a trend does *not* necessarily mean there really is a significant trend present. Data can be highly variable (that is, the number of incidents can fluctuate greatly from one time period to the next). It is not uncommon to see rather large changes in the numbers of incidents from year to year. When you are dealing with a small number of data points (e.g., comparing yearly incident frequencies from 1999 to 2000), you cannot see the underlying variability. One way to get a better appreciation for the variability is to look at the data by month or by quarter instead of by year. The most accurate way to identify true differences in frequencies and establish real trends is by using statistical analysis (for example, fitting the data to a linear function (linear regression) and determining whether the slope is significantly different from zero).

Both frequency analysis and looking for trends are ways to identify operational variables that may require closer examination. Notice that while the frequency or trend analysis will show you areas of concern, it does not answer the question as to *why* these differences are occurring. Once you've isolated the types of activities, operations, or situations of interest, you can use the next analysis technique to explore your incidents further.

6.4 Looking for Similar Incidents

If each incident report is coded with the type of incident (e.g., oil spill), and the activity during which it happened (e.g., filling a tank), one can search the database to identify all the incidents which had these features in common. One immediate advantage to this is it helps to identify your high-frequency events. Another big advantage is that you can now re-read the incident narratives and look for other similarities that might lead to the identification of a safety hazard that needs to be fixed. For example, in the case of spills caused by overfilling a tank, it may be that an overfill alarm needs to be added, or that the standard operating procedure needs to be changed so that the tank is continuously monitored by a crew member, and-or the fill rate decreased as the tank gets close to being filled. This type of analysis is an excellent way to identify equipment design flaws and poor operating procedures. The FAA-sponsored, NASA-run Aviation Safety Reporting System, has used this method successfully to identify equipment defects, runway design problems, and to make improvements to air traffic control protocols.

6.5 Determining Under What Conditions a Given Error Happens

In the construction of the incident database, it can be useful to do a risk assessment of various operations to identify things that "might" go wrong. The database can then be used to see under what conditions things actually *do* go wrong. For example, in a study of communications errors, the types of operations that depend on good communications were identified (e.g., vessel navigation with a marine pilot on board requires good communications between the pilot and the ship's bridge team; safe meeting and passing agreements depend on good ship-to-ship communications). The potential need for communication was then tagged in the database by answering five simple questions, such as "Was there a pilot navigating?" or "Were there two or more vessels involved in this casualty?". In analyzing the accident data, it was found that of the accidents in which one of these five questions was answered "yes", 76% of them had a communications error as a contributing factor to the accident. This is a powerful way to identify high-risk activities and situations.

6.6 Looking for Underlying Causes Using Meta-Analysis

If your incident investigators are adept at asking "why" enough to get to underlying human error causes, then you can use your incident database to determine which types of causes may precipitate many of your incidents. To extend the example above of communications-related casualties, the incident investigators used a form to identify specific communications problems, such as "did not communicate", "did not send information in a timely manner", "message was interrupted", "did not interpret the information correctly", and others. For each problem identified, the investigator went on to consider a list of contributing factors, such as "inadequate knowledge of company policies for communications", "limited English skills or knowledge", "did not operate communications equipment correctly", "distracted or interrupted by other tasks", "assumed there was no need to communicate", and others (see App. G for the complete communications investigation protocol).

A frequency analysis of the communication problems showed that the single biggest problem was a failure to communicate. That is, in 68% of the accidents, someone had information that could have prevented the accident, but chose not to tell anyone. These "failure to communicate" casualties were isolated and a frequency analysis was done to identify the most frequent contributing factors. While this identified factors such as "incorrect interpretation of the situation", "assumed incorrectly that other party already knows", and others, it didn't give a good sense of what might be at the crux of these accidents.

To get a clearer picture of what was going on, a "meta-analysis" was done in which the narratives of the different casualties were reviewed and additional characteristics of the situations were identified. The result was the finding that the most common apparent underlying cause in 92% of these "failure to communicate" accidents was that the person did not perceive a safety threat, either because he had misinterpreted the situation or because he failed to think about the ramifications of the situation beyond his own specific job responsibilities (that is, he did not consider how his actions might affect other people). These types of behaviors show a deficit in "situation awareness". The meta-analysis also showed that in almost half of these accidents, there was a second person who did not speak up. This person perceived the safety threat, but assumed it was not his job to say anything (he assumed someone else was aware of the problem and would take care of it). This failing shows a lack of "ship resource management". The meta-analysis allows one to go beyond the specific data categories in the incident database and to find underlying causes that may tie other, seemingly-disparate causes together. In a sense, a meta-analysis is like putting a puzzle together. Each database element is a piece of the puzzle, but the meta-analysis helps us see how to put the pieces together and get greater meaning from them. In this case, it was the meta-analysis which most effectively pointed us at the true underlying problems, suggesting the types of interventions (improvements in situation awareness and ship resource management) that would be productive.

6.7 Identifying Relationships Among Incident Attributes by Statistical Analysis

Statistics can be used to draw out meaningful relationships among elements of incidents, and sometimes they can be used to infer probable cause. Statistical analysis was used in a couple ways in a recent study of fatigue-related accidents (McCallum, Raby, & Rothblum, 1996). The purpose of the research was to understand not only how many marine accidents were related to fatigue, but also to look for underlying contributing factors (in other words, what was causing the fatigue). A database was established using scientific literature to identify the questions that should be asked (the resulting fatigue investigation questions can be found in App. G). The fatigue investigation was administered during routine casualty investigations, and the database was used to find out what attributes were significantly related to fatigue (that is, what data items had statistically different values in the fatigue-related accidents compared to accidents that did not result from fatigue). One set of tests looked at the number of hours worked by mariners who caused injuries (either to themselves or to another crew member).

The statistical tests (*t-tests*) determined that the number of hours on duty at the time of the accident, and the number of hours worked in the last 24/48/72 hours were all significantly different for the fatigue-related and non-fatigue injury cases. The averages for each of these comparisons are plotted below (Fig. 18). One must be careful about jumping to causal conclusions. In some cases, the difference seen between two groups may be due to something very different than what is being tested (remember our example of the number of incidents reported by the different oil rig crews). However, in this case, the scientific literature supports the relationship between long work hours and increasing fatigue. Therefore, these data were taken as strong evidence that an underlying cause of these fatigue-related injuries was long work hours.

Statistical analysis was used a second way in this study. It was used to consider all the different factors that were correlated with fatigue-related accidents and to come up with a quick "screening test" for fatigue. Because the full fatigue investigation took about 40 minutes, it was desirable to find a few questions that would indicate whether fatigue appeared to play a role, and whether, therefore, the investigator should collect all the fatigue data. A multiple regression analysis was performed to determine which factors were most predictive of fatigue-related casualties. The result was a simple *Fatigue Index* equation consisting of just three questions (the number of hours slept in the last 24 hours, the number of hours worked in the last 24 hr.,

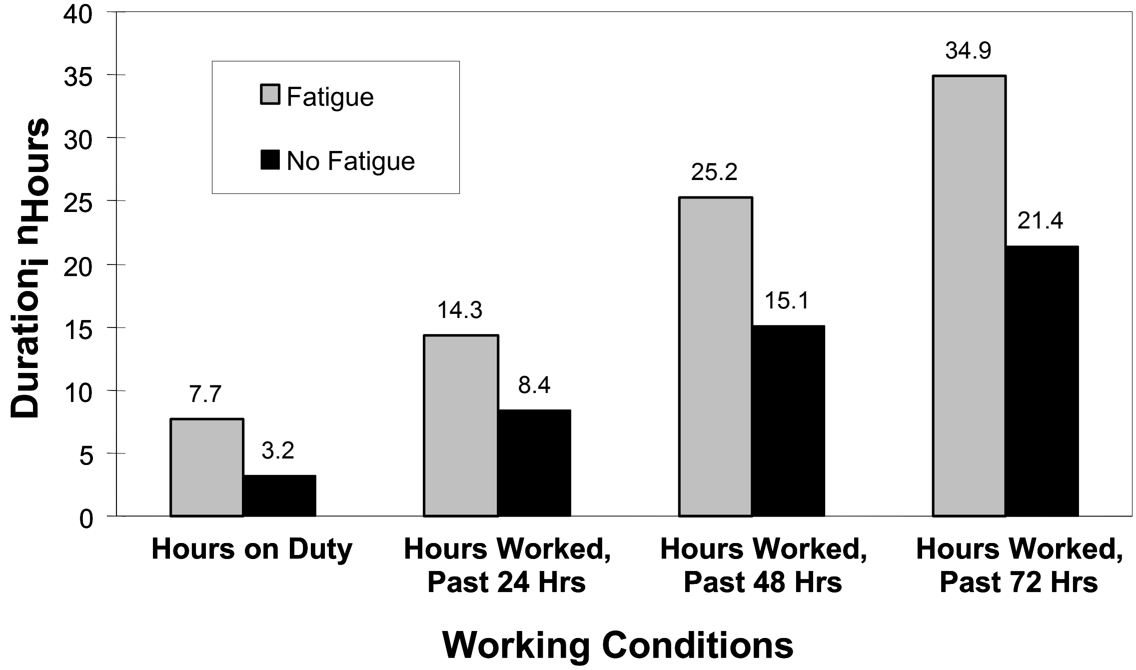

Figure 18. Result of Statistical Analysis of Incident Database Items
(from McCallum, Raby, & Rothblum, 1996)

and the number of fatigue symptoms experienced by the mariner). When the data from both the fatigue and non-fatigue casualties were put into this equation, it was found to be 80% correct in its ability to identify whether a given casualty was fatigue-related or not (the fatigue index worksheet is in App. G).

The purpose of statistical analysis is to determine whether apparent differences in data points are just due to the variability of the data or whether they are due to a true underlying difference or trend. For example, in Figure 17, the incidence of "caught between" injuries varies greatly over the four years shown. Is the downward trend from 1999 through 2001 "real", or is it just a matter of the normal variability of the data? Statistical tests can be used to determine this. It should be noted that just because something turns out to be "statistically significant", it does *not* necessarily mean that it is "important" or significant in practical terms. The size of the significant difference could be very small. For example, Figure 16 compared the number of incidents on three drilling rigs. It might be that the incident rate on Rig B is significantly lower than the rate on Rig A. But since both have a relatively low rate of incidents, from a practical standpoint, the difference just isn't interesting (not worthy of taking action).

6.8 After the Analysis

Webster's Dictionary (G & C Merriam Company, 1973) defines *data* as, "factual information (as measurements or statistics) used as a basis for reasoning, discussion, or calculation." The operative word is *basis*. The analysis of incident data serves as nothing more than a basis or a point of departure for discussion, reasoning, and perhaps additional study. It is not until the data have been pondered, organized, understood, and put into proper context that these bits of disparate facts turn into valuable and useful information. This subsection discusses two areas in which one needs to go beyond the data analysis in order to fully understand the data and take appropriate action.

6.8.1 Data-Driven Research: the Link Between Data Analysis and Solving Safety Problems

You cannot solve safety problems simply by analyzing incident data. In general, the analysis of incident data will identify a potential problem that then needs to be studied before it can be solved. For example, if you plot your company's injury data and find that a large percentage of the injuries are from slips, trips, and falls, you have identified a problem, but not a solution. The next step would be to investigate further and understand what seems to be causing the slips, trips, and falls. Where do these injuries occur and under what conditions? Are deck surfaces slippery or are stairway treads worn? Have personnel been provided with proper footwear, and if so, are they *wearing* it? (You'd be surprised at the number of times companies provide personnel protection gear of one sort or another, only to find that employees refuse to use it because it's either uncomfortable or interferes in some way with other aspects of their jobs. Protective gear must be designed to be compatible with the workers' needs and workplace tasks.)

As was discussed earlier (see Fig. 8 in Sec. 3), the analysis of incident data is the precursor to *data-driven research* used to understand the problems identified by the analysis. "Research" may be as simple and low-tech as a discussion with employees and line supervisors to get their perceptions of the problems and potential solutions, or it can be as detailed and intensive as a full-blown scientific study. The point is that the analysis of the incident data is a *starting point*, and that it takes follow-up study to understand the genesis of a problem and to devise successful safety interventions.

6.8.2 It May Be Data, But It's Not Necessarily Telling You Anything

One final caution: a database is only as good as the data that are put into it. If the investigator doesn't ask all the relevant questions, the database *cannot*, by definition, have the relevant data. This harks back to the recommendations given in Section 3 for building a successful incident investigation program. If the company does not promote an open, fair, and improvement-oriented culture, or if there isn't a common understanding about the scope and purpose of the incident investigation, or if the investigators are not appropriately trained, or if the incident database is hard to use, the data that populate the incident database may be less than accurate and complete. Obviously, analyses based on such data will be of questionable value ("garbage in, garbage out").

Even with the best of intentions, things may happen which affect the database. For example, a simple change in policy affecting which incidents will be investigated may result in the appearance of a greatly increased (or reduced) incident rate when comparing data from periods before and after the policy went into effect. Let's say a company decides to forego incident investigation on any incident which costs the company less than $10,000. If there are types of incidents which are predominantly low-cost, the frequency of those incidents will appear to be dramatically reduced after the policy takes effect (even though the true frequency of the incidents has not changed, or even increased – they just aren't being investigated anymore). Training for investigators may result in a better understanding of the classification scheme (such as HFACS) they are using. While this should result in improved data reliability in the future, it may also give the appearance of changes in certain types of incident rates (because some incidents may have been misclassified prior to the training).

Never put blind faith in your incident data analysis: always be on the lookout for procedural or other reasons (unrelated to actual incident rates) that might be affecting the analytic process. Keep records of changes made to the database, investigation policy, and investigator training – these could be great time-savers in understanding "mysterious" trends. Keeping records of important company policy or procedural changes can also be helpful in understanding changes in incident frequencies. The more you know about changes in the way you do business – both in the company at large and in the incident investigation program specifically – the better you will be able to differentiate between spurious "trends" and true safety issues.

6.9 Summary of Analysis Techniques

Data analysis can be used to identify areas in need of safety interventions. Oftentimes, data analysis shows an interesting trend, but does not give you sufficient information to take action. This will require follow-up studies to better define the problems and suggest workable solutions. Data analysis can also point out where the database and-or investigation procedures are lacking. For example, you may find out the company has a high rate of slips, trips, and falls – but that doesn't tell you enough about the problem. The database might need to be modified to add information on the types of slips, trips, and falls (e.g., where they occur, what operations were in progress, how much lost time resulted), and the incident investigators may need to ask additional questions to illuminate the causes of these accidents. Recall that Figure 8 shows a feedback loop from Database Analysis back to Incident Investigation. Data analysis is a great way to learn about the strengths and weaknesses of your investigation methods and database.

This section has provided examples of ways you can learn from your incident data. Frequency analysis and looking for trends are simple procedures that anyone can do quickly with the aid of a spreadsheet application. Looking for similar incidents and determining conditions which tend to be associated with them are fairly simple procedures, although a database with relevant index variables is helpful for doing such analyses efficiently. Statistical analysis, while requiring more expertise on the part of the safety analyst, can provide great benefits by finding underlying correlations and relationships. The important thing is not to let your incident data just sit there: analyze it and make it work for you.

7.0 FINDING SAFETY SOLUTIONS

Let's say you've collected incident information and run some analyses. Now you want to develop measures to prevent these incidents from recurring. What do you do? How do you find solutions that will be *effective*? Oftentimes, finding effective solutions is elusive. A study of offshore operations in an international oil and gas company demonstrates what can happen (Bryden, O'Connor, & Flin, 1998). This company had an incident investigation program. The database contained information on technical and human factors causes of the incidents and suggested remedial actions. Analysis of the recommended remedial actions showed that only 10% of them addressed the underlying causes of the incidents, while another 31% addressed only direct causes and no underlying causes. The shocker was that 59% of the recommended remedial actions were "quick fixes" which did not address the causes of the incidents at all! The ineffective quick fixes tended to be things such as telling the worker not to do it again, or mentioning the danger at the next safety meeting. A safety program based on trying to motivate the worker not to repeat a dangerous action, without taking steps to solve the underlying causes, is doomed to failure.

On the other hand, it is not so surprising that companies might fall into such a "quick fix" trap. One might say that the biggest problem with having a successful incident investigation program is that now there are data about which management must not only *think*, but also *do something constructive!* Perrow put it this way (Perrow, 1986, as quoted by Hollnagel, 2000, p.1):

> Formal accident investigations usually start with an assumption that the operator must have failed, and if this attribution can be made, that is the end of serious inquiry. Finding that faulty designs were responsible would entail enormous shutdown and retrofitting costs; finding that management was responsible would threaten those in charge; but finding that operators were responsible preserves the system, with some soporific injunctions about better training.

Remember Reason's (1990) Swiss cheese model – each slice of cheese (excluding unsafe acts) represents a layer of system defenses. The fact that incidents are occurring means that one or more of these layers of system defenses requires repair: they are not effective barriers to prevent unsafe outcomes. Hollnagel (2000), like Reason, has suggested that in order to prevent incidents, we must go beyond finding a single "root cause" (or making the operator the scapegoat, per Perrow) and understand how to improve the barriers (system defenses). Barriers can either avert an incident from taking place, or reduce the magnitude of the negative consequences (prevention and mitigation, respectively, as depicted in Fig. 8).

7.1 The Triangle of Effectiveness: A Guide to Safety Interventions

Gerry Miller (2000; Miller et al., 1997) adds his voice to those of Reason and Hollnagel in decrying the past tendency to place the blame for industrial incidents solely on "operator error". Instead, it is his contention that even the most safety-conscious employee will occasionally initiate unsafe acts at the job site, and that sometimes these acts are encouraged, led, or even coerced upon the employee by a variety of factors beyond the employee's control. However, Miller states that these acts can be prevented, or at least the consequences of the acts mitigated, through the application of barriers or safety interventions. He illustrates this concept through his "triangle of effectiveness" (see Fig. 19), which presents eight levels of barriers that can be used to prevent or mitigate incidents[12]. Starting at the base of the triangle, these eight elements are:

- Policies and culture[13] – management policies and corporate culture which promote a safe, human-centered work environment;
- Workplace design – ergonomically-designed and arranged equipment;
- Environmental control – keeping lighting, temperature, noise, etc. within human-compatible ranges;
- Personnel selection – selecting the right people for the job;
- Training and standard operating procedures (SOPs) – ensuring workers have the necessary knowledge and skills to do the job, and that SOPs are correct and consistent with best practices;
- Interpersonal relationships (communication) – the exchange of necessary information between team members;
- Job aids – understandable, easy-to-use task instructions and warning placards;
- Fitness for duty – ensuring that workers are alert, focused, and capable of safe job performance.

All eight barriers are important, Miller concludes, and must be included in a total behaviorally-based safety program. It should be emphasized, however, that the elements at the base of the triangle (i.e., policies & culture, workplace design, and environmental control) have the most significant impact on safety and should form the backbone of a company's safety program. (Each of these eight barriers will be discussed in more detail in the next section)

In Reason's model, these elements (at the base of the triangle) are controlled by the "Organizational Factors" layer of defenses. When the organization (company management) makes poor decisions, such as the selection of equipment which is not designed to support the

[12] Miller uses this triangle both as a model for accident causation and as a guide to selecting safety interventions. Like Reason's framework, Miller's emphasizes the multiplicity of causes of a given incident and attributes the causes to the lack or failure of barriers (system defenses in Reason's jargon). In this paper we have chosen to focus on Miller's triangle as a means for selecting interventions, since it bridges the gap between Reason's organizational model of system defenses (management – line supervisor – worker) and the concrete needs of a shipping or offshore company to select specific means to solve identified safety problems.

[13] Miller calls this factor "Management Participation". Workshop participants felt "Policies and Culture" was a more intuitive label.

human operator, that single poor decision has an enormous "trickle down" effect because so many operators and operations are affected. Such poor decisions at the Organizational Factors layer very often become latent contributors to incidents. In a similar fashion, *good* decisions made at the Organizational Factors layer, such as the selection of well-designed equipment (or other human-centered decisions contained at the base of the triangle), contribute very positively to the safety program, again because of the numbers of people and operations they touch.

Interventions based solely on elements at the top of the triangle (such as fitness for duty and job aids) will have the least impact on workplace safety, and therefore should have a lesser emphasis within the company's safety program. The factors at the top of the triangle depend primarily on the actions of individual workers. Interventions at this level are on a one-by-one basis – a less efficient and less effective way of dealing with safety issues.

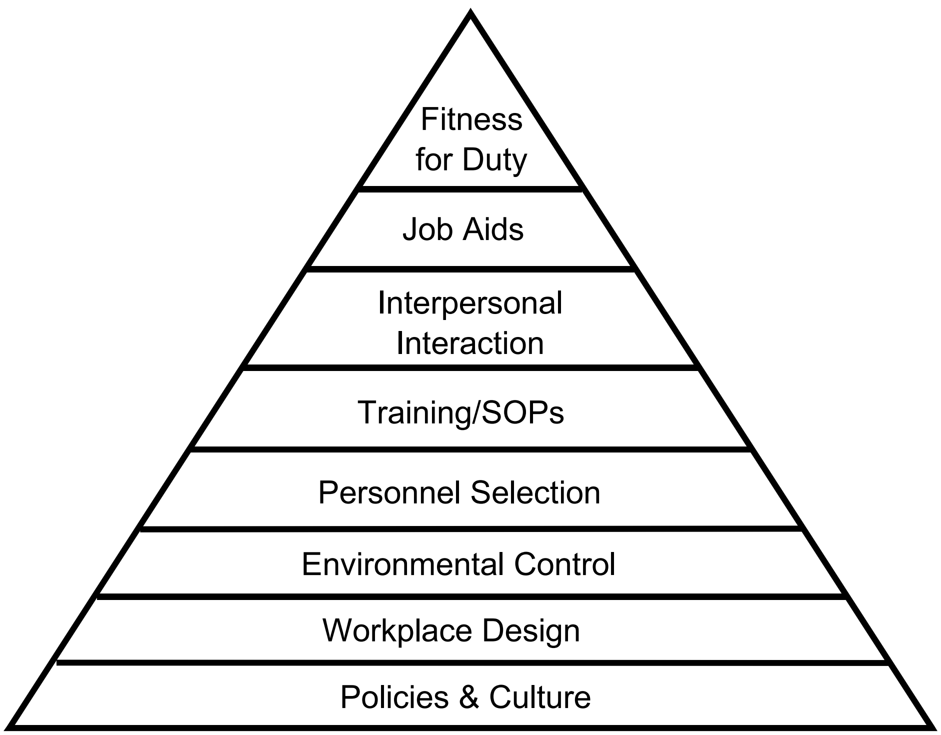

Figure 19. The "Triangle of Effectiveness" for Safety Interventions to Reduce Human Error
(after Miller, 2000)

An example will help to clarify this. Let's say Joe needed emergency medical attention because he accidentally sheared off one of his fingertips while cutting metal sheeting to make a repair. Telling Joe to "be more careful" will not likely have a big impact on safety. Training all the repair crews on the correct procedure for cutting sheet metal will have more of an impact, since more of the workforce is made aware of the problem and a way to protect themselves (assuming, of course, that supervision and peer pressure encourage and reinforce their behavioral changes). But the best way to prevent this type of incident is by having equipment that has been designed with a "guard" to prevent one's fingers from contacting the cutting mechanism (workplace design level).

Hollnagel (2000) points out that the purpose of an incident investigation program is to identify barriers (system defenses) that have failed or barriers that were missing which allowed an incident to happen. A good safety intervention program repairs and-or develops as many of these barriers as possible. Miller's (2000) addition to this line of thinking is that when it is not possible to implement all the relevant barriers, selecting those towards the base of the triangle will reap better protection than selecting only those towards the tip. Just as we need to probe deeper to find the underlying latent factors which cause incidents, we also want to make safety "fixes" and focus our safety program at the deepest levels possible (at the base of the triangle).

7.2 Relationship Between Reason's "Slices of Cheese" and the Triangle of Effectiveness

As shown in Figure 20, different layers of system defenses are related to different elements within the triangle of effectiveness. The Organizational Factors layer has the greatest span of control, and therefore, the greatest capacity for effective intervention. Remember that "organizational factors" refers to the policies, procedures, and decisions put into place by upper management. Management is usually responsible for designing the procedures and developing the work policies implemented by the line supervisors and workers. As such, this layer of system defenses can influence seven of the eight elements within the triangle of effectiveness, and is the only layer of defense which can effectively impact the most important lower three elements (see top of Fig. 20).

The Supervision layer of defenses represents the interventions that can be controlled by line management. Note that whereas the organizational factors layer is generally in charge of designing and developing policies and procedures, supervisors are responsible for carrying out those policies and procedures. This automatically limits the effectiveness that supervisors can exert, since they often cannot change existing policies and procedures, only report back on those which may appear to be latent factors in incidents. The middle section of Figure 20 displays the types of interventions to which supervisors can contribute. While they are not always directly involved in hiring and firing, line supervisors generally are involved in "personnel selection" from the standpoint of assigning people to tasks. In a similar vein, while they might not be involved in training or writing standard operating procedures (SOPs), they are responsible for seeing that these are properly carried out. They may also be the ones who recommend workers for remedial or advanced training.

The worker has the smallest span of control over safety interventions. The worker's level is basically contained within the layer of system defense called "Preconditions for Unsafe Acts". It becomes the worker's responsibility to adhere to standard operating procedures, learn to use equipment properly, communicate clearly, use job aids when needed, and to stay fit for duty. If, for example, a standard operating procedure is deficient or a management work-rest schedule causes excessive fatigue on the job, the worker's span of control is too limited to allow for meaningful intervention at that level. This is why it is so important to look for interventions at the base of the triangle, at the organizational factors layer of system defense.

Now let's discuss each the intervention elements within the "triangle of effectiveness" and see how they relate to the "layers of system defenses".

7.2.1 Policies & Culture

Management policies and corporate culture depend on the active participation of upper management in promoting a human-centered work environment and worksite. As such, policies and culture are key to an effective error reduction program: they are the base on which everything else rests. Management participation should be demonstrated in a variety of ways. It should be visible in its support and active encouragement of an open, "safety first" corporate culture, where "safety first" is not just a motto but a corporate mission. An atmosphere that provides incentives for personnel to question and improve work environments and standard operating procedures shows a caring management philosophy. Management actions and decisions should be *human-centered*, enabling the best personnel performance. Examples of

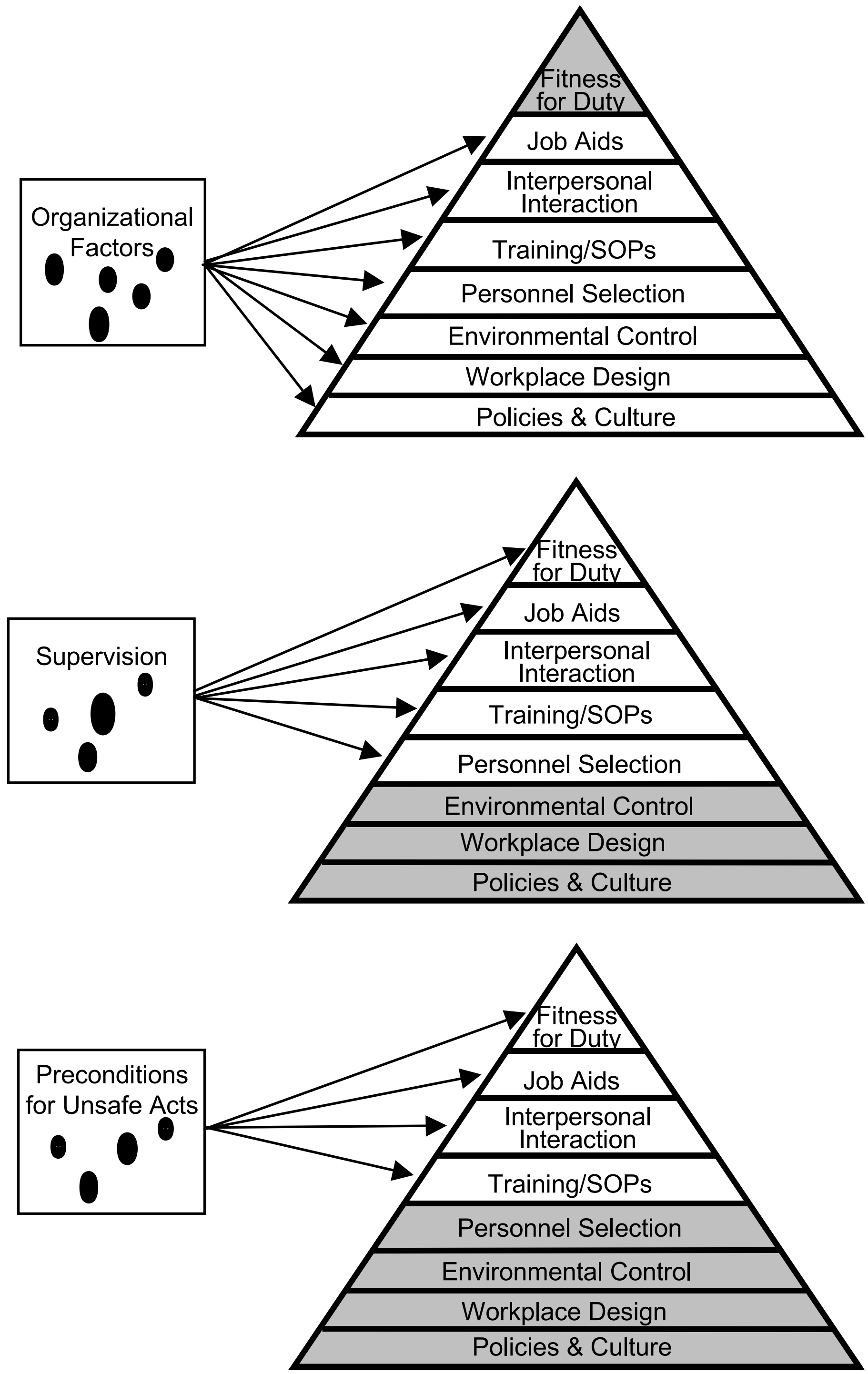

Figure 20. Types of Interventions Needed to Plug the "Holes" in the Layers of Defenses.
Different layers of system defenses ("slices of cheese" at left) can be bolstered by – and have the power to implement – different sets of interventions (unshaded elements in the triangles).

how management can demonstrate its commitment to a good employee safety program include establishing safe work loads and schedules based on known human physiological limitations and requirements (e.g., work-rest cycles); the creation of easily-understood and achievable company policies and practices; the establishment and consistent application of rewards (or punishments) for compliance (or lack thereof) with company policies; creation of reasonable product delivery schedules; providing physical facilities and equipments designed to match human capabilities and limitations; insistence on good facility maintenance; and a commitment to uncovering the underlying causes of incidents. By definition, management policies and corporate culture are a part of the “Organizational Factors” level of defenses. Whenever such organizational factors (like the examples just given) are discovered during an incident investigation, management policies and culture should be considered when designing interventions to stop future such incidents.

7.2.2 Workplace Design

Good, ergonomic workplace design can be extremely effective in reducing incidents. As underscored earlier in this paper, poor design of vessels, platforms, equipment, and work environments is an underlying precondition that can “set up” the human operator to make errors. In fact, the American Bureau of Shipping states that 88% of shipboard injuries and 50% of fatalities are the result of poor design (McCafferty, 2000). Unfortunately, examples of poor design abound in the maritime industry. As Miller says (2000, p. 7), “You cannot overcome human errors induced by poor design of the work place with more training, more manuals or written procedures, exhortations to work safer, or threats of punitive actions for job accidents.”

Good design is not a mystery: there have been decades of human factors research into a plethora of design facets. Further, there has been considerable experience acquired over the past decade in the offshore and shipping industries with applying HFE design criteria to new and remodeled facilities. In addition, well-established and accepted human factors design standards and guidance now exist for the maritime industry (ASTM, 1995; American Bureau of Shipping [ABS], 1998; ABS, 2001). In fact, when HFE design principles are introduced at the beginning of the design of a facility or system, it can drastically reduce life-cycle costs and prevent the need for costly modifications down the road (because it was built right the first time).

Good workplace design requires proactive management involvement; it is almost always beyond the span of control of the workers or line supervision. Thus, incidents resulting from workplace design flaws, even though some may be considered “equipment preconditions”, must look to the Organizational Factors layer of the organization for effective safety interventions.

7.2.3 Environmental Control

Lack of environmental control is another widespread, latent cause of maritime and offshore incidents. This element of the triangle refers to the work environment: temperature, humidity, lighting, noise, and vibration. Human beings have “safe operating ranges” just like equipment. Put a human in an environment that is outside his safe operating range, and he becomes an accident waiting to happen. Miller (2000, p.8) relates an all-too-frequent occurrence:

> As just one example, studies have shown that crane accidents are the second most frequent cause of injuries and fatalities on offshore platforms in the Gulf of Mexico (GOM). Yet, operator cabs on these cranes are traditionally not environmentally controlled. Some years ago during a visit to an offshore platform it was noted ... [that the temperature inside a crane cab was] 122 degrees F. With this combination of heat and July GOM humidity is it any wonder that an operator error of omission (i.e. the operator did not complete an act that he was suppose to have done) occurred that day resulting in damage to the crane and platform.

Emphasizing the importance of proper workplace environments, the American Bureau of Shipping (ABS) has prepared human performance-based environmental standards for both ships and offshore structures. These standards will be issued in 2002.

7.2.4 Personnel Selection

It has long been recognized that certain jobs require special physical, mental, or social skills not possessed by everybody who would like to work in those jobs. Finding the right people for the job is what personnel selection is all about. As an example, special physical and psychological screening tests have been used for at least the last thirty years in the public safety sector to screen out those who would not be suitable for the law enforcement or fire safety professions. If a person is selected to work in a job for which he/she is not suited, that can result in an increased probability of that person contributing to a workplace accident.

Personnel selection should consider the personality traits and special abilities needed for a given job. Just because someone has the desire to work in a particular job, or even has spent twenty years working elsewhere in the company, that doesn’t necessarily qualify that person for the open position. A given job may have certain physical requirements (e.g., good color vision for an electrician, or good visual acuity and depth perception for a crane operator), as well as intellectual aptitudes (e.g., good communication skills for a supervisor) and psychological requirements (e.g., good judgement and coolness under stress for a ship master or offshore installation manager).

As a "barrier" to incidents, personnel selection is active at two different levels. The Organizational Factors level (upper management) usually presides over personnel selection in terms of hiring and firing by developing job descriptions and qualifications requirements. A company which takes the quality of its personnel seriously can do much to ensure the right people are placed in the right jobs. The Supervision layer of system defenses also contributes significantly in terms of the way personnel are assigned to tasks. Again, if the supervisor takes this job seriously, the right numbers of people, fit for duty, and with the right qualifications can be assigned to operational and maintenance duties, helping to ensure safety.

7.2.5 Training and Standard Operating Procedures (SOPs)

Training and SOPs make up the next element in the triangle[14]. "More training" has too often been management's sole, knee-jerk remedy to incidents. As already stated, more training can *not* make up for inattention given to other barriers such as workplace design, environmental control, and management policies. Another frequent limitation to training is that it is assumed that someone who is experienced at a given task is therefore qualified to train others. Such training is haphazard, often poorly performed, and usually incomplete. There are rigorous methods (such as Instructional Systems Development) for analyzing tasks, determining performance objectives, and training and testing to these objectives (McCallum, Forsythe, Smith, Nunnenkamp & Sandberg, 2001). As automated systems become more prevalent in the maritime and offshore industries, thorough training, not just in the task at hand, but also in the operational parameters of the equipment, becomes increasingly necessary (Sanquist, et al., 1996). In summary, before resorting to training, make sure it really is the answer to the problem; and if training is what's needed, then it's worth doing right.

The second part of this element is standard operating procedures. Many times incidents occur *not* because the worker lacked skills or knowledge, but because the *SOP* was not designed appropriately for the given conditions. The Training/SOP element acts as a safety intervention in all three layers of system defenses (Fig. 20). At the Organizational Factors layer, the responsibility is to institute sufficient training and effective, safe SOPs. At the Supervision layer, the training/SOP defense is to ensure trained personnel are assigned to tasks and that they use the SOPs. At the Preconditions layer, the worker must ensure that he/she has the required training to do assigned work and that he/she understands and consistently uses SOPs. While all three layers of system defense are necessary to ensure safe operations, it is clear that a "hole" in the Organizational Factors layer (e.g., a decision to provide only the most basic training/SOPs, or to shirk the responsibility and place it wholly on supervision's shoulders) will do the most harm, since that "missing barrier" will affect the entire workforce.

[14] Miller refers to this element just as "training". However, a recent study (McCallum, Forsythe, et al., 2000) notes that many incidents attributed to inadequate knowledge and skills are actually promoted through incorrect SOPs, as opposed to insufficient training, per se.

A final note on standard operating procedures. Many of them are written so poorly that personnel are unable to use SOPs effectively. SOPs are important for safe operation, and they should be well-written in order to convey the needed information to the users. A good tutorial on writing SOPs is given by Information Mapping[15].

7.2.6 Interpersonal Relationships (Communication)

Interpersonal relationships (communication) is what makes teams work. Offshore, shipboard, and dockside activities all depend on teamwork. In earlier times, the Offshore Installation Manager or the ship's Master was the unquestioned authority in a one-way, top-down, chain of command (Miller, 2000). However, most shipping and offshore companies (and many other industries, such as aviation and nuclear power) have recognized that "crew resource management" is an essential component of safety. Personnel need to feel empowered to speak up, question, and double-check decisions and actions of other team members (including supervisors). Research has shown that when crew members do not communicate effectively, accidents result: 28% of personnel injuries and 18% of vessel casualties were related to inadequate communications (McCallum, Raby, Rothblum, Forsythe, Slavich & Smith, 2000, unpublished).

In the maritime and offshore environments, poor communications can be caused by factors in addition to a lack of crew resource management. Physical constraints (separating persons who need to be together via poor layout of rooms or facilities), inappropriate organizational structure which puts too many chains of command between individuals who need to communicate, and overloading workers so that they do not have the time to communicate can all contribute to poor interpersonal communications. This is a factor that is often, and mistakenly, overlooked in incident investigations.

Good communication is a safety intervention that must be established at all three layers of system defense. As was the case with Training/SOPs, the Organizational Factors layer must lay the foundation by making two-way communication a part of company culture and facilitate it through good workplace design and policies. Supervisors must actively support and encourage effective communications within and among teams. And to keep communications from becoming a Precondition for Unsafe Acts, workers need to be involved, responsive members of their work teams.

[15] For more information about seminars by Information Mapping, please see their web site at http://www.infomap.com or call (800) INFO MAP (463-6627).

7.2.7 Job Aids

Job aids come in several forms such as hazard identification (warning) signs, operator and maintainer manuals, and specific operating procedures. These can be of help in reducing human-induced incidents, especially when learning a new task, performing a task that is done infrequently, or completing a job that must be performed in an exact sequence. However, a poorly prepared job aid can lead to incidents rather than prevent them. Examples of critically important job aids found on ships and platforms are the lifeboat launching instructions and the operating instructions for manually releasing the fire fighting suppressant system. Unfortunately, these safety-critical instructions are typically confusing and difficult to understand (Miller, 2000).

There is a lot of research available on how to prepare good job aids, instructional placards, and warning signs (Curole, McCafferty & McKinney, 1999; Laughery, Wogalter & Young, 1994; Wogalter, Young & Laughery, 2001; and seminars by Information Mapping[11]). One concept, called *information mapping* (Curole, et al., 1999), utilizes research on the human learning process to provide very specific guidelines on how to prepare manuals, procedures, checklists and other printed and-or pictorial job aids. Properly prepared job aids can be a useful barrier to the prevention of maritime incidents. By the same token, poorly-written or missing job aids can contribute to incidents and are an important aspect to be considered both during the incident investigation and in the preparation of preventive recommendations.

7.2.8 Fitness for Duty

Fitness for duty is another term for adverse mental or physiological states that are severe enough to reduce the individual's capacity to perform. These states can be due to physiological conditions of illness or fatigue, or to the use of alcohol or drugs (including over-the-counter medications). These states can also be psychological in nature such as emotional trauma due to family or financial problems, or from a neurotic or even psychotic disorder. If any of these things is sufficient to distract or otherwise impact the person's performance of safety-related duties, it can be a definite contributor to an incident. This is another factor that is often overlooked during the incident investigation process, but should receive attention.

Essentially, fitness for duty is the responsibility of the worker to keep it from becoming a precondition. Line supervisors have a responsibility to ensure that workers are, in fact, fit for duty. This is the one element of the triangle that the Organizational Factors layer doesn't explicitly address (for example, work-rest policies and worksite environment, both of which can affect an employee's physiological and mental fitness for duty, would fall under other triangle elements).

Fitness-for-duty testing is a controversial area. There are some tests available for determining whether a person is under the influence of drugs or alcohol or severely fatigued; however, the reliability of most of these tests is a hotly-debated issue. Some trucking companies have successfully used a simulator-type test to ensure a trucker's driving performance is up to par before getting on the road. Such scientifically-validated and operationally-relevant screening techniques have yet to be developed for the maritime and offshore industries.

An alternative approach to testing is to implement a crew endurance program (Comperatore, Rothblum, Kingsley, Rivera, & Carvalhais, 2001). This type of program educates personnel as to how fitness for duty can affect not only job performance but long-term health and assists personnel in controlling the hazards that affect fitness for duty (note that such a program would be part of the Policies & Culture and Training/SOP elements of the triangle, not the Fitness for Duty element). Since many of the variables that influence fitness for duty are job-related (e.g., fatigue from poorly designed work schedules, or lack of coordination and manual dexterity from working in too-cold temperatures), a crew endurance program helps to prevent latent factors at all three layers: organizational factors, supervision, and preconditions for unsafe acts.

To summarize, the precursor for effective safety solutions is an in-depth analysis of incidents. Only by understanding all the latent factors which contributed to an incident can one determine what "barriers" would be effective in either averting or reducing the effects of similar incidents in the future. It is helpful to establish "barriers" or interventions within all layers of system defenses in order to reduce the likelihood of future incidents. However, when this is not feasible, try to implement interventions in the areas of policies & culture, workplace design, and environmental control, as these are often latent factors for many incidents and are usually more effective at preventing incidents than interventions towards the tip of the triangle of effectiveness. One last key to successful interventions: make your safety interventions "SMART"; that is, they should be specific, measurable, attainable, reasonable, and timely.

8.0 USER EXPERIENCES WITH STARTING AN INCIDENT INVESTIGATION PROGRAM

This section provides two examples of agencies which have begun to incorporate human factors incident investigations. Their experiences demonstrate how human factors incident investigation is used and provide some "lessons learned".

8.1 U.K. Marine Accident Investigation Branch

8.1.1 Background

The Marine Accident Investigation Branch (MAIB) is an independent division of the United Kingdom's Department for Transport, Local Government and the Regions (DTLR). The chief inspector reports directly to the Secretary of State, and is empowered to investigate marine accidents and hazardous incidents occurring onboard or to UK registered ships worldwide, and to all other vessels within UK territorial waters. Each year MAIB receives over 2,000 incidents. Presently, about 60 field investigations are undertaken annually by 13 inspectors working individually or as a team. Such field investigations, including the formal report produced, take about 10-12 months. MAIB inspectors also investigate about 550 additional incidents by paper and telephone.

The fundamental purpose of an MAIB investigation is to determine the circumstances and causes of an accident or incident with the aim of improving the safety of life at sea and the avoidance of accidents in the future. It is *not* the purpose to apportion liability nor to apportion blame: MAIB is not an enforcing authority; that role is taken by the Maritime and Coastguard Agency, a totally separate organization within the DTLR. An MAIB investigation is conducted in accordance with the provisions of *The UK Merchant Shipping (Accident Reporting and Investigation) Regulations 1999*, and aims to determine: what happened; how it happened; why it happened; and what can be done to prevent it from happening again.

8.1.2 Events Leading to Human Factors Investigations

In the 1980's the Surveyor General Organization (predecessor of the Maritime and Coastguard Agency) commissioned the Tavistock Institute of Human Relations, London, to carry out a series of studies on the human element in shipping casualties. This was done in order to understand, and hence reduce, the dangers associated with human frailty in the United Kingdom merchant fleet. This was the first systematic attempt to consider human error in shipping casualties in the UK. Some of the recommendations from the study were that:

- More attention should be paid to the structure, order, and timing of questions in accident investigation.
- A check-list of human element questions should be developed to help the investigator in relating his thoughts to the general body of human factors knowledge.
- A search for alternative explanations to accidents should be consciously developed. This would discourage a pre-occupation with finding a single best explanation, which may be counterproductive to revealing the true facts about specific casualties.
- Regular seminars should be conducted to exchange experiences about casualty investigation.
- A computerized and flexible accident data system should be developed to aid human factors research.

MAIB was set up as a separate organization in July 1989. It was chartered to investigate accidents, keeping this function separate from the Maritime and Coastguard Agency's responsibility for the regulation of ship safety.

8.1.3 MAIB's Classification of Human Factors Causes

MAIB began with a relatively simple taxonomy of human factors, looking mainly at operator error and organizational factors. In 1994, MAIB developed a more comprehensive classification of human factors contributions to accidents and incidents. Based on Reason's model of accident causation, the classification developed aimed to show how active human errors or violations are shaped by latent failures. MAIB currently has six top-level human factors classifications:

- External bodies liaison (e.g., regulations)
- Company & organization

- Crew factors
- Equipment
- Working environment
- Individual

There are sub-classifications under each of these headings (see Appendix D for the full taxonomy). The database was designed to encourage the examination of accident context either from the individual outwards to the regulatory and policy context, or from the context and company inwards to the vessel and the individuals who operate it. In this way, MAIB increases the likelihood of identifying contributing factors at all levels. Some of these levels may be related: for example, company policy on training may influence skills and knowledge at an individual level. In many cases, there will be unrelated human factors areas which contribute to an accident. All the human factors causes which can be identified from the evidence available should be classified.

8.1.4 Human Factors Training for MAIB Inspectors

The development of inspector skills and understanding of human factors investigation has been an evolutionary process. The thirteen MAIB inspectors work under one roof in Southampton which provides an ideal opportunity to share with each other, on a daily basis, experiences with accident investigation. Initially, MAIB inspectors attended human factors training courses provided by the Transportation Safety Board of Canada and by Det Norske Veritas (DNV) in Atlanta. Inspectors were encouraged to attend seminars and lectures on human factors.

This was an ad-hoc, but to some extent effective, approach to introducing a more formal method of human factors investigation. However, a significant drawback was the difference in terminology used by the varying sources of training and guidance. This hindered investigation team effectiveness and made quality assurance of the investigation process and reporting difficult and inconsistent.

To enable a common understanding of human factors investigation, an MAIB training course was developed to achieve a more consistent and reliable approach by inspectors to evaluate the human factors causes of accidents. A certain amount of consistency of reporting and data input has been achieved, but inconsistency and occasional confusion does sometimes arise. MAIB tries to overcome these problems by internal seminars on human factors, regular reviews and audits of the investigation process and outcomes, and attendance of the MAIB course. The course content adapts to the changing needs and experience of the inspectors.

The most recent MAIB course lasted two days and included topics such as: a general introduction to human factors (human performance, teamwork, basic methods, terms, and tools); human factors and accident investigation, including models of causation; human error and error analysis (such as, what is human error, why does it occur, how is it assessed, performance influencing factors, the SHEL model, preventing errors and violations and minimizing the impact of errors, safety management, and safety culture).

A formal approach to human factors investigation has also highlighted the importance of effective interviewing techniques. Consequently, attendance by all inspectors on an in-house interviewing techniques course run by an experienced trainer is mandatory. Continuous development of inspector competence in human factors investigation is also promoted through mini-coaching sessions, self-study, and the day-to-day application of MAIB's formal investigation process. As a result, MAIB now has a team of inspectors competent in the investigation and identification of human factors contributors to marine casualties.

8.1.5 Benefits of MAIB's Database

More than 1,000 accidents investigated by MAIB inspectors are recorded in the database. A measure of success of the database is the increasing demand from diverse interests in the marine industry. Excluding MAIB, the main users of the database are the Maritime and Coastguard Agency (MCA), university researchers, and consultants, all seeking patterns and trends in accident types and causes. Information in the database has been particularly helpful to the MCA who, along with other flag states, is introducing codes of operational inspections and risk assessments and certificates of competency based on performance standards.

The historical information from similar accidents has also proven to be a powerful tool to promote MAIB arguments for safety changes. For example, MAIB analysis has uncovered trends in accidents during lifeboat launching and recovery caused by a multiplicity of human factors. The study was able to identify common factors leading to these accidents, and the risks associated with lifeboat launching systems, by examining the common problems encountered. Operators make mistakes in maintenance and operation of launching equipment because of overly complex design and inadequate operator manuals. Over the years, the size and weight of lifeboats and equipment have increased, diminishing the ability of seamen to handle launching and recovery operations safely. The database analyses have allowed MAIB to understand the problems and to make safety recommendations.

8.2 California State Lands Commission, Marine Facilities Division

8.2.1 Background

The Marine Facilities Division (MFD) of the California State Lands Commission is headquartered in Long Beach, California. Created in 1990, the MFD is tasked with pollution prevention at marine oil terminals. Towards this end, MFD inspectors monitor activities and enforce regulations at 85 marine facilities along the California coast. Inspectors oversee and evaluate the safety of such operations as oil transfers to and from oil tankers and barges and make comprehensive inspections of marine oil terminals and pipelines. At a Facility's request, Division Specialists also conduct safety management assessments aimed at identifying potential trouble areas in an organization's defenses against adverse incidents.

8.2.2 Initiation of Human Factors Investigations

MFD specialists and inspectors also investigate oil spills as a means of informing prevention strategies. Up until recently, those inquiries identified personnel, organizational, and equipment factors as primary or secondary causes of spills, but without clearly distinguishing active failures from latent system conditions. Additionally, it was difficult to capture within the investigation framework the multiple factors that often conspired to bring about a single adverse event. In May of 2001, MFD introduced its inspectors to the Human Factors Analysis and Classification System (HFACS; Wiegmann & Shappell, 1999) and has begun using that model to support inquiries and to analyze system failures that contribute to spills. The HFACS taxonomy was selected in part because it is particularly well-suited for prevention, in that it encourages a focus on failed system defenses, rather than on individual failures. This allows users of the resulting data to address the appropriate system components in devising prevention strategies.

8.2.3 Adaptations to HFACS

It was initially clear that MFD needed to extend the tool to cover certain structural and mechanical faults as well as environmental conditions in order to cover the spectrum of contributors to oil spills. Note that this is not a deficiency on the part of HFACS: HFACS was intended to guide the human factors portion of an investigation. Naturally, there will be equipment factors, weather factors, and other non-human factors that contribute to many casualties and incidents. It will be necessary for any company to develop its own set of classifications to capture these types of problems. However, MFD observed that most of the contributing factors to oil spills were, in fact, human factors, so they found it handy to use HFACS as their main classification tool and add the equipment and environmental factors to it.

Their complete investigation taxonomy is shown in Appendix E (see “HFACS Layer Guides”). Equipment factors were appended to the Layer 1 Guide (Unsafe Acts from HFACS) as “Structural/Mechanical Damage/Failure”. This is the equipment analog of an unsafe act, in that the damage or failure appears as the immediate cause of an incident (e.g., the oil spill appeared to be caused by a damaged valve). Similarly, equipment and environmental factors were added to the Preconditions layer (Layer 2). Just as “complacency” is an adverse mental state (precondition) that can lead to a routine violation (unsafe act) like taking a shortcut that causes an incident, substandard equipment design, such as an ambiguous display, can be the precondition for an unsafe act (misreading the display and causing an incident). In this way, MFD combined the major oil spill causal factors – both human and non-human – into a single, HFACS-like taxonomy.

Adaptations were made to the human factors taxonomy as well. HFACS was originally developed for aircraft accidents, and thus incorporates certain terminology and causal factors related to aviation (such as “hypoxia” and “spatial disorientation”). These terms were dropped. Maritime industry specific terms are captured using event data forms, which require an incident specific statement of the actor (an individual or group, or a structure/part) and a situation-specific description of the action/inaction or system failure that contributed to the incident. This remains an ongoing process.

8.2.4 Training and Job Aids

HFACS was introduced to MFD when their human factors analyst took a full-day workshop on the topic led by Drs. Wiegmann and Shappell. He then developed and provided training on HFACS to MFD's inspectors and specialists. Discussions among MFD staff occur during monthly meetings, and along with input from other maritime industry representatives, these meetings led to modifications in the taxonomy (discussed above) and to the development of job aids. The job aids used by MFD inspectors are provided in Appendix E.

New job aids and revisions of existing ones are considered regularly in response to issues that arise during monthly meetings. Situation-specific guidance sheets are presently under development to guide team members in collecting essential information in response to particular circumstances. Guidance is in a bulleted "If – then" form. For example,

If the incident involves *turning an incorrect valve*,

Then

- photograph the valve and its immediate area;
- ask about a history of such incidents;
- ask whether the involved personnel were experienced with the equipment;
- detail communications leading up to the action.

The intention of these sheets is to assure that relevant data are collected before they are lost.

8.2.5 Benefits of Human Factors Investigations

MFD is less than a year into using the revised HFACS investigation tool, and is still learning about the process and making changes to its procedures. However, an early analysis of six incidents shows that inspectors are learning to use the tool. Of the 21 causal factors identified, 20 could be completely categorized by the inquiry team – which included marine safety inspectors, specialists and a human factors analyst – using HFACS.

Not surprisingly, inquiry teams were more successful at identifying unsafe acts and preconditions than they were at finding problems in other latent factors like unsafe supervision and organizational influences. Team members felt that they had sufficiently considered and identified all relevant unsafe acts in five (of the six) incidents, and had identified all the preconditions in four of the incidents. However, teams judged that they had identified all the potential types of unsafe supervision in only three of the incidents, and had identified all the organizational factors in only one incident.

There are five issues that may contribute to the difficulty of identifying latent factors. The first is that it can take substantial time and resources (on the parts of both the investigator and those being investigated) to dig beneath the surface and unearth latent factors. Sufficient time is not always available. Second, when a regulatory body (such as MFD) or an employer is also the investigator, the fear of punishment can be a disincentive for those under investigation to fully cooperate and help identify latent factors. Third, necessary information may be unavailable, either because it is confidential (e.g., personnel records) or unrecoverable (e.g., a momentary state of mind, an absent maintenance record). Fourth, organizational influences in particular sometimes only become apparent over the course of several incidents rather than in a single one. Team members have addressed this through incorporating a structured note rather than assigning a contributing factor when they have reason to believe – but not definitive evidence – that an organizational factor is among weakened defenses in a particular case. Finally, those conducting the inquiry may lack the know-how or experience to ask the appropriate questions. This can occur for those with considerable maritime knowledge as well as those with human factors knowledge, since for any one investigator that knowledge is likely to be centered around particular areas (ship, terminal, company operations, or management), and their ability to establish a comfortable rapport with key individuals related to the incident will vary accordingly.

While there are too few cases yet to allow for meaningful analysis, there have already been "lessons learned" that can help commercial companies improve safety. MFD is starting a newsletter as a way of sharing this information with the marine terminal companies. Another benefit from these initial uses of HFACS has been the discovery of an area in which MFD can improve its reviews of preventative maintenance programs. Additionally, notes have been expanded to capture instances when "outside influences" – factors other than terminal and vessel organizations – contribute to incidents. In summary, MFD's human factors incident investigation program has gotten off to a good start and shows promise in discovering how marine terminals can change their policies and operations to improve safety and reduce oil spills.

8.3 Stolt-Nielsen Transportation Group

8.3.1 Background

Stolt-Nielsen S.A. is one of the world's leading providers of transportation services for bulk liquid chemicals, edible oils, acids, and other specialty liquids. The company, through its parcel tanker, tank container, terminal, rail and barge services, provides integrated transportation for its customers. Stolt-Nielsen Transportation Group owns 72 ships involved in the chemical parcel trade: 51 ships in world-wide trade and 21 ships in coastal trade in Europe and the Far East.

Stolt-Nielsen has developed a full International Ship Management (ISM) Quality and Safety Program for its ships. This program is to the highest standards of the industry and is audited by three classification societies. The safety program tracks and investigates all incidents and uses statistical process control methods to identify trends. In turn, this information is used to develop training and educational programs designed to reduce risks and losses. As an industry leader, Stolt-Nielsen also shares its data and benchmarks with other companies through groups such as the National Safety Council[16].

8.3.2 Human Factors Incident Investigation

Stolt-Nielsen has been doing incident investigation for a number of years. Since it already had an ongoing training and Quality Assurance program, the incident investigation program was added under the same umbrella at minimal cost to the company. In 1992, a human factors investigation taxonomy was added. Stolt's investigation form (see App. F), while simpler than those used by MAIB and MFD, has nevertheless proven to help the company detect and correct a variety of safety hazards.

Incident investigation is a combined responsibility of ships' officers and of Stolt's Division of Marine and Safety Services. Officers are trained on incident investigation, and other Quality Assurance topics, every three years. Because Stolt's officers and crew are from around the world, training is an expensive undertaking. All incident forms are sent to the Assistant Manager of Marine and Safety Services, who completes the investigation. By having a single person ultimately responsible for the incident data helps to keep the data reliable (consistent use of terms and coding). The major problem with investigating incidents is that the fleet is distributed worldwide, making timely and accurate reporting a challenge. However, persistence on the part of the investigator and a shared understanding of the importance of the incident program has led to a successful program.

The Assistant Manager is also responsible for the data analysis, which is a "plus", since the analyst knows the terminology and understands the constraints under which the data were collected, which in turn reduces the likelihood that unwarranted data comparisons will be made. Stolt analyzes their incident data quarterly, looking both for trends within the company and benchmarking their incident rates against those of other shippers that are members of the National Safety Council. "Lessons learned" from incident analyses are disseminated widely through the company via Loss Control Bulletins and training programs.

8.3.3 Benefits of the Incident Database

Stolt enjoys a lower incident rate than the industry average (Fig. 21), due in large part to its attentive tracking of incidents and responsive safety interventions. Stolt uses frequency analysis and analyzes trends over years to identify safety problems and track the success of its interventions. As described in the Analysis section, Stolt had used incidents to determine that crew members suffered a high frequency of slips, trips, and falls. In response, the company acquired new safety shoes designed for better traction on wet surfaces. Follow-up statistics

[16] The Waterborne Transport Division of the National Safety Council currently keeps safety data that members can use for benchmarking. There are plans to produce guidance and training to help members improve their safety analysis and benchmarking capabilities. For more information, please see their website at http://www.waterbornetransport.com or contact William Boehm by phone at (281) 860-5043 or by email at wboehm@stolt.com .

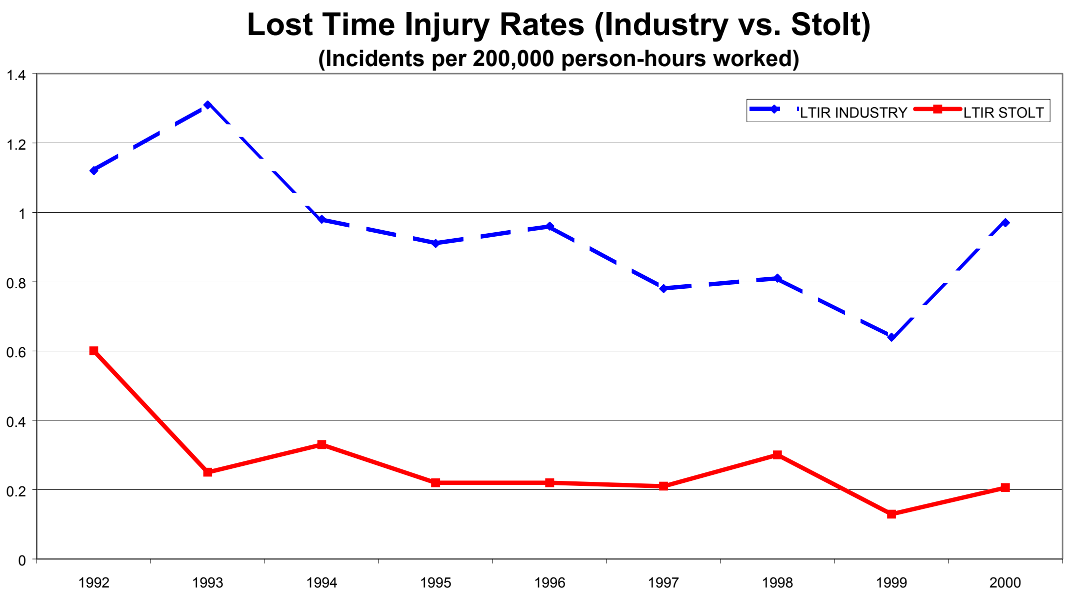

Figure 21. Comparison of Lost Time Injury Rates between Stolt and an Industry Average from 1992 through 2000
This is an example of how Stolt uses incident data to benchmark its safety relative to other companies. (Data courtesy of Stolt-Nielsen Transportation Group.)

revealed a marked decrease in slips, trips, and falls, which appear to show the success of the intervention.

Another use of incident data is shown in Figure 22, which depicts a comparison of the frequencies of various types of injuries (data for the first three quarters of 2001). As can be seen in the graph, injuries to the head and eyes happened most frequently, and these findings were supported by data from prior years. Thus, Stolt has reviewed the types of safety glasses and hardhats used by crew members and have identified problems with the current safety equipment. An alternate type of safety glasses is now being tried which hopefully will provide better protection. Regarding hardhats, one of the problems discovered was that current hardhats were uncomfortable, and crew members did not wear them consistently. A new type of head protection – a ball cap with a "butcher's hard cap" inserted inside – is being trialed as a result.

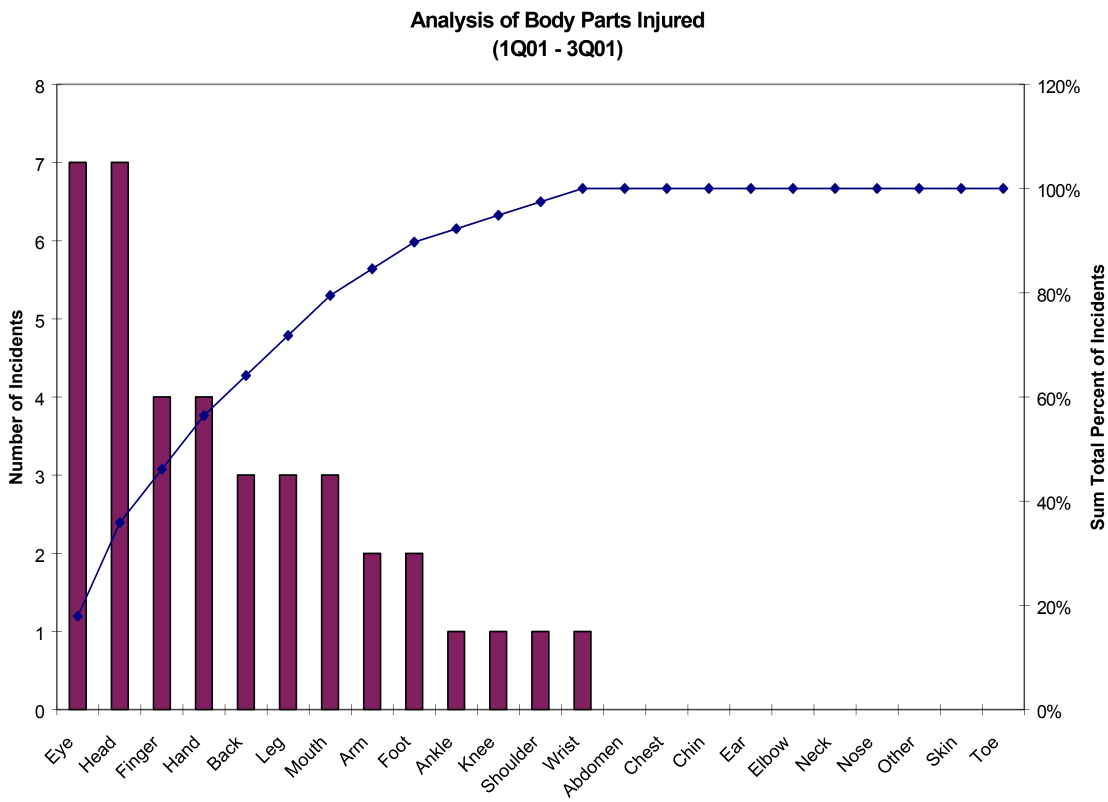

Figure 22. Number of Incidents as a Function of Body Part Injured. (Data from first three quarters of 2001; courtesy of Stolt-Nielsen Transportation Group.) This shows how Stolt uses incident data to identify safety hazards.

Stolt regards its incident investigation program to be a resounding success. By using incident investigation as a part of its overall Quality Assurance program, Stolt has been able to identify and correct safety problems, many of which have human factors causes. Through a consistent focus on incident causes and efforts to remediate those causes, Stolt has achieved lower injury, accident, and pollution rates than the industry average. The company is justifiably proud of its safety record.

9.0 SUMMARY

As we have seen, human error (and usually multiple errors made by multiple people and at multiple levels of the organization) contributes to the vast majority (over 80%) of marine casualties and offshore incidents, making the prevention of human error of paramount importance if we wish to reduce the number and severity of maritime and offshore incidents. Many types of human errors were described, the majority of which were shown not to be the "fault" of the human operator. Rather, most of these errors tend to occur as a result of technologies, work environments, and organizational factors which do not sufficiently consider the abilities and limitations of the people who must interact with them, thus "setting up" the human operator for failure.

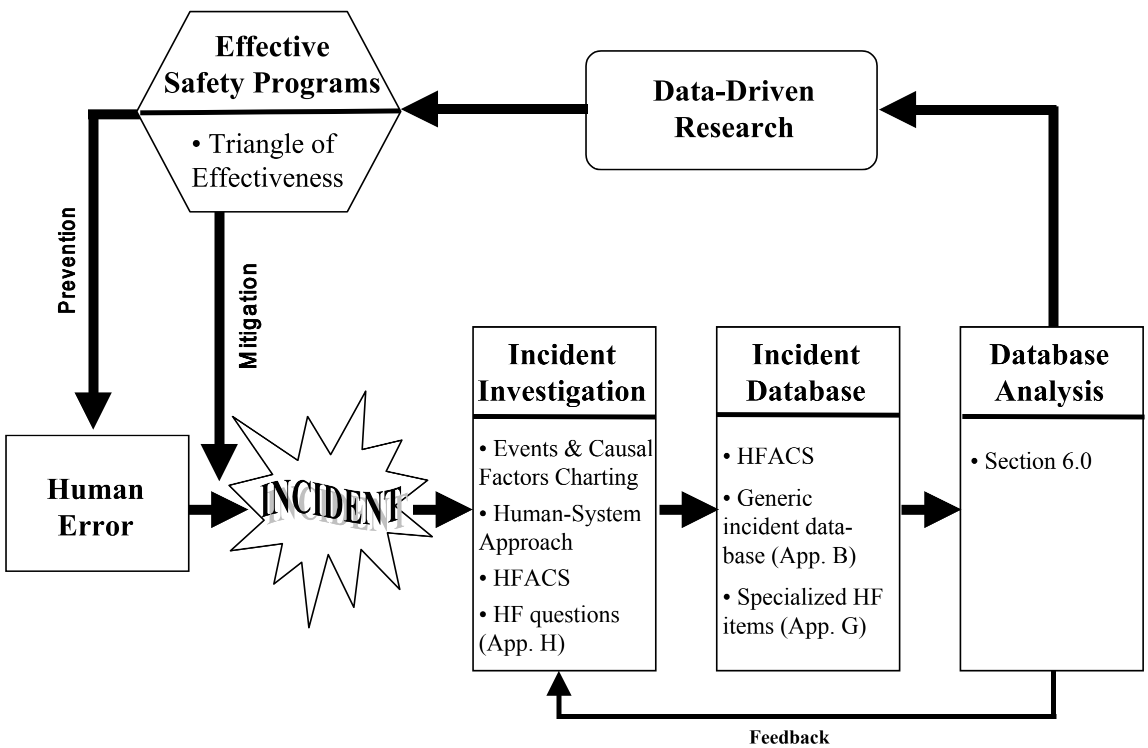

Figure 23. Tools for an Effective Incident Investigation Program

Incident investigation that includes an analysis of human error is needed if we are to prevent these incidents in the future. This paper has presented several different tools that can be used to perform a human factors incident investigation and to use the resulting data to improve the company's safety program (Fig. 23). Appendix H presents a selection of human-related questions that can be asked to identify potential human error issues. The human-system approach helps the investigator consider suboptimal interfaces and interactions between people, technology, organization, and environment that may have contributed to the incident.

Reason (1990) created a useful framework for categorizing the types of human error. His "Swiss cheese" model considers not just the unsafe acts of the operator, but also considers several layers of system defenses that may need mending if the safety program is to be effective: preconditions for unsafe acts, unsafe supervision, and organizational factors. Reason's model has been captured in the Human Factors Analysis and Classification System (HFACS; Shappell & Wiegmann, 1997a, 2000; Wiegmann & Shappell, 1999), an incident investigation system which has been used widely and successfully in military and industrial incident investigation. HFACS was presented in this document because it is relatively easy to learn and use, and because it has a history of enabling successful safety programs. HFACS can be used by the offshore and maritime industries to supplement existing incident data systems with human factors information. For companies that have not yet begun an incident investigation program, additional classification schemes, both for specific human-related errors (fatigue, communications, and skills and knowledge) and for non-human incident data (e.g., vessel or platform type, activities/operations during which the incident occurred, environmental and weather conditions that may have played a role) are provided in the Appendices. Event and Causal Factors Charting was introduced as an additional tool to aid in understanding the events that led to an incident and the causal factors that underlie those events. Used together, Event and Causal Factors Charting followed by an HFACS analysis of the causes can provide a powerful way to represent the development of an incident and to identify the system failures that generated and perpetuated the incident.

It cannot be overemphasized that a good incident database is only the starting point for a successful incident prevention program. An open, fair, improvement-seeking culture, a common understanding of the purpose and scope of the incident investigation program, appropriate training for incident investigators, a simple, user-friendly database, and feedback on the results of the incident investigation program are all essential elements to the collection of valid and complete incident data. In addition, regular analysis of the incident data is required to identify potential problems and to evaluate the results of new safety programs. Several data analysis techniques were summarized that can help companies make the most of their incident data. As was pointed out, one cannot do data analysis blindly – one must consider changes in policies and procedures that may have had an effect on the way data were collected and classified. Thoughtful analysis will help to distinguish spurious results from real trends that may require intervention. Follow-up studies ("data-driven research") are usually needed to thoroughly understand a given safety issue and determine what types of interventions may be needed.

Finally, we considered how to select interventions based on the types of system defenses that have failed. By linking Reason's "Swiss cheese" with Miller's "triangle of effectiveness", we have a tool for finding the most effective ways to solve safety problems. While traditional safety management seems to focus on reprimanding, cajoling, and "more training", the triangle of effectiveness shows that these are the least effective ways for reducing incidents. A safety culture must start at the top, and so, too, must the most effective interventions. Management participation, human-centered workplace design, and human-compatible environmental control may require more up-front effort than “yet another training course”, but because these elements are integral to the safe design and operation of the workplace, they will reap much larger safety benefits. The safety-conscious organization “starts at the top” when developing safety interventions to protect its employees, products, and the environment.

Human errors *can* be reduced significantly. Other industries have made tremendous progress in controlling human error through careful documentation of incidents, analysis of incident data, follow-up studies, and top-down, human-centered interventions. Indeed, maritime/offshore industries can do the same: the U.K.’s Marine Accident Investigation Branch, California’s Marine Facilities Division, and Stolt-Nielsen Transportation Group have all shown that the maritime/offshore sector can put human factors incident investigation to effective and profitable use. By using human factors incident investigation to identify weaknesses in our system defenses, and by crafting safety interventions through the human-centered design of technologies, work environments, and organizations, we can support the human operator and foster improved performance and fewer incidents.

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APPENDIX A. SAMPLE INCIDENT REPORTING FORM[17]

The first step in learning from incidents is to find out that they happened! This appendix presents a form that can be used by workers to report incidents and near-misses. If your company's incident database is to contain information from both investigated (i.e., someone acts on the information in the reporting form and opens an investigation of the incident) and non-investigated (i.e., the reporting form is the only source of information) incidents, it becomes important to be able to judge the "goodness" or validity and completeness of the incident data. You may want to add a field to your database to show whether the incident was investigated or not (or the degree to which it was investigated). Another example of rating the completeness of the incident data is shown in App. E at the bottom of the HFACS Event Data Form. All these incidents are investigated, and the investigators mark whether they believe they were able to do a full investigation.

The reporting form in this appendix was developed for the anonymous reporting of near-misses. As such, it requests information about both the incident and the person reporting the incident. Information about the reporter is requested in order to infer the likelihood that the reporter has experience in the incident context (that is, is the reporter likely to know what correct procedures should have been, and would he/she understand the ramifications of the steps that led to the incident). Question 6 seeks to aid the assessment of the reliability of the reported information by finding out whether the person who reported it was actually involved in the incident first-hand. In this way, one can attempt to weigh the potential value of the information in the incident report.

[17] based on a prototype of the International Maritime Information Safety System (IMISS; see Rothblum, Chaderjian, & Mercier, 2000).

Incident Reporting Form

Tell us about yourself

1. In what maritime sector are you involved?
- ❑ deep draft
- ❑ inland
- ❑ off-shore
- ❑ terminal
- ❑ recreational
- ❑ other ______________________________

2. What is your specific job? (*e.g., Ordinary Seaman, 2nd Asst. Engineer, drilling supervisor, dock worker, USCG XO)*

3. Type of vessel / facility / structure where you typically work? *(e.g., crude oil tanker, tension leg platform, liquid bulk terminal)*

Incident / Potential Hazard

4. Type of incident or hazard (e.g., near-collision, near-injury; buoy off-station, dangerous work practice)

5. When did the incident / hazard occur?

Date: ____/____/____
mm / dd / yy

Time: _________ am/pm

- ❑ dawn
- ❑ daylight
- ❑ dusk
- ❑ night

6. How were you involved in the incident (or discovering the hazard)?
- ❑ directly involved – I was an active participant.
- ❑ indirectly involved – I was at the scene, and saw/heard everything that happened.
- ❑ observed from a distance – I did not see/hear everything.
- ❑ not involved – I heard about this from someone else.
- ❑ other *(describe):*

7. Type of vessels, platforms, structures, or facilities involved *(e.g., lineboat, trawler, shipyard, jack-up rig)*:

8. Describe the visibility, weather, and water conditions.
(e.g., overcast, light rain, no wind, river stage 8 ft. and rising)

9. Where did it happen? *(specify the waterway, port, location on ship, etc.)*:

10. What specific operation(s) was occurring at the time of the incident or hazard? *(e.g., normal bridge/pilothouse watch, normal engineroom watch, cargo transfer operation, ballasting, making tow, fishing)*

11. Describe what happened. What were the events which led up to the problem? How was the problem discovered? What happened next? *(be as specific as possible, and put events in the order in which they happened)* For a potential hazard, describe the situation and what *could have happened.*

12. What do you think caused the incident or contributed to the events surrounding the incident? *(Consider: decisions; actions; inactions; information overload; communication; fatigue; drugs or alcohol; physical or mental condition; procedures; policies; design of equipment / ship / facility / waterway; crew / workers (experience, manning); weather; visibility; equipment failure (why did it fail?); maintenance.)*

13. What went right? How was an accident avoided? *(Consider: corrective actions; contingency plans; emergency procedures; luck.)*

14. How can we prevent similar incidents (correct the hazard)? What changes need to be made? By whom? This block is also for describing Lessons Learned, Safety Tips, and Suggestions.

APPENDIX B. DATABASE ITEMS ON GENERAL INCIDENT INFORMATION[18]

(to be collected *in addition to* the human error data)

Time, Location, and General Conditions

Date: ___/___/___.
mm / dd / yy

Month and Year: ___/___.
mm / yy

Day of Week: Su Mo Tu We Th Fr Sa

Local Time: ______ (24-hr clock)

Location of vessel/platform/facility
- Port/Harbor
- Terminal
- Pier
- At Anchor
- Restricted waters (marked channel, bay, etc.
- Ocean (≥ 12 nm)
- Coastal (< 12nm)
- Inland waters
- River
- Great Lakes
- Lake
- Bay / Sound / Strait
- Offshore Platform in State Waters (<3nm)
- Offshore Platform in Federal Waters (>3nm)
- Other ______________________________

Specific Location
- Lat: _____
- Long: ______
- Type of Aid to Navigation: _____
- Waterbody / Waterway name: __________________________
- Port / Harbor name: ____________________________
- Water depth _______ ft.
- Mile Marker_________

[18] based on a prototype of the International Maritime Information Safety System (IMISS; see Rothblum, Chaderjian, & Mercier, 2000).

Light
- Dawn (morning twilight)
- Daylight
- Dusk (evening twilight)
- Night

Visibility
- Visibility: ______ nm
- Clear
- Cloud cover
- Fog
- Other

Weather

Calm	Thunderstorm
Rain	Sleet
Snow	Hurricane
Hail	Tornado
Waterspout	
Other ________________________	

Water Conditions

Salinity (fresh/salt) _________
- river stage ____ ft. Rising OR Falling
- Flood stage ____ Above gauge level ___ At gauge level _____
- Below gauge level ____ Low gauge level ____

Swells:_______ ft. OR sea state _____
Wave height _______ ft; Wave period_________ sec; Wave Direction ______degrees
Current velocity: _________
Current direction__________
Ebb/Flood
Tide: Rising/ Falling Hours since high/low water_______
Obstructed/Floating debris: Describe___________________________
Other ________________________

Wind: direction: _____ speed: ____ kts.

Number of vessels involved _____

Number of facilities/platforms involved ______

Number of people involved _____

Vessel activity, Vessel #1 (check all that apply)

Vessel not underway
Docked
At anchor
Moored

Vessel in port
Docking/undocking
Mooring/Releasing Lines
Maneuvering
Shifting dock-to-dock
Embark/disembark pilot
Embark/disem. Passengers
Transfer oil/chemicals
Transfer containers
Transfer bulk cargo
Transfer break bulk
Bunkering
Tug escort
Break Bulk Cargo
Other cargo activity _____
Other port activity ______

Transiting

Channel inbound
Channel outbound

Port inbound
Port outbound
Open waters transit
Great Lakes transit
Meeting

Passing/Overtaking
Crossing
Overtaking
Tug escort
Other transit _________

Fishing
Fishing
Trolling
Trawling
Longlining
Dive
Siening
Dragging
Hauling Gear
Setting Gear
Setting pots/traps
Fish processing
Other fishing __________

Towing
Towing/pushing/hip
Locking
River upbound
River downbound
Make/break tow
Other towing _________

Other Commercial Activity
Production (platform)

Logging
Drilling Crew shift

Tank cleaning
Ballasting/deballasting
Lightering
Bunkering/Fueling

Transfer-related
Cargo Transfer at Anchor
Diving
Touring
Launch Service
Other commercial _______

USCG / Military
CG – patrolling
CG – boarding
CG – interdiction
CG – transit
CG – towing
CG - setting buoys
CG - ice breaking
CG – assist
CG - helo ops
UNREP Ops
Other CG ops _________
Other military ops _______

Test & Repair
Testing main engines
Shut-down Engines/Cargo
Equipment testing
Deck Machinery
Electronics
Maintenance
Repairs
Safety Equipment Test

Engine Dept Equipment Test
Deck Equipment Test
Cargo Monitor Equipment Test

Other Vessel Activities
Recreational boating
Evacuation
Prep for extreme event (e.g., hurricane)
Other _______________

Vessel Activity, Vessels #2 and #3 (repeat above)

Facility Activity (check all that apply)

Maintenance	Rail Operations	VTS operations
Equipment testing	Truck Operations in Yard	Bridge opening/closing
Dry docking	Training Workers	Lock operations
Dock loading/unloading	Oil Transfer	Other activity ________
Dock crane operations	Dry Bulk Transfer	
Loading Containers	Break Bulk Transfer	
Staging Containers	Chemical Transfer	

Incident/Hazard Event (check all that apply)

Vessel/platform event

Abandonment	Evasive maneuver	Loss of electrical power
Allision	Explosion	Loss of maneuverability
Blowout	Fire	Loss of stability
Capsize	Flooding	Material failure
Collision	Fouling	Material failure, diving
Damage to cargo	Grounding	Set adrift
Damage to environment	Implosion	Sinking
Emergency response		Other ________________

Personnel event

Amputation	Drowning	Sprain/strain
Asphyxiation	Electrocution	Struck by object
Broken bone	Fall into water	Other ________________
Burn	Paralysis	
Crush	Severe bleeding	
Cut	Slip/trip/fall	

Type of Vessel: Vessel # 1 (check one)

Tank Vessel
Petroleum
LNG tanker
Chemical
Other tanker ___________

Freight Vessel
Breakbulk
Bulk, Ore
Bulk, Grain
Bulk, Other ___________
Container ship

Tow and Barge
Towing vessel
Tow and barge combo
Barge w/o towboat
Tank barge _________
Freight barge ________
Other barge _________
Tug escort
Composite Unit

Passenger
Passenger, small
Passenger, large
Ferry
Casino boat
Cruise ship

Other Vessels/Platforms
Fishing vessel
Fish processor
Offshore supply vessel
Platform/rig
Workboat (platform)
MODU
OBO
Heavy lift
Dredge
Pilot boat
Other commercial _______
HSC [High speed craft]
Hydrographic survey
Emergency Response

USCG / Military
CG cutter
CG small boat
CG ice breaker
CG buoy tender
CG other _____________
Other military ___________

Recreational
Jet Ski
Sail boat
Powerboat
Other recreational boat ___

(repeat above for vessels #2 and #3)

Type of Facility: Facility # 1 (check one)

Cargo Facilities
Port / pier / dock
Container terminal
Liquid Bulk terminal
Solid Bulk with self loading systems
Bulk cargo facility
Break bulk cargo facility

Oil/chemical facility
Container facility
Other cargo facility _______

Moorings
Single point moorings
Multi buoy moorings
Offshore moorings

Platforms / Drilling
Offshore, Fixed platform
Jack-up rig
Mobile Oil Production Units
Compliant Tower
Tension Leg Platform
Other deep water production/drilling facilities
Lifeboat

Other Facilities
Designated waterfront facility
Shipyard / Dry dock
Marina
VTS
Waterfront Facility

(repeat above for Facility # 2)

Person # 1 (check one)

Crew on Deep Draft Ship
Master

Chief mate

1 Mate
2 Mate
3 Mate
4 Mate
AB
OS
Boatswain
Other Deck ____________
Chief Engineer
1 Asst. Eng.
2 Asst. Eng.
3 Asst. Eng.
QMED/Oiler/Wiper
Maintenance Dept.
Other Eng. ____________

Chief Steward
Steward
Chief Cook
Cook
Purser
Waiter
Other Deep Draft _______
Cadet
Trainee
Pumpman
Entertainer

Crew on Towing Vessel
Captain/Pilot (towing)
1st Class operator
Mate (towing)
2nd Class Operator
Deckhand
Engineer
Cook
Other towing __________

Port / Dock Workers
Dock/Harbor Master
Port Engineer
Port Captain
Port Pilot
Port Safety Rep.
Mooring Master
Line Handlers
Hose Crew (Hook up)
Hose Watch

Terminal Person in Charge
Longshoreman
Dock Worker
Gaugers
Pilot
Docking Pilot
Other Port _____________

Shipyard / Inspections
Shipyard worker
Ship chandler
Government Inspector
Class society inspector
Insurer
Surveyor
Other ____________

Crew on USCG/Military
CG Command (CO,XO,EO)

CG bridge crew

CG engineering
CG other ____________
Other military _________

Waterway Personnel
Lock Master
Bridge Tender
VTS
Federal Pilot
State Pilot
Other Waterway ________

Platform / Rig Crew
Operations supervisor
Logging personnel/contractor
Drilling supervisor/engineer
Platform foreman
Platform crew
Drilling supervisor/engineer
Drill rig personnel
Other _____________

Other Personnel
Vendor
Agent
Visitor
Passenger
Recreational boater
Ship Chandler
Other _______________

Person #1's Activity at Time of Incident (check as many as apply)

On-board Activity
Watch / work / OT
Off duty

Navigation watch
Engineering watch
Eng. Maintenance/repair
Deck maintenance
Handling lines
Make/break tow
Load/discharge cargo
Load/discharge passengers
Meal prep./serve
Other on-board ________

Facility Crew Activity
Describe __________

Platform Crew Activity
Drilling operations
Normal production operations
Crane operations
Maintenance
Testing
Evacuation
Off duty
Other platform _________

Shipyard Crew Activity

Dry dock
Ship repair
Logging
Other shipyard _________

Military Crew Activity
Watch / work
Off duty

Collateral duty
Navigation watch
Engineering watch
Maintenance
CG boarding team

CG helo ops
CG setting ATONs

CG launching small boat
CG other ____________
Other military _________

Other _____________

Person #1's Impairments (check as many as apply to incident)

Fatigue
Suspected alcohol intoxication
Suspected drug intoxication
Rx/OTC medications
Illness
High stress
Chronic health condition: __________________
Psychological condition: __________________
Other ____________________

Hearing impairment
Vision impairment
Impaired mobility
Speech impediment
Poor or no English

(repeat Person, Activity, and Impairments for Persons # 2, 3, and 4)

Equipment Factors (check as many as apply to the incident)

Vessel Equipment which failed:
Steering gear
Engine
Generator
Reefers
Radar/ARPA
Electronic chart
Communications system
Other bridge equipment
Winch
Lines
Crane

Electrical
Piping
Door/hatch
Sanitation
Anchor/chain

Vent system
Pump
Valves
Remote control/monitoring systems
Other vsl equip___________

Platform Equipment which failed:
Drill rig
Drill equipment (tanks)
Pipelines & valves
Crane
Compressors
Safe shut-down equipment
Gas handling units
Hoses
Separators
Fire detection/control
Command & Control equipment
O-ring/gasket
Other platform _________

Safety & Personal Protection Gear
Firefighting equipment
Fire suppression equipment
Life jackets/preservers
Life boats
Cold water immersion suits
Hearing protection
Eye protection
Head protection
Chemical protection gear
Respirators
Other safety ____________

Problem:

Inoperable
Operated incorrectly

Cause:
Lack of maintenance
Improper maintenance
Design/manufacture error
Improper use
Operator error
Inadequate training
Other __________________

Location of equipment
Bridge
Engine room
Deck

Tanks
Other _______________

Waterway Factors (check all that apply)

high/low river stage
strong current
buoy off-station
nav aid not working
poorly marked waterway
bridge not marked
Last Chart Survey of Area
Where charts corrected for latest survey (ship on dock)
Additional permitted activities
Debris in water

dangerous crossing
dangerous traffic scheme
channel width/depth not as charted
Narrow channel
dangerous sandbars/shoals
dangerous port design/layout

Nav aid not available such as DGPS off air

Severe weather/waves
Other:___________

APPENDIX C. EXAMPLES OF HUMAN FACTORS TAXONOMIES
(in alphabetical order by system name)

Incident/Accident System	Agency	Reference
Aviation Safety Reporting System (ASRS)	run by NASA for the FAA; used by commercial aviation (flight crews, ground crews, and air traffic control)	Reynard W.D., Billings C.E., Cheaney E.S., & Hardy R. (1986). *The Development of the NASA Aviation Safety Reporting System.* NASA Reference Publication 1-1-14. National Aeronautics and Space Administration.
Confidential Hazardous Incident Reporting Programme (CHIRP)	Concerted Action Committee on Casualty Analysis (European Commission)	Concerted Action Committee on Casualty Analysis (1998). *Confidential Hazardous Incident Reporting Programme.* FP4 Waterborne Transport Tasks 21 and 36. (draft)
Human Error Root Cause Analysis (HERCA)	U.S. Dept. of Energy	Collopy M.T. & Waters R.M.
Human Factors Analysis and Classification System (HFACS)	US Navy and Marine aviation	Shappell S.A. & Wiegmann D.A. (1997) A human error approach to accident investigation: The taxonomy of unsafe operations. *International J. Aviation Psychology, 7*(4), 269-291.
Human Factors Checklist, and others based on the SHEL-GEMS models	International Civil Aviation Organization (ICAO); Transportation Safety Board (TSB) of Canada; US Coast Guard; International Maritime Organization (IMO)	ICAO (1993). *Investigation of Human Factors in Accidents and Incidents.* Human Factors Digest No. 7, ICAO Circular 240-AN/144. Montreal, Canada: Author. TSB of Canada (1988). *An Integrated Process for Investigating Human Factors.* Montreal: Author. International Maritime Organization (1998). *Role of the Human Element in Maritime Casualties.* Maritime Safety Committee, 69^{th} Session, Agenda Item 13 (MSC/69/13-1). London: Author.

Human Factors Investigation Tool (HFIT)	prototype in testing	Gordon R., Flin R. & Mearns K. (2001). Designing a Human Factors Investigation Tool to Improve the Quality of Safety Reporting. *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting*, 1519-1523.
Human Performance Investigation Process (HPIP); TapRooT (a commercial revision of HPIP)	Nuclear Regulatory Commission and various industries	Paradies M., Unger L., Haas P., & Terranova M. (1993) *Development of the NRC's Human Performance Investigation Process, Vol. 1-3.* Report # NUREG/CR-5455. Washington, DC: Nuclear Regulatory Commission. Paradies M., Unger L., & Busch D. (199x). *Root Cause Tree User's Manual,* Revision 3.
Influence Networks	UK Maritime and Coastguard Agency (MCA); UK Health and Safety Executive (HSE); International Maritime Organization (IMO)	Embrey, D (1992) Incorporating Management and Organisational Factors into Probalistic Safety Assessment. *Reliability Engineering, 38*, 199-208. BOMEL Limited (2001) *FSA of Bulk Carriers – Develop-ment and Quantification of Influence Networks* (undertaken for MCA, UK).
International Maritime Information Safety System (IMISS)	prototype system developed by a SNAME working group, sponsored by US Coast Guard and US Maritime Administration	Rothblum A., Chaderjian M., and Mercier K. (2000). Development and Evaluation of the International Maritime Information Safety System (IMISS). Presented at the Society of Naval Architects and Marine Engineers, IMISS Public Meeting, May 2000.
Marine Safety Reporting System (MSRS)	Human Factors Group	Safe Marine Transportation (SMART) Forum of Puget Sound, 1997. *Marine Reporting: The Development of a Northwest Marine Safety Reporting System.* Seattle, WA: Author. (see App. D)

APPENDIX D. HUMAN FACTORS TAXONOMY USED BY THE U.K. MARINE ACCIDENT INVESTIGATION BRANCH

External Bodies Liaison	Non compliance Communication Equipment design - manufacturer Training, skills, knowledge Working environment/workplace Incorrect installation/defective equipment
Company & Organisation	Company standing orders inadequate, insufficient, conflicting Manufacturer's instructions Communication Pressures - organisational Inadequate resources Training, skills, knowledge
Crew Factors	Communication Management and supervision inadequate Allocation of responsibility inappropriate Procedures inadequate Manning (rotation/watches) Training Discipline - crew/passengers Unsafe working practices
Equipment	Equipment misuse Equipment not available as needed Equipment poorly designed for operational use Equipment badly maintained Personnel unfamiliar with equipment/not trained in use Automation means crew not trained in use of manual alternatives
Working Environment	Performance affected by noise Performance affected by vibration Performance affected by temperature Performance affected by humidity Performance affected by visual environment/visibility Performance affected by ship movement/weather effects Poor housekeeping Layout unsuitable for task Accommodation
Individual	Communication

Competence and skill
Training, inexperience, knowledge
Violation of procedures
Health: drugs/alcohol
Health: medical condition
Domestic issues
Fatigue and vigilance
Perceptual abilities
Poor decision making/information use
Perception of risk
Workload

Appendix E. Adaptation of HFACS by the California State Lands Commission, Marine Facilities Division

This appendix shows how the Marine Facilities Division (MFD) of the California State Lands Commission has adapted the Human Factors Analysis and Classification System (HFACS) to their specific needs. Below are the guides (job aids) provided to MFD inspectors for their use in investigating the human factors and other causes of oil spills. The job aids contained herein include:

- HFACS Terminology
- HFACS Layer Guides
- HFACS Event Data Form (filled out during a spill investigation)
- Event Data Form Instructions

Note that the term “Layer” refers to the “slice of cheese” being considered: Layer 1 equates to Unsafe Acts; Layer 2 to Preconditions; Layer 3 to Unsafe Supervision; and Layer 4 to Organizational Influences. The term “Tiers” is a short-hand notation for the levels of the taxonomy being considered. For example, Tier 1 is the Layer or top level classification (e.g., unsafe act). Tier 2 would be the next level of classification, such as an “Error” (unintentional) as the type of unsafe act. Tier 3 would be the bottom or most specific level of classification, such as “Skill-based” errors. “Pick-List” refers to the items or types of the Tier 3 factor, such as “omitted step in procedure” under Skill-Based Errors.

As discussed in the report, MFD adapted HFACS to its needs by incorporating non-HF items into the investigation paradigm. For example, in addition to Unsafe Acts under Layer 1, MFD included the category Structural/Mechanical Damage/Failure to help inspectors consider the equipment factors that contributed to the incident and how human factors caused or complemented the equipment factors in the evolving oil spill.

HFACS Terminology

Accident: An unintended event which results in personal injury, illness, property damage, or environmental impairment.

Near Miss: An unintended event which has the potential for causing personal injury, illness, property damage or environmental impairment.

Incident: An unintended event which results in or has the potential for causing personal injury, property damage, or environmental impairment.

Routine Violation (from Reason, 1990): Two factors, in particular appear to be important in shaping habitual violations: (a) the natural human tendency to take the path of least effort; and (b) a relatively indifferent environment (i.e., one that rarely punishes violations or rewards observance). Everyday observation shows that if the quickest and most convenient path between two task-related points involves transgressing an apparently trivial and rarely sanctioned safety procedure, then it will be violated routinely by the operators of the system. Such a principle suggests that routine violations could be minimized by designing systems with human beings in mind at the outset.

Error: a generic term to encompass all those occasions in which a planned sequence of activities fails to achieve its intended outcome, and when these failures and when these failures cannot be attributed to some chance agency.

Slip and lapse: errors which result from some failure in the execution and/or storage of an action sequence, regardless of whether or not the plan which guided them was adequate to achieve its objective. Slips are observable; lapses not.

Mistake: deficiencies or failures in the judgemental and/or inferential processes involved in the selection of an objective or in the specification of the means to achieve it, irrespective of whether or not the actions directed by this decision-scheme run according to plan.

LAYER 1 GUIDE: UNSAFE ACTS

Unsafe Acts

Errors Skill-based	Perceptual	Decision
failed to prioritize attention	misjudged distance/rate/time	improper procedure or maneuver
inadvertent use of controls	misread dial or indicator	misdiagnosed emergency
omitted step in procedure, or executed step out-of-sequence.	failed to see/hear/otherwise sense	wrong response to emergency
omitted checklist item or completed check list item out-of sequence.		poor decision

Violations Routine	Exceptional
(Fill in) Definition: Common or habitual instance of breaking the rules and regulations (taking a shortcut) that is part of a person's behavior pattern and is often tolerated by the organization	*(Fill in)* Definition: Isolated departure from authority, rules and regulations (taking a shortcut) that is typically not condoned by management

Structural/Mechanical Damage/Failure

Vessel Control System	Vessel Structural	Terminal Control System	Terminal Structural
	containment		containment
	flange/gasket		flange/gasket
	hose		hose
	inert gas system		loading arm
	loading arm		pipeline
	pipeline		pump
	piping		shell plating
	pump		valve
	shell plating		
	stern tube		
	valve		

LAYER 2 GUIDE: PRECONDITIONS FOR ADVERSE EVENTS

Preconditions For Adverse Events		
Substandard Conditions of Operators		
Adverse Mental States	**Adverse Physiological States**	**Physical/Mental Limitations**
channelized attention	impaired physiological state	insufficient reaction time
complacency	medical illness	poor vision/hearing
distraction	physiological incapacitation	lack of knowledge
mental fatigue	physical fatigue	incompatible physical capability
haste		
loss of situational awareness		
misplaced motivation		
task saturation		

Substandard Practices of Operators	
Crew Resource Mgt.	**Personal Readiness**
impaired communications due to language difference	self-medicated
interpersonal conflict among crew	inadequate rest
failed to use all available resources	
failure of leadership	
misinterpretation of traffic calls	
failed to conduct adequate brief	
impaired communication/conflict due to cultural difference	

Substandard Work Interface				
Substandard Design		**Substandard Maintenance**		**Adverse Environmental Conditions**
design inadequate for use	**design inadequate for maintenance**			low visibility
ambiguous instrumentation		poorly maintained equipment		storm
inadequate layout or space		poorly maintained workspace		extreme temperature
substandard illumination		poorly maintained communications equipment		extreme sea state
substandard communications equipment				
equipment substandard for job				

LAYER 3 GUIDE: UNSAFE SUPERVISION

Unsafe Supervision

Inadequate Supervision	Planned Inappropriate Operations	Failed to Correct a Known Problem	Supervisory Violations
failed to provide guidance	failed to provide correct data	failed to correct document in error	authorized an unnecessary hazard
failed to provide operational doctrine	failed to provide adequate brief time	failed to identify an at-risk behavior	failed to enforce rules and regulations
failed to provide oversight	improper manning	failed to initiate corrective action	authorized unqualified crew
failed to provide training	adequacy of operational procedure or plan	failed to report unsafe tendencies	
failed to track qualifications	provided inadequate opportunity for crew rest		
failed to track performance			

LAYER 4 GUIDE: ORGANIZATIONAL INFLUENCES

Organizational Influences

Resource Management	Organizational Climate	Organizational Process
inadequate management of human resources	adequacy of organizational structure	adequacy of established conditions of work
inadequate management of monetary resources	adequacy of organizational policies	adequacy of established procedures
inadequate design and maintenance of facilities	adequacy of safety culture	adequacy of oversight

HFACS Event Data Form

Control #:	OES #:	Event Date:	Event Time:
Facility WO #:	Facility Name:		
Vessel Name:		Reviewed by: ____ ____ ____ ____	
Substance:			Quantity : gallons

Event Type

___ Spill
___ Class 3 Violation

Evolution

___ Ballasting/Deballasting
___ Bunkering
___ Fueling
___ Idle
___ Intra-Terminal
___ Intra-Vessel
___ Load/Discharge
___ Maintenance
___ Maneuvering
___ Term/Term
___ Testing
___ Other

Event

___ Arrival
___ Depart
___ Disconnect
___ Hook-up
___ Start-Up
___ Steady
___ Stripping
___ Topping off
___ N/A

Who/What	Incident Causal Factor	Tier 1	Tier 2	Tier 3	Pick-List

Transfer- Related: ___ Yes ___No | **Responsible Party**: ___ Vessel ___ Terminal ___ Other | **Layer Completeness 1: Y N 2: Y N 3: Y N 4: Y N**

Updated Substance: | Quantity: | Date:

Notes (Outside Influences; recommendations; contributors):

Event Data Form Instructions:

Top Sections

1. **Control #:** The control # uniquely identifies the database record for this event. This number gets assigned at the point of computer data entry. It can be left blank by the inspector/specialist/analyst completing the form.
2. **OES#:** This number is assigned by The Office of Emergency Services and can be found on the *Hazardous Materials Spill Report* associated with the spill event. For a class 3 violation, this section should be left blank.
3. **Event Date:** Enter the month, day and year of the spill or violation event in mm-dd-yyyy format.
4. **Event Time:** For spills, enter the time of day that the spill occurred. This time can usually be found on the *Hazardous Materials Spill Report*. For class 3 violations, enter the time of day the violation was noted.
5. **Facility WO #:** Enter the work order number associated with the facility where the event occurred.
6. **Facility Name:** Enter the name of the facility where the event occurred.
7. **Vessel Name:** Enter the name of the vessel, if any, involved in the event.
8. **Reviewed by:** Each staff member that produces or reviews the completed form should initial here. Each form should be produced by and reviewed by a specialist, inspector and human factors analyst at a minimum before it is ready for data entry.
9. **Substance:** Enter the product(s) involved. For a violation, enter the product involved only if the violation occurred during a transfer event.
10. **Quantity:** For a spill event, enter the amount of product spilled, in gallons. For a violation, this section should be left blank .

Left Sections

1. **Event Type:** Check the appropriate blank indicating whether the event is a spill or a class 3 violation.
2. **Evolution:** Check appropriate blank(s) indicating the type of operation that was in progress when the event occurred.
3. **Event:** If the event occurred during a transfer, note the phase of the transfer by checking the appropriate phase.

Center Grid Sections

1. **Who/What:** Indicate one of the following:
   - A *person* or *group of persons* associated with the incident causal factor identified identify in column two. Use job titles rather than names; For example, tankerman, dockworker, TPIC, VPIC, chief mate, operations manager, terminal manager, barge company, shipping company, etc.
   - A damaged or malfunctioning *facility structure* or piece of *equipment* associated with the incident causal factor identified in column two.
   - An *environmental condition* or event associated with the incident causal factor identified in column two.
2. **Incident Causal Factor:** a prevailing condition, act, or omission that contributes to bringing about an adverse event.

   Note: For each row in the grid, The "Who/What" (column 1) entry and the "Incident Causal Factor" (column 2) entry should combine to form a sentence.

   Refer to the document *Human Factors Analysis and Classification System – Marine Facilities: Definitions* for a description of each tier & classification in HFACS. You can also use the *HFACS Tier and Layer Chart* for a map of tiers and layers.
3. **Tier 1:** Enter the most general category for the who/what & incident causal factor listed.
4. **Tier 2:** Enter the subcategory for the who/what & incident causal factor listed.
5. **Tier 3:** Enter the subtype for the who/what & incident causal factor listed.
6. **Pick-List:** For subcategories and subtypes that have pick-list items listed in the *HFACS Layer Guides*, select a specific factor from the list that best describes the incident causal factor.

Bottom Sections

1. **Transfer-Related:** Check to indicate whether the spill or class 3 violation is transfer- related.
2. **Responsible Party:** For spills, check to indicate the party responsible for the release.
3. **Layer Completeness:** For each layer, circle yes if you believe all causal factors that contributed to the event were identified as a result of the inquiry. Circle no if you believe other causal factors could have been identified had you been able to get more information during the inquiry.
4. **Updated Substance:** If the product determined to be involved in the event changes over the course of the inquiry, note the change here.
5. **Quantity:** enter the final estimate of the amount of product spilled.
6. **Date:** Enter the date the HFACS EVENT DATA FORM is completed.
7. **Notes (Outside Influences; recommendations)**: If groups outside the terminal-vessel organizations contributed to the event, note it here. Examples of outside influences include government agencies, local public political pressure and economic pressures. Also, specific comments about the event, or recommendations that result from the inquiry should be added here.

APPENDIX F STOLT-NIELSEN ACCIDENT/INCIDENT INVESTIGATION

SHIP:	***DATE, TIME & PLACE OF INCIDENT: CONT***
LOCATION ONBOARD:	

LOSS DESCRIPTION: (check all applicable)

___ DAMAGE
- ***___ Property Damage***
- ***___ System/Equipment Damage***
- ***___ Cargo Loss/Damage/Contamination***
- ***___ Ship Damage***

___ POLLUTION
- ***___ Contained***
- ***___ Water Pollution***
- ***___ Air Pollution***
- ***___ Personnel Exposure***

___ GROUNDING

___ INJURY
- ***___ Death***
- ***___ Serious***
- ***___ Minor***

___ ADMINISTRATIVE
- ***___ Operational Delay***

___ Regulatory Violation
- ***___ Inspection Deficiency***

___ FIRE/EXPLOSION

___ COLLISION

___ PIRACY/THEFT

___OTHER (describe):____

LOSS SEVERITY: (check) **__ Major __ Serious __ Minor**	**PROBABILITY OF OCCURRENCE: (check)** **__ Frequent __ Occasional __ Seldom**

DESCRIPTION OF THE EVENT:

IMMEDIATE CAUSES: (What substandard actions and conditions caused or could cause the event?)

UNDERLYING CAUSES: (What specific personal or job factors caused or could cause the event?)

REMEDIAL ACTIONS/RECOMMENDED CHANGES: (To control the causes listed)

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Page 2:

RESPONSIBILITY (For remedial action/changes):

CODING OF IMMEDIATE CAUSES: (check all applicable)

SUBSTANDARD ACTIONS:

__ 1. Operating equipment without authority
__ 2. Failure to warn
__ 3. Failure to secure
__ 4. Operating at improper speed
__ 5. Making safety devices inoperable
__ 6. Removing safety devices
__ 7. Using defective equipment
__ 8. Using equipment improperly
__ 9. Failing to use proper personal protective equipment
__10. Improper loading
__11. Improper placement
__12. Improper lifting
__13. Improper position for task
__14. Servicing equipment in operation
__15. Horseplay
__16. Drugs/Alcohol
__17. Fatigue
__18. Procedural error

SUBSTANDARD CONDITIONS:

__ 1. Inadequate guards or barriers
__ 2. Inadequate or improper protective equipment
__ 3. Defective tools, equipment or materials
__ 4. Congestion or restricted action
__ 5. Inadequate warning systems
__ 6. Fire or explosion hazards
__ 7. Poor housekeeping; disorder
__ 8. Hazardous environmental conditions
__ 9. Noise exposure
__10. Radiation exposure
__11. High/low temperature exposure
__12. Inadequate or excess illumination
__13. Inadequate ventilation
__14. Installation failure
__15. Equipment failure
__16. System failure

CODING OF UNDERLYING CAUSE: (check all applicable)

PERSONAL FACTORS:

__ 1. Fatigue
__ 2. Inadequate capability
__ 3. Lack of knowledge
__ 4. Lack of skill
__ 5. Stress
__ 6. Improper motivation

JOB FACTORS:

__ 1. Inadequate Leadership/Supervision
__ 2. Inadequate Personnel
__ 3. Inadequate Engineering
__ 4. Inadequate Maintenance
__ 5. Inadequate Tools/Equipment
__ 6. Inadequate Work Standards
__ 7. Wear and Tear
__ 8. Abuse or Misuse

SUBMITTED BY (print name): _____________ **DATE OF REPORT:** ____________

SAFETY COORDINATOR SIGNATURE: ______________________________________

SHIPS CAPTAIN CONCURRENCE: __________________________________

FLEET MANAGERS APPROVAL: __________________________________

(Please provide any additional comments on additional sheets and attach.)

Appendix G. Sample Taxonomies for Investigating for Fatigue, Communications Problems, and Inadequate Skills and Knowledge

The U.S. Coast Guard Research and Development Center has performed three studies of the roles of specific human errors in marine casualties: fatigue, communications problems, and inadequate skills and knowledge. These studies focused on "critical" casualties, that is, casualties which resulted in significant damage to the vessel, cargo, or the environment, or which resulted in significant injury to personnel.

The first two pages (following this introduction) represent data that were found useful for determining whether or not *fatigue* played a role in the incident (McCallum, Raby, & Rothblum, 1996). Earlier studies (Marine Transportation Research Board, 1976; National Research Council, 1990) had found fatigue to be the "number one" concern of mariners. This study corroborated that concern, finding that fatigue played a role in 16% of critical vessel casualties (groundings, collisions, allisions, etc.) and in 33% of critical personnel injuries (lacerations, amputations, crushings, etc.). The types of data reflected in the Fatigue Information form focus on scientifically validated causes, symptoms, and effects of fatigue. This form is recommended for use by organizations interested in controlling crew fatigue and reducing the casualties fatigue can cause.

As mentioned in Section 6 in the discussion of statistical analysis, the data from the fatigue investigations were submitted to a multiple regression analysis. The analysis showed that the Coast Guard could significantly streamline its initial investigation of fatigue to just three questions: how many hours did the person sleep during the 24-hour period prior to the casualty; how many hours did the person work during the 24-hour period prior to the casualty; and how many fatigue symptoms did the person experience while on duty prior to the casualty? The answers to these questions are put into an equation, as shown on the Fatigue Investigations Worksheet (third page of this Appendix), and the result was found to correctly identify whether fatigue was a causal factor in 80% of the cases. *Please note that the Fatigue Index Score is offered only as an example of the use of statistical analysis of incident data*, and it is *not* recommended for use by anyone other than the Coast Guard. The selection and weightings of the variables in the Fatigue Index equation may well reflect the somewhat guarded atmosphere of a USCG investigation (i.e., since one's license could be on the line, one is less likely to be open and forthright about one's condition and everything that occurred). We would anticipate that in the "open, blame-free culture" recommended for safety-conscious companies, a very different set of weighting factors (and maybe a different set of variables altogether) would apply.

Inadequate communications was found to play a role in 18% of critical vessel casualties and in 28% of critical personnel injuries (McCallum, Raby, Rothblum, Forsythe, Slavich, & Smith, 2000, unpublished). The communications investigation procedures provided in this appendix are based on a scientific model of communications (described in the Instructions for Investigating Communications Problems in Marine Casualties). The gist of the procedure is to identify under what types of situations communication is normally required – a list that can easily be modified to suit any company's operations – then to determine whether necessary communications were absent or ineffective and why. As described in Section 6, this investigation protocol was not only sufficient to identify casualties in which inadequate communications were a contributing cause, it also supported a meta-analysis to illuminate underlying causes of the communications failures. In addition, it was found that the five screening questions (Step 1 on the communications investigation form) captured 76% of the casualties in which communications errors were involved, making it a simple and effective way to determine whether the complete communications investigation needs to be performed.

The final set of investigation forms assess whether *skill and knowledge limitations* may have contributed to the incident. A study of skill and knowledge errors showed that they played a role in 22% of critical vessel casualties and in 32% of critical personnel injuries (McCallum, Forsythe, Raby, Barnes, Rothblum, & Smith, 2000, unpublished). Step 4 of the Mariner Skill & Knowledge Limitations Investigation Screening form essentially seeks to distinguish errors of knowledge and skilled performance (Decision Errors in HFACS) from slips and lapses (Skill-based and Perceptual errors in HFACS) and from violations. If it appears that the individual did not intentionally break a rule (violation) and failed to perform an action properly given an honest effort, it is assumed that a lack of knowledge or skill is the cause. The remainder of the skill and knowledge forms provide lists of common skill and knowledge areas relevant to different types of activities (bridge, deck, engineering, and safety & emergency operations) – obviously, these forms can be modified to suit any type of operation. The crux of the forms is to identify the type of error (skill or knowledge that was lacking) and to determine whether the error resulted from a lack of training/experience on the part of the person or from a poorly designed standard operating procedure (SOP) or policy. Note that while this analysis will determine whether insufficient training, experience, or a poor SOP was a contributing cause, that the best solution to such problems may turn out to be other types of interventions, such as a redesign of equipment, tasks, or work environment (see Sec. 8).

Fatigue Investigation Form

*Form should be completed for **each** individual who was directly linked to the casualty.*

Section 1: Casualty Day

1. Experience of involved individual — year(s) / month(s)

	year(s)	month(s)
a) in the industry	________	________
b) with this company	________	________
c) in present job or position	________	________
d) on present vessel	________	________

2. Individual's activity at time of casualty

3. Specific location on vessel

4. Number of hours on duty at time of casualty

5. Any break (awake) prior to casualty? ☐ No break ☐ Yes, when ____________

6. Time and last meal (breakfast, lunch, dinner) taken prior to casualty

7. Was the schedule on day of casualty different from usual?
   ☐ No ☐ Yes
   a. What was the difference?__________________________
   b. How long had you been on this schedule?____________

8. Did you experience any of these factors during the last 24 hours prior to the casualty? (*Check all that apply.*)
   - ☐ Disruptive ship vibrations
   - ☐ Disruptive ship motion
   - ☐ High noise level
   - ☐ Stormy weather
   - ☐ Cold temperature
   - ☐ Hot temperature
   - ☐ Boredom
   - ☐ None
   - ☐ High stress
   - ☐ Other__________________
   - ☐ Demanding task

9. Did you experience any of the following while you were on duty prior to the casualty? (*Check all that apply.*)
   - ☐ Forgetful
   - ☐ Difficulty keeping eyes opened
   - ☐ Difficulty operating equipment
   - ☐ Sore muscles
   - ☐ Desire to sit or lay down
   - ☐ Distracted
   - ☐ Less motivated
   - ☐ None
   - ☐ Other____

Section 2: Working Schedule

10. Number of days on tour at time of casualty (including shipyard)

11. Please shade the days on which you had 24 hours off in the previous 30 days

30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Day of Casualty

(over)

☐ ☐ ☐ ☐

Fatigue Information - Side 2

12. Normal Schedule	Work Rec Sleep 0000 midnight · 0200 · 0400 · 0600 · 0800 · 1000 · 1200 noon · 1400 2 pm · 1600 4 pm · 1800 6 pm · 2000 8 pm · 2200 10 pm · 2359	very low … very high 1 2 3 4 5 Workload level ☐ ☐ ☐ ☐ ☐ Fatigue level ☐ ☐ ☐ ☐ ☐ Sleep quality ☐ ☐ ☐ ☐ ☐

*From the time of casualty, trace back the **work, recreation, and sleep** periods for the last 72 hours (3 days) prior to the casualty. Sleep also includes naps. Please mark time of casualty with vertical line.*

13. Day of Casualty	Work Rec Sleep 0000 midnight · 0200 · 0400 · 0600 · 0800 · 1000 · 1200 noon · 1400 2 pm · 1600 4 pm · 1800 6 pm · 2000 8 pm · 2200 10 pm · 2359	very low … very high 1 2 3 4 5 Workload level ☐ ☐ ☐ ☐ ☐ Fatigue level ☐ ☐ ☐ ☐ ☐ Sleep quality ☐ ☐ ☐ ☐ ☐
14. Day 1 Prior to Casualty	Work Rec Sleep 0000 midnight · 0200 · 0400 · 0600 · 0800 · 1000 · 1200 noon · 1400 2 pm · 1600 4 pm · 1800 6 pm · 2000 8 pm · 2200 10 pm · 2359	very low … very high 1 2 3 4 5 Workload level ☐ ☐ ☐ ☐ ☐ Fatigue level ☐ ☐ ☐ ☐ ☐ Sleep quality ☐ ☐ ☐ ☐ ☐
15. Day 2 Prior to Casualty	Work Rec Sleep 0000 midnight · 0200 · 0400 · 0600 · 0800 · 1000 · 1200 noon · 1400 2 pm · 1600 4 pm · 1800 6 pm · 2000 8 pm · 2200 10 pm · 2359	very low … very high 1 2 3 4 5 Workload level ☐ ☐ ☐ ☐ ☐ Fatigue level ☐ ☐ ☐ ☐ ☐ Sleep quality ☐ ☐ ☐ ☐ ☐
16. Day 3 Prior to Casualty	Work Rec Sleep 0000 midnight · 0200 · 0400 · 0600 · 0800 · 1000 · 1200 noon · 1400 2 pm · 1600 4 pm · 1800 6 pm · 2000 8 pm · 2200 10 pm · 2359	very low … very high 1 2 3 4 5 Workload level ☐ ☐ ☐ ☐ ☐ Fatigue level ☐ ☐ ☐ ☐ ☐ Sleep quality ☐ ☐ ☐ ☐ ☐

17. Are there any company or union policies regarding work hour limits?
☐ No ☐ Yes Maximum hours:_________

18. In the involved individual's opinion, was fatigue a contributing factor to this casualty?
☐ No ☐ Yes Why:____________________

Section 3: For the Investigator Only

19. What was the decision/action that was considered improper given the existing circumstances?

- ☐ Failure to secure equipment
- ☐ Failure to notice something important
- ☐ Failure to take action at proper time
- ☐ Failure to recognize code/symbol
- ☐ Failure to decide on an action
- ☐ Forgetting to accomplish task
- ☐ Prone to take risks
- ☐ Erroneous judgment of situation
- ☐ Erroneous calculations
- ☐ Improper procedures
- ☐ Slow reaction to circumstance
- ☐ Other ______________________________

20. a) Was alcohol/drug testing done? ☐ Yes ☐ No
b)Was the result: ☐ Positive ☐ Negative ☐ No result

21. In your opinion, was fatigue a contributing factor to this casualty?
☐ No ☐Yes Why__________

22. On a scale of 1 to 5, do you feel that the mariner gave you true and accurate information?

☐	☐	☐	☐	☐
1	2	3	4	5
not at all true & accurate				extremely true & accurate

Additional Comments

FATIGUE INVESTIGATION WORKSHEET

The formula <u>s(21.4) + wh(6.1) - sh(4.5) = Fatigue Index Score</u> has been established to determine if fatigue may have affected an individual involved in a marine casualty. It should only be used for examining cases in which direct human error contributions are present, i.e., those situations which involve an individual's decisions, actions or inactions as casual factors occurring immediately before the casualty.

<u>Using the Formula</u>

s(21.4) + wh(6.1) - sh(4.5) = Fatigue Index Score

s = total number of fatigue symptoms (0-7) experienced while on duty before the casualty

wh = total number of hours worked in the last 24 hours (to the nearest tenth)

sh = total number of hours slept in the last 24 hours (to the nearest tenth)

1. Interview the individual whose errors directly contributed to the casualty (or another person who can verify the information) to determine the total number of fatigue symptoms (*s*) listed below, if any, that the individual experienced while on duty prior to the casualty.

<u>Fatigue Symptoms (*s*)</u>

- forgetful
- distracted
- sore muscles
- less motivated
- desire to sit or lay down
- difficulty keeping eyes opened
- difficulty operating equipment

2. Obtain the individual's total work hours (*wh*) and sleep hours (*sh*) for the 24 hour period before the casualty. Determine the Fatigue Index Score using the formula.

3. If the Fatigue Index Score is greater than 50, assume that fatigue was a contributing cause of the casualty. Our research has shown that this formula will produce correct results 80% of the time.

Example: At 0130, the F/V SEA MONKEY ran aground while returning to port. The mate on watch reported that he had slept 3.2 hours and worked 18.6 hours in the 24 hours preceding the casualty. He also said that while on watch before the casualty, he had difficulty keeping his eyes opened and felt distracted. The equation for this casualty would then read:

s(21.4) + wh(6.1) - sh(4.5) = Fatigue Index Score

2(21.4) + 18.6(6.1) - 3.2(4.5) = Fatigue Index Score

141.9 = Fatigue Index Score

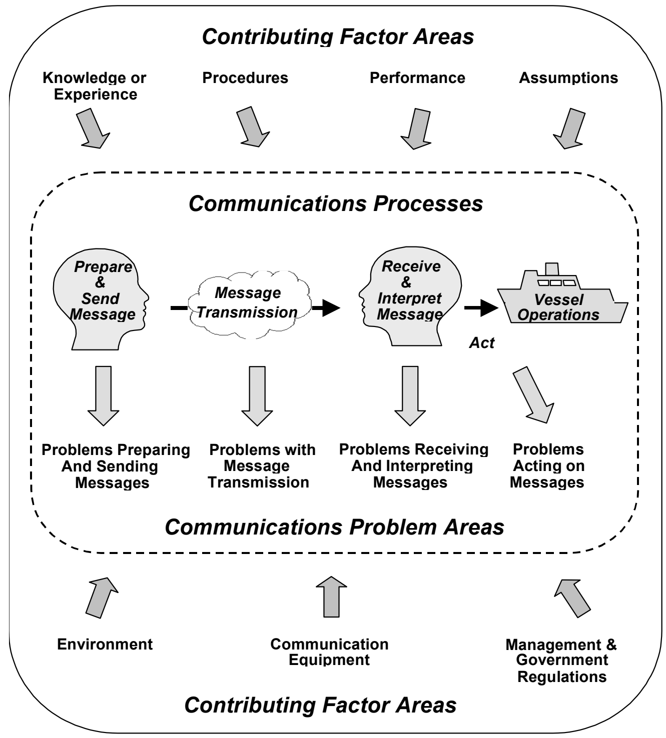
Since the results are greater than 50, fatigue is assumed as a contributing factor to the casualty.

Instructions for Investigating Communications Problems in Marine Casualties

These instructions provide an aid in using the *Communications Problems Screening and Investigation Procedures* to investigate communications problems in vessel and personnel injury casualties.

Background

These procedures were developed as part of a Coast Guard study of how best to investigate and report on communications problems. As part of that study, a general model of communications problems was developed, shown in the adjacent figure. This model divides communications into four *Communications Processes* (prepare and send message, message transmission, receive and interpret message, and act on message) and four corresponding *Communications Problem Areas*. The model further identifies seven *Contributing Factor Areas* that can cause or contribute to communications problems.



Basis

Investigation procedures based on this model were developed and then applied by Investigating Officers as part of the study. During the study, investigators screened casualties to identify those that required effective communications to support safe operations. Of those casualties identified as requiring effective communications, 76 percent were subsequently found to have a communications problem that contributed to the casualty. Following their initial screening of cases, investigators conducted in-depth investigations and analyses of selected casualties to identify specific communications problems and contributing factors. Investigating Officers were able to use the procedures to reliably identify communications problem areas and specific factors contributing to the casualties. Overall, the study found that 18 percent of critical vessel casualties and 28 percent of critical personnel injuries had a communications problem that contributed to the casualty.

Instructions

Step 1 is conducted to identify if there was a potential for a communications problem to have contributed to the casualty. This step identifies casualties where there is a 76 percent probability that ineffective, inappropriate, or a lack of communications contributed to the casualty, according to the results of the research study.

Step 1: Review the five conditions, check any that apply, and identify the type(s) of communications that should be further analyzed (vessel-vessel, bridge-pilot, vessel-shore authority, crew-crew, and vessel-shore worker).

The remaining steps call for a further investigation of the specific communications causes that contributed to the casualty. Complete Step 2 to identify the specific communications causes, if any. Complete Step 3 to document your conclusions regarding the type of communications that contributed to the casualty. Use Step 4 as an aid in investigating and reporting any communication types identified in Step 3.

Step 2: For each communication type identified in Step 1, consider the actions in which ineffective, inappropriate, or a lack of needed communications could have contributed to the casualty.

Step 3: Check the types of communications that likely contributed to this casualty and complete Step 4 for each type checked.

Step 4: For this step, it will typically be necessary to contact individuals involved in the casualty to determine the events leading up to the casualty, specific communications problems that occurred, and the factors that contributed to these problems.

Communications Problem Screening and Investigation Procedures

Please refer to the ***Instructions for Investigating Communications Problems in Marine Casualties*** *for a summary of the background and basis for these procedures, as well as general instructions for their use.*

Step 1: Was there a potential for a communications problem contributing to the casualty?

Review the following casualty conditions, check ☑ all that apply, and note the corresponding communication type(s) for further review in Step 2. If no conditions apply, communications were likely not required in the situation.

	Casualty Condition	Communication Type
❑	Two or more vessels were involved in this casualty.	Vessel-Vessel
❑	There was a pilot (other than a member of the vessel's crew) responsible for navigation of the ship.	Bridge-Pilot
❑	The vessel was navigating in an area under the supervision of a VTS operator, a bridge tender, a lockmaster, or a light operator.	Vessel-Shore Authority
❑	Two or more crewmembers who were directly involved in this casualty were working together, or this casualty could have been prevented if someone had shared additional information with another crewmember.	Crew-Crew
❑	The casualty occurred during coordination of activities between the vessel and shore-based personnel (e.g., dock worker, crane operator, or vessel agent).	Vessel-Shore Workers

Step 2: What specific communications actions contributed to the casualty?

Check ☑ all actions in which ineffective, inappropriate, or a lack of needed communications may have contributed to the casualty. Note any other causes not listed. If any potential causes are identified, continue with Steps 3 and 4.

Vessel-Vessel Communication Problems
- ❑ Vessel communication using a VHF radio system
- ❑ Vessel communication using sound signals
- ❑ Other:
- ❑ Vessel communication using visual signals
- ❑ Vessel communication using some other means

Bridge-Pilot Communication Problems
- ❑ Pilot request for vessel and situation information
- ❑ Bridge crew warned pilot of equipment malfunction
- ❑ Pilot brief to bridge crew on navigation plan
- ❑ Other:
- ❑ Pilot brief to bridge crew on operating conditions
- ❑ Pilot update to bridge crew on change in plans
- ❑ Crew update to pilot of change in situation

Vessel-Shore Authority Communication Problems
- ❑ Vessel call to shore authority
- ❑ Shore authority advisory to vessel of situation
- ❑ Other:
- ❑ Vessel statement of intentions to shore authority
- ❑ Shore authority acknowledgement of vsl intentions

Crew-Crew Communication Problems
- ❑ Use of direct and verbal conversation
- ❑ Use of hand signals
- ❑ Other:
- ❑ Use of communications devices
- ❑ Use of written communications

Vessel-Shore Worker Communication Problems
- ❑ Use of direct and verbal conversation
- ❑ Use of hand signals
- ❑ Other:
- ❑ Use of communications devices
- ❑ Use of written communications

No Potential Communication Problems Identified
- ❑ Further investigation failed to support communications as a causal factor

Step 3: Which of the following types of communication contributed to this casualty?

Based on the response to Step 2, check ☑ the types of communication, if any, that likely contributed to this casualty and complete Step 4 for each type checked.

- ❑ Vessel-Vessel Communications
- ❑ Bridge-Pilot Communications
- ❑ Vessel-Shore Authority Communications
- ❑ Crew-Crew Communications
- ❑ Vessel-Shore Worker Communications
- ❑ N/A--no communication problems identified

Step 4: What specific communications problems and factors contributed to this casualty?

For each type of communication checked in Step 3, check ☑ all communications problems that contributed to the casualty. For each problem identified below, list at least one contributing factor from the list below by indicating its corresponding identification number (#1-41). For example, ☑ Did not request information…3 , 15 , 28.

Communications Process	Communications Problem	Contributing Factor (see 1 – 41 below)
Prepare & Send Message (includes spoken and written communications, hand and sound signals)	❒ Did not communicate	___ ___ ___
	❒ Communicated ambiguous, incorrect, or incomplete information	___ ___ ___
	❒ Did not question others' actions or assert own interpretation of situation	___ ___ ___
	❒ Did not request information	___ ___ ___
	❒ Did not send information in a timely manner	___ ___ ___
	❒ Sent different information than intended	___ ___ ___
Message Transmission	❒ Message was not transmitted	___ ___ ___
	❒ Message was interrupted	___ ___ ___
	❒ Message was incomprehensible	___ ___ ___
Receive & Interpret Message	❒ Did not monitor communications	___ ___ ___
	❒ Did not listen to complete message	___ ___ ___
	❒ Did not acknowledge information reception	___ ___ ___
	❒ Did not interpret the information correctly	___ ___ ___
	❒ Did not verify the validity or accuracy of the information	___ ___ ___
Act on Message	❒ Took no action	___ ___ ___
	❒ Action was not in accordance with agreement	___ ___ ___
Others:		___ ___ ___

Knowledge or Experience

1. Improper use of signaling techniques (hand, light, flag)
2. Improper use of standard marine technical vocabulary
3. Inadequate knowledge of company procedures or policies
4. Inadequate knowledge of correct communications protocol
5. Inadequate knowledge of regulatory requirements
6. Limited English skills or knowledge
7. Language difficulty (e.g., enunciation, strong accent)
8. Lack of common language
9. Other: ____________

Procedures

10. Did not carry communications equipment on person
11. Did not operate the communications equipment correctly
12. Selected incorrect communications channel or frequency
13. Selected incorrect communications device
14. Other: ____________

Performance

15. Distracted or interrupted by other tasks (e.g., high workload)
16. Forgot information or intended actions
17. Tired or sleepy
18. Individual not at work station
19. Not willing to challenge authority
20. Not willing to communicate
21. Other: ____________

Assumptions

22. Assumed that there was no need to communicate
23. Assumed lack of response as implicit (silent) confirmation
24. Assumed incorrectly that other party knew the information
25. Assumed that individual in charge recognized the problem
26. Confusion regarding who was communicating
27. Confusion regarding who was in charge of situation
28. Incorrect interpretation of the situation
29. Other: ____________

Environment

30. Excessive ambient noise
31. Excessive electronic or atmospheric disruption of signal
32. Excessive traffic (i.e., too many users, too lengthy) on the assigned communications channel
33. Other: ____________

Communications Equipment

34. Communications equipment malfunction
35. Communications equipment not available
36. Communications equipment turned off
37. Other: ____________

Management and Government Regulations

38. No regulatory requirement to communicate
39. Not part of individual's job description or responsibilities
40. Inadequate Standard Operating Procedures
41. Other: ____________

COMMUNICATIONS REPORTING FORM

Section 1. Reference Information

1. Name of Investigator	2. Office	3. Case Number	4. Vessel Name

Section 2. Individuals Contacted

5. Name & Job Position of Individual	6. Individual contacted	7. Individual's Fluency in English Language
Name ______ Job ______	‘ By phone ‘ By deposition ‘ In person ‘ Unable to contact	‘ a. No English ‘ b. Standard maritime phrases ‘ c. Limited conversation ‘ d. Fluent ‘ e. Unknown
8. Name & Job Position of Individual	**9. Individual contacted**	**10. Individual's Fluency in English Language**
Name ______ Job ______	‘ By phone ‘ By deposition ‘ In person ‘ Unable to contact	‘ a. No English ‘ b. Standard maritime phrases ‘ c. Limited conversation ‘ d. Fluent ‘ e. Unknown
11. Name & Job Position of Individual	**12. Individual contacted**	**13. Individual's Fluency in English Language**
Name ______ Job ______	‘ By phone ‘ By deposition ‘ In person ‘ Unable to contact	‘ a. No English ‘ b. Standard maritime phrases ‘ c. Limited conversation ‘ d. Fluent ‘ e. Unknown

Section 3. Communications Contribution

This form relates to which type of communications problem? *(check only one – use separate form for each type)*

‘ bridge-pilot ‘ vessel-vessel ‘ crew-crew ‘ vessel-shore workers ‘ vessel-shore authority

14. Were communications or coordination between (the groups checked above) advisable during the events leading up to the casualty?
‘ Yes ‘ No
If Yes, briefly describe activities (e.g., course change, passing, line handling, cargo transfer, locking) or situation requiring communications:

15. Describe any needed communications that were either not done or done ineffectively.

16. In the Investigator's opinion, were communications a contributing factor to this casualty?
‘ Yes. Describe the specific type of communications problems checked above (i.e., Who? What? How?).
______
‘ No. Indicate the apparent cause(s) of the casualty______
If No is checked, proceed with Section 4, but skip Section 5 (Communications Analysis), otherwise complete both sections 4 & 5.

Section 4. Conclusions and Comments

17. On a scale of 1 to 5, do you feel that the individual(s) gave you true and accurate information?

		Not at all true & accurate				Extremely true & accurate
‘ N/A since nobody was contacted	Individual's initials ______	1. ‘	2. ‘	3. ‘	4. ‘	5. ‘
	Individual's initials ______	1. ‘	2. ‘	3. ‘	4. ‘	5. ‘
	Individual's initials ______	1. ‘	2. ‘	3. ‘	4. ‘	5. ‘

18. To what extent was there a discrepancy in the information received from the various individuals contacted?

	Complete disagreement				Complete agreement
‘ N/A since only 1 individual was contacted	1. ‘	2. ‘	3. ‘	4. ‘	5. ‘

19. Safety recommendations to prevent similar communications-related casualties

20. Additional Comments

Section 5. Communications Analysis

*Please complete this section if **bridge-pilot** communications is a contributing factor to this casualty. Check ☑ all bridge–pilot communications process problems that apply. For each process problem identified, list at least one contributing factor from the list below by indicating its corresponding identification number* (#1-41). *(e.g., ☑ Did not request information _6_, _8_, _11_)*

21. Process Problems		Contributing Factors
Communications Process	Process Problems	(see 1 – 41 below)
Prepare & Send Message (includes spoken and written communications)	‘ Did not communicate	___ ___ ___ ___
	‘ Communicated ambiguous, incorrect, or incomplete information	___ ___ ___ ___
	‘ Did not question others' actions or assert own interpretation of situation.	___ ___ ___ ___
	‘ Did not request information	___ ___ ___ ___
	‘ Did not send information in a timely manner	___ ___ ___ ___
	‘ Sent different information than intended	___ ___ ___ ___
Message Transmission	‘ Message was not transmitted	___ ___ ___ ___
	‘ Message was interrupted	___ ___ ___ ___
	‘ Message was incomprehensible	___ ___ ___ ___
Receive & Interpret Message	‘ Did not monitor communications	___ ___ ___ ___
	‘ Did not listen to complete message	___ ___ ___ ___
	‘ Did not acknowledge information reception	___ ___ ___ ___
	‘ Did not interpret the information correctly	___ ___ ___ ___
	‘ Did not verify the validity or accuracy of the information	___ ___ ___ ___
Act on Message	‘ Took no action	___ ___ ___ ___
	‘ Action was not in accordance with agreement	___ ___ ___ ___
Others:		___ ___ ___ ___

Contributing Factors

Knowledge or Experience

1. Improper use of signaling techniques (hand, light, flag, Morse)
2. Improper use of standard marine technical vocabulary
3. Inadequate knowledge of company procedures or policies
4. Inadequate knowledge of correct communications protocol
5. Inadequate knowledge of regulatory requirements
6. Limited English skills or knowledge
7. Language difficulty (e.g., enunciation, strong accent)
8. Lack of common language
9. Other:_______________

Procedures

10. Did not carry communications equipment on person
11. Did not operate the communications equipment correctly
12. Selected incorrect communications channel or frequency
13. Selected incorrect communications device
14. Other: _______________

Performance

15. Distracted or interrupted by other tasks (e.g., high workload)
16. Forgot information or intended actions
17. Tired or sleepy
18. Individual not at work station
19. Not willing to challenge authority
20. Not willing to communicate
21. Other: _______________

Assumptions

22. Assumed that there was no need to communicate
23. Assumed lack of response as implicit (silent) confirmation
24. Assumed incorrectly that other party knew the information
25. Assumed that individual in charge recognized the problem
26. Confusion regarding who was communicating
27. Confusion regarding who was in charge of situation
28. Incorrect interpretation of the situation
29. Other: _______________

Environment

30. Excessive ambient noise
31. Excessive electronic or atmospheric disruption of signal
32. Excessive traffic (i.e., too many users, too lengthy) on the assigned communications channel
33. Other: _______________

Communications Equipment

34. Communications equipment malfunction
35. Communications equipment not available
36. Communications equipment turned off
37. Other: _______________

Management and Government Regulations

38. No regulatory requirement to communicate

41. Not part of individual's job description or responsibilities

42. Inadequate Standard Operating Procedures

41. Other: _______________

MARINER SKILL & KNOWLEDGE LIMITATIONS INVESTIGATION SCREENING

Step 1: Human Factors Involvement

Did at least one person's actions, inaction, or decisions directly contributed to the casualty or its severity? ☐YES – Go to Step 2. ☐NO – Human factors are likely not involved and further investigation of mariner skill and knowledge limitations is unwarranted.

Step 2: Contributing Individuals

List the names and job positions of up to three persons whose actions, inaction, or decisions most directly contributed to the casualty. For each person, identify the general area(s) of vessel operations that contributed to the casualty, then go to Step 3.

Mariner's Name	**Job Position**	**Vessel Operations Contributing to Casualty** *(Bridge, Deck, Engineering, Safety & Emergency)*
1.		
2.		
3.		

Step 3: Contributing Activities

Briefly describe each person's actions, inaction, and/or decisions that contributed to the casualty.

Mariner 1:
Mariner 2:
Mariner 3:

Step 4: Potential for Skill and Knowledge Limitations

For each mariner, respond to the following questions. If possible, interview the mariner(s) in-person or by telephone to address these questions.	**Mariner 1**	**Mariner 2**	**Mariner 3**
a. Did this person's action or inaction result in their **knowing** violation of an applicable law, rule, policy or standard operating procedure? ***If NO for any involved mariner, go to b.*** *If YES for all involved mariners, end report. This casualty is likely a **violation**, not the result of skill and knowledge limitations.*	☐YES ☐NO	☐YES ☐NO	☐YES ☐NO
b. Has each person successfully demonstrated the contributing activities many times before under similar circumstances and within the last five years? ***If NO for any involved mariner, go to Step 5.*** *If YES for all involved mariners, end report. This casualty is likely either a **slip** or a **lapse**, not the result of skill and knowledge limitations.*	☐YES ☐NO	☐YES ☐NO	☐YES ☐NO

Step 5: Completion of Operations Form(s)

*Complete applicable operational area investigation form(s) for **Bridge, Deck, Engineering, and/or Safety & Emergency Operations**, for each mariner with **NO** answers to Questions 4a and 4b.*

Bridge Operations – Mariner Skill & Knowledge Limitations

Please complete a separate copy of this form for each person whose bridge activities contributed to the casualty.

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **bridge** actions, inaction, or decisions contributed to the casualty:

Now, check ☑ all bridge activities (10-17) that directly contributed to the casualty.

10. Did **changing bridge watch** activities contribute? ☐ YES *Check all activities that apply.* ☐ NO *Go to 11.*
- ❑ a. Check and acknowledge passage plan, orders, and special information
- ❑ b. Assess traffic and weather conditions
- ❑ c. Check status of ship's equipment
- ❑ d. Ensure that watch is relieved

11. Did **visual monitoring and lookout** activities contribute? ☐ YES *Check all activities that apply.* ☐ NO *Go to 12.*
- ❑ a. Instruct Lookout as to duties and ensure Lookout is prepared to assume the watch
- ❑ b. Maintain lookout to detect objects, traffic, or navigational aids and assess visibility
- ❑ c. Determine type, aspect, and relative motion of other vessels
- ❑ d. Receive and verify reports of visual contact

12. Did **collision avoidance** activities contribute? ☐ YES *Check all activities that apply.* ☐ NO *Go to 13.*
- ❑ a. Adjust and operate radar/ARPA
- ❑ b. Monitor radar/ARPA and radar contacts
- ❑ c. Assess collision threat and determine avoidance maneuver
- ❑ d. Recognize and apply COLREGS

13. Did **grounding avoidance and navigation** contribute? ☐ YES *Check all activities that apply.* ☐ NO *Go to 14.*
- ❑ a. Establish a passage plan based on navigation information and knowledge of are
- ❑ b Determine vessel position using available systems
- ❑ c. Calculate course changes based on navigation information, local conditions, and local regulation
- ❑ d. Check and update navigation charts and publications

14. Did **shiphandling** activities contribute? ☐ YES *Check all activities that apply.* ☐ NO *Go to 15.*
- ❑ a. Maneuver in accordance with sea/river/weather conditions
- ❑ b. Maneuver in accordance with vessel and/or tow handling characteristics
- ❑ c. Maneuver vessel in accordance with conning orders
- ❑ d. Maneuver vessel during docking, anchoring, and mooring
- ❑ e. Manage and coordinate assist vessels

15. Did **bridge communications** contribute? ☐ YES *Check all activities that apply.* ☐ NO *Go to 16.*
- ❑ a. Communicate and coordinate effectively among the vessel's crew (Bridge, Engine, and Deck)
- ❑ b. Communicate and coordinate between the bridge watch team and the federal/state pilot
- ❑ c. Interpret and reply to signals (flag signals, flashing light, and ship's whistle)
- ❑ d. Establish and maintain VHF radio communications with other vessels and appropriate shore authorities

16. Did **port or anchor watch** activities contribute? ☐ YES *Check all activities that apply.* ☐ NO *Go to 17.*
- ❑ a. Inspect for leaks, loose or weak mooring lines, and smoke or fire
- ❑ b. Monitor vessel position to determine if anchor is dragging

17. Did a **bridge activity not listed above** contribute? ☐ YES *Briefly describe activity below.* ☐ NO *Go to 18.*

(Bridge Operations – Mariner Skill & Knowledge Limitations, cont.)

Step 5.3: Training and Procedures

Write the identification numbers of up to three bridge activities checked in Step 5.2 that most contributed to the casualty. (Example: Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.) Then, complete the remaining items under each listed activity.

18. Activity 1:	23. Activity 2:	28. Activity 3:
19. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	24. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	29. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
20. Briefly describe the mariner's most relevant training for **Activity 1**.	25. Briefly describe the mariner's most relevant training for **Activity 2**.	30. Briefly describe the mariner's most relevant training for **Activity 3**.
21. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	26. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	31. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
22. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? ☐YES ☐NO	27. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? ☐YES ☐NO	32. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? ☐YES ☐NO

Step 5.4: Conclusions and Recommendations

*Respond to items 33-34 **after** completing Step 5.3.*

33. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *33* and *34*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE
b. The mariner most likely lacks **knowledge** in this activity.	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE

34. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties?

Minimum:

Ideal:

Deck Operations – Mariner Skill & Knowledge Limitations

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **deck** actions, inaction, or decisions contributed to the casualty:

Now, check ☑ all deck activities (10-21)) that directly contributed to the casualty.

10. Did **vessel stability and integrity management** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 11.*
❑ a. Load and unload a vessel taking into account load lines, stability, trim, and stress principles and calculations	❑ b. Adjust ballast as required to maintain stability ❑ c. Operate vessel in compliance with Stability Letter ❑ d. Ensure vessel's water tight integrity
11. Did **deck equipment operations** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 12.*
❑ a. Board pilot ❑ b. Conduct docking, anchoring, and mooring operations	❑ c. Assist in tug/escort vessel tie-up operations ❑ d. Prepare and stow cargo handling equipment
12. Did **container cargo operations** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 13.*
❑ a. Establish container stowage plan ❑ b. Load and unload containers	❑ c. Lash all containers ❑ d. Monitor and maintain cargo security
13. Did **bulk cargo operations** contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 14.*
❑ a. Establish bulk cargo loading plan ❑ b. Load and unload bulk cargo	❑ c. Monitor and maintain cargo security ❑ d. Handle dangerous and hazardous cargo
14. Did **petroleum cargo** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 15.*
❑ a. Operate pumping equipment ❑ b. Monitor piping and pumping systems	❑ c. Clean petroleum cargo tanks ❑ d. Conduct inert gas and gas-free operations
15. Did **towing and fleeting operations** contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 16.*
❑ a. Establish a tow diagram ❑ b. Make up, check, and tighten towlines and headwires	❑ c. Check tow for water and pump barges ❑ d. Conduct locking and lock assist operations
16. Did **fishing operations** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 17.*
❑ a. Set, retrieve, and handle fishing gear ❑ b. Bring aboard and load catch	❑ c. Unload or transfer catch ❑ d. Process catch
17. Did **deck communications** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 18.*
❑ a. Communicate effectively between deck and bridge ❑ b. Communicate effectively among deck crew	❑ c. Coordinate between deck and assist vessels ❑ d. Coordinate between deck and dock crew
18. Did **deck maintenance** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 19.*
❑ a. Perform deck, hull, and surface chipping, painting ❑ b. Maintain deck equipment	❑ c. Work in confined spaces ❑ d. Perform hot work
19. Did **general activities on deck** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 20.*
❑ a. Embarking or disembarking vessel ❑ b. Moving around the vessel	❑ c. General off-duty activities onboard vessel
20. Did **passenger safety** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 21.*
❑ a. Ensure the safety of passengers during embarkation and disembarkation ❑ b. Ensure the safety of passengers when underway and during ship operations	❑ c. Inspect passenger spaces for hazards and take appropriate action ❑ d. Confine passenger access to safe vessel spaces only
21. Did a **deck activity not listed above** contribute?	☐ YES *Briefly describe activity below.* ☐ NO *Go to 22.*

(Deck Operations – Mariner Skill & Knowledge Limitations, cont.)

Step 5.3: Training and Procedures

Write the identification numbers of up to three deck activities checked in Step 5.2 that most contributed to the casualty. (Example: Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.) Then, complete the remaining items under each listed activity.

22. Activity 1:	27. Activity 2:	32. Activity 3:
23. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	28. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	33. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
24. Briefly describe the mariner's most relevant training for **Activity 1**.	29. Briefly describe the mariner's most relevant training for **Activity 2**.	34. Briefly describe the mariner's most relevant training for **Activity 3**.
25. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	30. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	35. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
26. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? ☐YES ☐NO	31. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? ☐YES ☐NO	36. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? ☐YES ☐NO

Step 5.4: Conclusions and Recommendations

Respond to items 37-38 ***after*** *completing Step 5.3.*

37. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *37* and *38*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE
b. The mariner most likely lacks **knowledge** in this activity.	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE

38. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties?
Minimum:
Ideal:

Engineering Operations – Mariner Skill & Knowledge Limitations

Please complete this form separately for each person whose engineering activities contributed to the casualty.

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **engineering** actions, inaction, or decisions contributed to the casualty:

Now, check ☑ all engineering activities (10-16)) that directly contributed to the casualty.

10. Did **changing engineering watch** activities contribute to casualty? ☐ YES *Check all activities that apply.* ☐ NO *Go to 11.*
- ❑ a. Check and acknowledge standing orders, night orders, and special information
- ❑ b. Check status of ship's equipment
- ❑ c. Assess traffic and weather conditions
- ❑ d. Ensure that watch is relieved

11. Did **engineering systems operations** activities contribute to casualty? ☐ YES *Check all activities that apply.* ☐ NO *Go to 12.*
- ❑ a. Operate main propulsion system (engines, boilers, fuel and steering
- ❑ b. Operate generating and electrical systems
- ❑ c. Operate motors, pumps, and lubrication systems
- ❑ d. Operate service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)
- ❑ e. Load, discharge, or transfer fuel between tanks

12. Did **engineering systems inspection and testing** activities contribute to casualty? ☐ YES *Check all activities that apply.* ☐ NO *Go to 13.*
- ❑ a. Inspect and test main propulsion system (engines, boilers, fuel, and steering)
- ❑ b. Inspect and test generating and electrical systems
- ❑ c. Inspect and test motors, pumps, and lubrication systems
- ❑ d. Inspect and test service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)

13. Did **routine, scheduled, and preventive maintenance** activities contribute to casualty? ☐ YES *Check all activities that apply.* ☐ NO *Go to 14.*
- ❑ a. Maintain main propulsion system (engines, boilers, fuel, and steering)
- ❑ b. Maintain generating and electrical systems
- ❑ c. Maintain motors, pumps, and lubrication systems
- ❑ d. Maintain service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)

14. Did **unscheduled, corrective repair** activities contribute to casualty? ☐ YES *Check all activities that apply.* ☐ NO *Go to 15.*
- ❑ a. Repair main propulsion system (engines, boilers, fuel, and steering)
- ❑ b. Repair generating and electrical systems
- ❑ c. Repair motors, pumps, and lubrication systems
- ❑ d. Repair service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)

15. Did **engineering communications** activities contribute to casualty? ☐ YES *Check all activities that apply.* ☐ NO *Go to 16.*
- ❑ a. Communicate and coordinate effectively among the vessel's crew (Bridge, Engine, and Deck)
- ❑ b. Communicate and coordinate effectively among the engineering crew

16. Did **engineering activity not listed above** contribute to casualty? ☐ YES *Briefly describe activity below.* ☐ NO *Go to 17.*

(Engineering Operations – Mariner Skill & Knowledge Limitations, cont.)

Step 5.3: Training and Procedures

Write the identification numbers of up to three engineering activities checked in Step 5.2 that most contributed to the casualty. (Example: Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.) Then, complete the remaining items under each listed activity.

17. Activity 1:	22. Activity 2:	27. Activity 3:
18. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	23. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	28. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
19. Briefly describe the mariner's most relevant training for **Activity 1**.	24. Briefly describe the mariner's most relevant training for **Activity 2**.	29. Briefly describe the mariner's most relevant training for **Activity 3**.
20. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	25. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	30. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
21. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? ☐YES ☐NO	26. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? ☐YES ☐NO	31. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? ☐YES ☐NO

Step 5.4: Conclusions and Recommendations

*Respond to items 32-33 **after** completing Step 5.3.*

32. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *32* and *33*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE
b. The mariner most likely lacks **knowledge** in this activity.	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE	☐ TRUE ☐ FALSE

33. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties?

Minimum:

Ideal:

Safety & Emergency Operations – Mariner Skill & Knowledge Limitations

Please complete this form separately for each person whose safety and emergency activities contributed to the casualty.

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **safety and emergency** actions, inaction, or decisions contributed to the casualty:

Now, check ☑ all safety and emergency activities (10-18)) that directly contributed to the casualty.

10. Did **general safety** activities contribute to casualty?	☐ YES *Check all activities that apply.* ☐ NO *Go to 11.*
❑ a. Embark and disembark vessel safely ❑ b. Walk about vessel safely	❑ c. Perform off-duty activities safely
11. Did **safety equipment inspection and service** activities contribute to casualty?	☐ YES *Check all activities that apply.* ☐ NO *Go to 12.*
❑ a. Inspect and service fire detection equipment ❑ b. Inspect and service fire extinguishing equipment ❑ c. Inspect and service lifesaving equipment, locating devices, and flotation devices	❑ d. Inspect and service survival craft ❑ e. Inspect and service emergency generator, batteries, etc.
12. Did **controlling and fighting fires** activities contribute to casualty?	☐ YES *Check all activities that apply.* ☐ NO *Go to 13.*
❑ a. Establish and maintain a Fire Safety Plan ❑ b. Organize and conduct fire drills ❑ c. Identify the type of fire	❑ d. Use fire-fighting equipment and procedures ❑ e. Maintain escape routes
13. Did **confined space rescue** activities contribute to casualty?	☐ YES *Check all activities that apply.* ☐ NO *Go to 14.*
❑ a. Locate individual(s) ❑ b. Establish a rescue plan	❑ c. Use breathing apparatus and other required equipment ❑ d. Maintain back-up personnel and escape routes
14. Did **person overboard procedures** contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 15.*
❑ a. Initiate warning ❑ b. Locate person overboard	❑ c. Maneuver vessel ❑ d. Bring person aboard
15. Did **abandon vessel operations** contribute to casualty?	☐ YES *Check all activities that apply.* ☐ NO *Go to 16.*
❑ a. Don survival suits and personal flotation devices ❑ b. Launch, load, and maneuver lifeboats and life rafts	❑ c. Employ locating devices properly
16. Did **emergency medical and life-saving procedures** activities contribute to casualty?	☐ YES *Check all activities that apply.* ☐ NO *Go to 17.*
❑ a. Use medical chest and first aid items	❑ b. Apply First Aid/CPR
17. Did **emergency communications** activities contribute?	☐ YES *Check all activities that apply.* ☐ NO *Go to 18.*
❑ a. Establish and maintain communications with crew ❑ b. Establish and maintain communications with passengers ❑ c. Establish and maintain emergency communications with other vessels	❑ d. Establish emergency communications with shore authorities ❑ e. Monitor GMDSS and other emergency frequencies as required
18. Did **safety and emergency activity not listed above** contribute to casualty?	☐ YES *Briefly describe activity below.* ☐ NO *Go to 19.*

(Safety & Emergency Operations – Mariner Skill & Knowledge Limitations, cont.)

Step 5.3: Training and Procedures

Write the identification numbers of up to three safety and emergency activities checked in Step 5.2 that most contributed to the casualty. (Example: Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.) Then, complete the items under each listed activity.

19. Activity 1:	24. Activity 2:	29. Activity 3:
20. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	25. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	30. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
21. Briefly describe the mariner's most relevant training for **Activity 1**.	26. Briefly describe the mariner's most relevant training for **Activity 2**.	31. Briefly describe the mariner's most relevant training for **Activity 3**.
22. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	27. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	32. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
23. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? ❑YES ❑NO	28. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? ❑YES ❑NO	33. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? ❑YES ❑NO

Step 5.4: Conclusions and Recommendations

*Respond to items 34-35 **after** completing Step 5.3.*

34. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *34* and *35*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	❑ TRUE ❑ FALSE	❑ TRUE ❑ FALSE	❑ TRUE ❑ FALSE
b. The mariner most likely lacks **knowledge** in this activity.	❑ TRUE ❑ FALSE	❑ TRUE ❑ FALSE	❑ TRUE ❑ FALSE

35. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties? *Minimum:*
Ideal:

Appendix H. Human Factors Investigation Questions

The following is taken from "Role of the Human Element in Maritime Casualties," by the Joint ILO/IMO adhoc Working Group on Investigation of Human Factors in Maritime Casualties, Maritime Safety Committee, MSC 69/13/1 ([MSC], 1998, Annex 4, Appendix 2). These are questions designed to help the casualty investigator ask questions appropriate to discovering human errors which may have contributed to an incident. While no list of questions can be comprehensive, this one provides a good set of initial inquiries into the events and underlying causes. Investigators can use these to explore many facets surrounding the incident, choosing relevant areas for follow-up. Even though the questions below assume an accident to a commercial ship, the questions can easily be tailored to investigate incidents on any type of facility or vessel. The text of the MSC document is provided below.

Note: The following questions are designed to aid the investigator while investigating for human factors, particularly fatigue. Skilful [sic] questioning can help the investigator eliminate irrelevant lines of inquiry and focus on areas of greater potential significance.

The order in which the questions should be asked will depend on who is being interviewed and on his or her willingness and ability to describe personal behaviour and personal impressions. Also, it may be necessary to verify, cross-check or augment information received from one person by interviewing others on the same points.

These areas of inquiry can be used in training investigators as well as in planning interviews. The following questions are not intended as a checklist, and some may not be relevant in the investigation of a particular accident.

1 Safety Policy

.1 Does the company have a written safety policy?
.2 Is there a designated person for shipboard safety matters in the company?
.3 When did a company Representative last visit the vessel or when were you last in contact with the company?
.4 When were you last provided safety training? What was the training and how was it provided?
.5 When was the last emergency drill (e.g., fire, abandon ship, man-overboard, pollution response, etc) and what did you do during the drill?
.6 Was appropriate personal protective equipment provided and did you use it?
.7 Are you aware of any personal accidents which occurred on board in the period prior to the accident?

2 Activities prior to incident

.1 (If the ship was leaving port at the time of the accident) In general, how did you spend your time while the ship was in port?
.2 (If the ship was approaching port or at sea at the time of the accident) How long has the ship been on passage since its last port or terminal operation?

.3 What were you doing immediately prior to coming on watch or reporting for duty, and for how long? Recreational activity? Physical exercise? Sleeping? Reading? Watching T.V.? Eating? Paperwork? Travelling to vessel?
.4 Specifically what were you doing approximately 4 hours .... 1 hour .... 30 minutes .... before the accident?
.5 What evolution was the ship involved in when the accident occurred? What was your role during that evolution?
.6 Immediately prior to the accident, what were you thinking about?
.7 At any time before the accident, did you have any indication that anyone was tired or unable to perform their duty?

3 **Duties at the time of accident**

.1 Where were you on the ship when the accident occurred?
.2 What specific job or duty were you assigned at the time? By whom? Did you understand your assignment? Did you receive any conflicting orders?
.3 How often have you performed this job in the past (on the specific ship involved in the accident)?

4 **Actual behaviour at time of accident**

.1 Precisely where were you located at the time of the accident?
.2 What specific task were you performing at the time of the accident?
.3 Had you at any time since reporting for duty found that you could not concentrate (focus your attention/keep your mind) on a task you were trying to perform?

5 **Training/Education/Certification/Professional Experience**

.1 How long have you been assigned to this ship? Have you requested that your assignment be lengthened or shortened?
.2 How long have you filled your crew position? What other crew positions have you held on this ship?
.3 How long have you held the certificate indicating your qualifications?
.4 Before being assigned to this ship, did you work on other ships? If so, what crew positions have you held?
.5 What is the longest time you have been to sea in a single voyage? How long have you been at sea on this passage? What was your longest single passage?

6 **Physical condition**

.1 Were you feeling ill or sick at any time in the 24 hours immediately before the accident? If so, what symptoms did you have? Did you have a fever, vomit, feel dizzy, other? Also, did you tell anyone? What do you believe the cause was?
.2 When was the last meal you had prior [to] the accident? What did you eat? Was it adequate?
.3 Do you exercise regularly while onboard? When did you last exercise (before the accident)? How long was the session?

7 **Psychological, emotional, mental condition and employment conditions**

.1 When was the last time you felt cheerful or elated onboard the ship, and what were the circumstances that generated this emotion?
.2 When was the last time you were sad or depressed or dejected, on board the ship? Why? Did you talk about it with anyone else?
.3 Have you had to make any difficult personal decisions recently? Have you had any financial or family worries on your mind recently?
.4 Have you been criticized for how you are doing your work lately? By whom? Was it justified?
.5 What was the most stressful situation you had to deal with on the voyage (prior to the accident)? When did the situation occur? How was it resolved?
.6 What are the contractual arrangements for all crewmembers?
.7 Have there been any complaints or industrial action in the last (12) months?

8 **Workload/Complexity of Tasks**

.1 What is the shipboard organization?
.2 Is the shipboard organization effective?
.3 What is your position in the shipboard organization (i.e., who do you work for, report to or assign duties to)?
.4 What is the nature of your work? Sedentary? Physically demanding?
.5 Was anyone involved in the accident impaired due to heavy workload?

9 **Work-period/rest-period/recreation pattern**

.1 What is your normal duty schedule?
.2 Are you a day worker or a watchstander?
.3 What was your duty schedule on the day before the accident and during the week before the accident?
.4 Were you on overtime at the time of the accident?
.5 How long had you been on duty, or awake performing other work, at the time of the accident?
.6 When was your lat period of sleep? How long did it last? How often did you awaken during your last sleep period? Did you awaken refreshed? If not, what would have made your sleep period more restful?
.7 How do you normally spend your off-duty time while on board? Play cars? Read? Listen to music? Watch T.V.? Other?
.8 When was your last extended period of off duty time when you were able to rest?

10 **Relationship with other crewmembers and superiors/subordinates**

.1 Who among the crew would you consider to be a friend?
.2 Do you find any members of the crew unpleasant to be with?
.3 Do you have difficulty talking with any of the crewmembers because of language barriers?
.4 Have any new crewmembers recently joined the ship? Have you had a chance to get acquainted with them?
.5 Did you have any argument recently with another crewmember?
.6 In an emergency, would you trust your fellow crewmembers to come to your assistance?

.7 Has another crewmember ever offered to take your place on watch or perform a duty for you to let you get some extra rest?
.8 What was the subject of your last conversation with another crewmember before reporting for duty (when the accident occurred)?
.9 Have you talked with any other crewmembers since the accident? If so, what was the subject of your conversation? Have you talked with anyone else about the accident prior to being interviewed?

11 **Living conditions and shipboard environment**

.1 Do you consider your personal area on board the ship to be comfortable? If not, how would you like it to [be] improved?
.2 Prior to the accident, did you have any difficulty resting as a result of sever weather, noise levels, heat/cold, ship's motion, etc.?

12 **Manning levels**

.1 Is the manning level sufficient in your opinion for the operation of the vessel?

13 **Master's standing orders**

.1 Are there written standing orders to the whole crew complement from the Master?
.2 Did the Master/Chief Engineer provide written or verbal standing orders to the watchkeeping personnel?
.3 Were the orders in conflict with the company safety policy?

14 **Level of automation/reliability of equipment**

.1 In your opinion, was the system reliable?
.2 Were there earlier failures in the system?
.3 Were the failures repaired by the crew or shore-based workers?

15 **Ship design, motion/cargo characteristics**

.1 Did you observe anything out of the ordinary on this passage concerning the ship design, or motion or cargo characteristics?

Questions 16-24 [25] are EXAMPLES OF QUESTIONS THAT MAY BE DIRECTED TO SHORESIDE MANAGEMENT

16 **Scheduling of work and rest periods**

.1 What is the company's work schedule and relief policy?

17 **Manning level**

.1 How is the manning level determined for your fleet?

18 **Watchkeeping practices**

.1 Do you require the Master to stand watch?

.2 Do you leave the watchkeeping practices to the discretion of the Master?

19 **Assignment of duties**

.1 Do you leave this matter to the Master?

20 **Shore-ship-shore support and communications**

.1 How do you support the vessel's Master?

21 **Management policies**

.1 Does the company have a written safety policy?

22 **Voyage planning and port call schedules**

.1 How does the Master plan the voyages?

23 **Recreational facilities**

.1 Are welfare/recreational services and facilities provided on board?

24 **Contractual and/or industrial arrangements and agreements**

.1 What are the contractual agreements for all crewmembers?
.2 Have there been any complaints or industrial action in the last (12) months?

25 **National/international requirements**

.1 Are the management/Master complying with the requirements and recommendations of the applicable international conventions and Flag State regulations?

Appendix I. Norwegian Petroleum Directorate Near-Miss System

In 2000, Norway instituted a near-miss database to assess risk levels in the continental shelf offshore industry. The database contains reports on major hazards, occupational injuries, occupational disease, cultural risk factors, and perceived risks. The focus is on preventing risk to personnel on offshore facilities, such as production installations, mobile drilling units, and flotels. A report, "Trends in Risk Levels on the Norwegian Continental Shelf," gives an overview of the near-miss system and findings to date. The report can be found on the Norwegian Petroleum Directorate (NPD) web site (http://www.npd.no ; click on the British flag for English, then go to the Health, Environment & Safety (HSE) page). This appendix gives a brief presentation of the near-miss system and a couple examples of the data, courtesy of Professor Jan Erik Vinnem.

The near-miss database is limited to incidents that may have the potential to cause major accidents, if multiple barrier failures occur. Some other incidents that are essential for emergency preparedness planning are also covered. The operators on the Norwegian Continental Shelf have a duty (enforced by NPD through regulations) to notify NPD about injuries, accidents and near-misses within a short time after the occurrence of these events. (For the most serious incidents, further investigation reports will be required for submission.) The cut-off limits for which incidents to report are somewhat loosely defined, and there are significant differences between the companies, with respect to reporting practices. The database is based on a subset of these mandatory reports, and includes those which have been extensively reviewed and verified to ensure consistency and which have established exposure data (activity levels).

The NPD classifies major hazards into eleven types (or DFUs), shown below. Each DFU presents a specific, potentially-serious hazardous situation.

DFU	Event Scenario
1	Unignited hydrocarbon leak
2	Ignited hydrocarbon leak
3	Kick/loss of well control
4	Fire/explosion, excluding DFU#2
5	Vessel on collision course
6	Drifting object/vessel on collision course
7	collision with field related traffic
8	Structural damage
9	Leak from subsea installation
10	Damage to subsea installation
11	Evacuation (precautionary/emergency)

Although the near-miss database was not formally brought on-line until 2000, the NPD had incident data from several prior years. The NPD has analyzed yearly incident data in terms of the DFUs, as shown in the trend analysis presented in Figure I-1 (see Sec. 6.3 for information on trend analysis). It is clear from the figure that unignited hydrocarbon leaks are a primary source of potential accidents. These data have been further analyzed by size of leak in Figure I-2. The NPD system demonstrates how near-miss data can be used to identify potential hazardous situations so that the industry can seek safety solutions before a significant accident results.

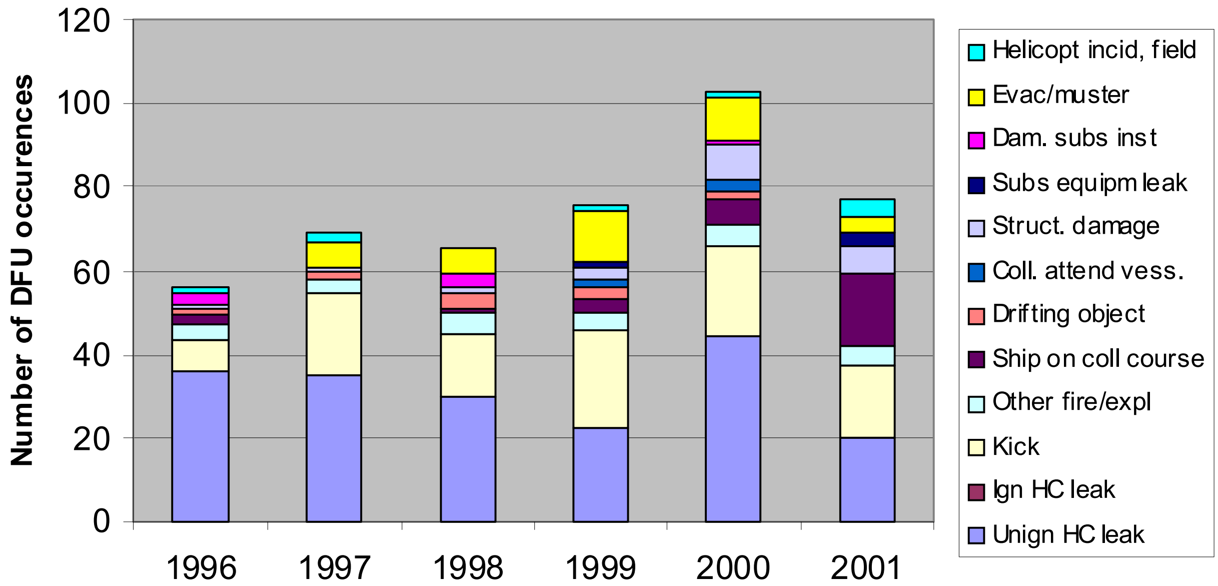


Figure I-1. Norwegian Petroleum Directorate Near-Miss Data. Six years of incident data for all major hazard DFUs, representing near-misses at all continental shelf offshore installations.

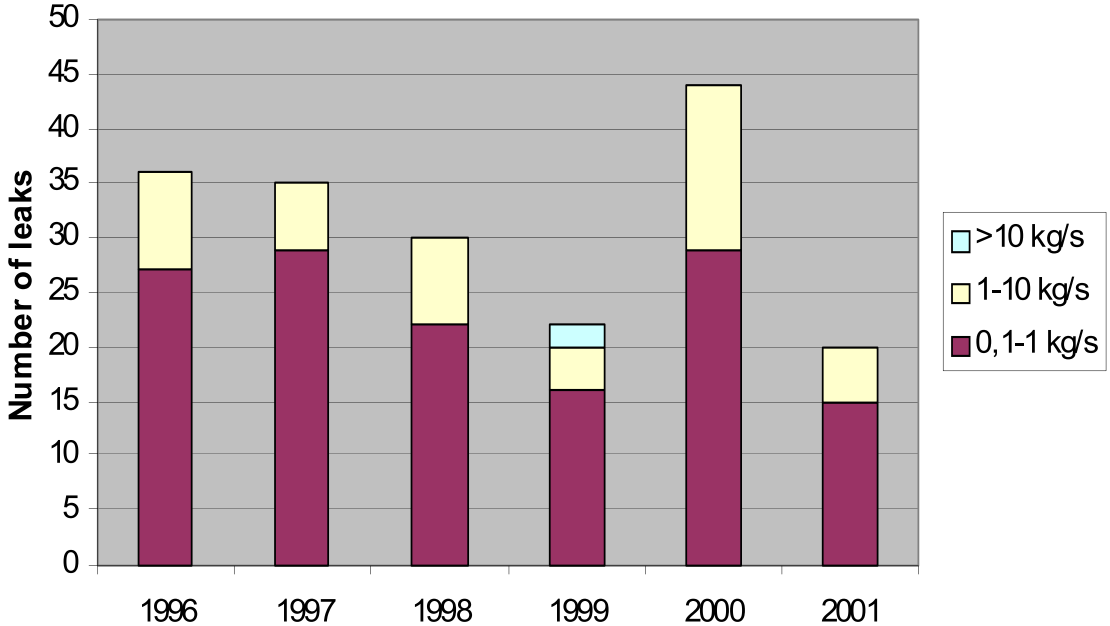


Figure I-2. NPD Data on Unignited Hydrocarbon Leaks. Data are segmented by size of the leak.

Working Group 2

2nd International Workshop on Human Factors in Offshore Operations (HFW2002)

Effectively Including Human Factors in the Design of New Facilities

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Abstract

Human error is a major cause of incidents in the offshore industry. For example, in the Gulf of Mexico region in 1998, 38% of all incidents were attributed to human error with an additional 9% of incidents resulting from slips, trips, and falls (MMS 2000-021, OCS Report). Human Factors, when integrated during the design of a new offshore facility, can reduce the potential for human error and the occurrence of unfortunate incidents.

Quite often the implementation of Human Factors (HF) during design is disregarded because of the notion that it will add unacceptable costs. Review of the cost/benefit data contained in this paper proves that notion to be untrue. Although cost/benefit is important, it was not the *primary* focus of this Working Group. This paper's focus is to develop a means or a strategy to effectively integrate the application of HF design principles into all phases of a new capital design project.

This Working Group's objective during the Second International Workshop on Human Factors in Offshore Operations was to generate discussion concerning HF integration strategies and to focus on specific implementation issues that have been shown to be successful. These include but are not limited to:

- The factors critical to the success of HF integration
- What HF activities should be conducted
- At what stage during the various design phases should HF activities take place
- HF strategies, how to decide what level of human factors engineering is required
- The qualifications and responsibilities of those executing HF activities

Effectively Including Human Factors in the Design of New Facilities

1.0 INTRODUCTION

1.1 What is Human Factors?

At a high level "human factors" (sometimes referred to as ergonomics) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (IEA, 2000).

At a lower or more detailed level, "human factors" (as it relates to this particular paper) refers to a domain of specialization within the human factors discipline called physical human factors engineering. Physical Human Factors Engineering is largely concerned with human anatomical, anthropometric, physiological, behavioral, and biomechanical capabilities and limitations as they relate to human activity and the human-technology environment. Examples include, but are not limited to: workplace layout and design, working postures, materials handling, line of sight, repetitive movements, and safety.

A third practical working definition of Human Factors Engineering is the total effort put forth for analysis, design and verification and or evaluation of the work, facility, or item in question. Through repeated application of the cycle of these three components the design, operability, and maintainability of the work, facility, or item are improved to meet the needs of the user.

The practitioners of Human Factors Engineering fully recognize the importance and significance of the other domains of specialization within human factors, which also contribute to the reduction of human error in new system designs. These domains include cognitive and organizational human factors. Cognitive human factors topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design. Organizational human factors topics include communication, crew resource management, work design, design of working times, teamwork, participatory design, cooperative work, new work paradigms, virtual organizations, and quality management.

For a comprehensive application of human factors to a new system design ALL of the different domains of human factors will need to be incorporated into the system's design, construction, commissioning, and start-up.

1.2 What is the Cost and Return on Investment of Incorporating Human Factors?

Management has a legitimate concern that Human Factors Engineering (HFE) may add costs to the acquisition process through HFE requirements (e.g., those associated with design) and the expense of HF Personnel. However, HFE involvement in several recent offshore projects has demonstrated numerous instances where HFE inputs have reduced total acquisition costs (Miller and McSweeney, 2000).

How much does HFE really cost? In no case according to Miller (1999), who monitored the HFE costs over a nine-year period covering several offshore platform design and construction programs, did the total HFE program cost more than 0.12% (and consistently ran closer to 0.08%) of the acquisition cost of the platform. On the SABLE Project the original estimated cost (personnel charges only) for the HFE program was 0.07% of the facilities budget. The actual HFE cost for this project was 0.035% of the facilities cost, or half of the estimated cost.

HFE has a proven track record of returning many times the value of the initial investment throughout the operational life of a project. Miller (1999) reported that proposed HFE changes in the design of the riser tensioner system for an offshore platform lowered the system's construction cost by $242,000 as estimated by the company's engineers. This change was the result of a HFE review of the riser tensioner's maintenance/replacement requirements. Curole et. al. (1999) reported a case where HFE suggested modifications reduced the time required for the removal of a gas turbine from a compressor package enclosure. The maintenance time was reduced from 10 hours to 3 ½ hours approximately and the maintenance task is now conducted in a safer manner.

The overall availability or uptime of a facility is a function of the reliability and maintainability of both hardware/software and the reliability and efficiency of the personnel operating and maintaining the system. When the time required for maintenance can be reduced, especially for equipment that requires frequent maintenance or lengthy maintenance periods, as was the case with the removal of the gas turbine, it will improve the availability or uptime of a facility. The impact of each individual reduction in maintenance time may seem small. However, the sum of all maintenance time improvements in conjunction with increased system reliability, which is a function of a reduction in human error, will improve the availability of the facility. Based on historical data, Rensink and Van Uden (1998) discovered that for a typical $400 million petrochemical project, integrating HFE into a new plant design can result in a reduction of 0.25% in capital expenditure, 1% in engineering hours and 3% to 6% of the facility's life-cycle costs.

A review of company pre and post HFE involvement in offshore platform design also demonstrated the value of integrating HFE into new capital projects. As an example, the review of accident data (prior to the incorporation of HFE) on the offshore installations of one of the major operators in the Gulf of Mexico (GoM), revealed twenty-seven serious injuries over a five year period from falls down stairs and vertical ladders. This review effort resulted in a design specification for stairs, ladders and walkways based on HFE research data. This design specification was then used on subsequent offshore platforms and only one stair fall accident was recorded over the four-year period since the specification's introduction.

Curole et. al. (1999) reported that operators, maintainers, and the commissioning staff stated that the extensive HFE based labeling program (adopted by a major GoM Exploration and Production company) has been one of the most successful HFE improvements the company has incorporated. This HFE labeling program decreased the commissioning time of one facility by approximately three weeks.

However, it is pointed out here and in the following sections that the largest cost advantage will be attained when HFE is incorporated in advance of or concurrent with the design of the facility. Much of the cost advantage associated with the HFE effort will be lost if the designed or constructed facility must be changed to incorporate HFE recommendations.

1.3 What are the Benefits of Incorporating Human Factors in the Design?

As illustrated in the examples above, the return on investment in HFE can be quite substantial. It is also reasonable to expect that HFE can be applied to the offshore industry in a cost-effective manner. In general, some of the benefits that an operator might expect from a proactive HFE program include:

- Improved equipment design and controls that can result in fewer accidents, proper operation of equipment, and improved maintainability. This can generate improved up time for the facility, lower maintenance costs, improved personnel utilization, lower personnel exposure time and risk in hazardous areas as well as fewer incidents and near misses.
- Improved installation layout that can result in a better flow of personnel throughout the facility. This is especially important during emergency events. HFE could make the difference between a person living to tell of the incident, or not.
- Improved human-computer interface design for computer generated process, marine display and control screens. This can improve operator information processing and process control and alarm handling under both normal and upset conditions.

- Improved equipment and facility design can lead to improved human performance, less physical stress and fatigue, improved quality of work, and a work environment, which can improve worker satisfaction and morale.
- Equipment that is easy to operate and maintain through the provision of properly designed and easily understandable instructions, job aids, operating manuals, and procedures. An additional benefit is the potential reduction in personnel training time requirements.
- Reduced exposure to hazardous environments as a result of reduced maintenance and inspection times.

2.0 CRITICAL SUCCESS FACTORS FOR INTEGRATING HFE

The key ingredients for the successful integration of HFE during the various phases of a capital project are:

- Management commitment
- The support of people at all levels of the project organization
- Use of Human Factors Personnel
- User input during all project phases
- Early focus on known problem areas.

These factors will ensure that HFE is executed effectively and efficiently at every stage of the project. The critical success factors for the implementation of the HFE strategy are as follows:

2.1 Management Commitment

Management commitment can be exhibited in many ways beginning with project management's full support for HFE integration from the highest levels of project management. Some other examples of management commitment include:

- <u>Appointment and empowerment of an HFE Champion</u> - The HFE Champion acts as the company HFE representative on the project management team. The HFE Champion should be convinced of the benefits of HFE in design. Past offshore project experience shows that the HFE Champion should be in the Engineering Department, or, as a second choice, within the Operations Department. Placing the HFE Champion within a support group, such as Health, Safety and Environment (HSE) has not been as successful as when placed in Engineering or Operations. HF Personnel should be located in the same place organizationally. See 3.3.2.2 for further discussion on the HFE Champion.

- Early and continuous involvement of HFE throughout the project - It is extremely important to plan for and involve HFE from the Concept Phase of a project and to ensure continued involvement throughout the Operational Phase of the project. This will prevent late changes to the design at extra costs. It is essential to ensure that HFE is embodied in all phases of the project by integrating it into procedures and work methods of the company and contractor. HFE should be applied to the overall working-environment and human-machine interface design. HFE should be applied to the design of components and subsystems, as well as during the integration of the various subsystems into the total system.
- Develop an HFE integration strategy for the company and require an implementation plan from the contractors – Human Factors Engineering Plans (HFEPs) must be developed by the company and/or contractors describing their respective scope of HFE work to be completed for the project, the deliverables, schedule, organizational structure, and responsibilities of those involved including subcontractors and vendors.
- Mandate HFE in design – It is imperative to the success of a HFEP that HFE be mandated in the design through the inclusion of relevant HFE design standards or design requirements in the project specification.
- HFE Performance – HFE should be a focused activity and project management should actively track the effectiveness of the overall HFE effort as it does for other engineering disciplines.
- Use HF Personnel – Project management should ensure that HF Personnel are involved and are an integral part of the design team. HF Personnel should be continually involved throughout all the project phases to provide real time HFE input to engineers, designers, and draftsmen during system design or supervise and/or audit the HFE activities and deliverables of contractor personnel assigned HFE tasks.
- Organizational structure – Project management should physically and organizationally locate the HFE activity such that it promotes interaction between HFE, Engineering, Operations and HSE. The optimal location of HF Personnel would be under Engineering with Operations as a good second choice. Incorporating HFE under HSE is least preferred as HFE's ultimate customer is Operations and close cooperation between these two groups should therefore be generated. Whenever feasible HF Personnel should fall under the operating company to ensure that the highest level of commitment supports their effort. This does not preclude the contractor from also obtaining the services of HF Personnel.

- Resources – Project management should ensure that adequate resources are allocated towards HFE activities. Furthermore, HFE should be given the same consideration as other business/engineering demands in the planning and execution stages of day-to-day operations during the project's conception, design, and construction.
- Awareness training – Project management should commit resources towards HFE awareness training to the company project team, design agents, Operations and Maintenance personnel, inspectors, and vendors.
- HFE areas outside design – Project management can show their commitment through the requirement of HFE principles in areas outside of engineering design; i.e., personnel selection, staffing levels, shift work, and procedure/manual preparation.

2.2 Human Factors Personnel

With the decision made to include HFE, the relevant issue becomes the involvement of HF Personnel. Some companies and contractors believe that all that is needed for successful implementation of HFE into their design process is several days of HFE training for designers and engineers along with a set of HFE requirements (regulations, specifications, standards, checklists, procedures). It is also sometimes assumed that these HFE requirements would function in a similar fashion to the technical requirements of the project and will not require suitably qualified and experienced HF Personnel to take ownership of and ensure compliance with these requirements. These assumptions, along with the opinion that HFE is "common sense" and that "their designers have been doing it for years," will significantly reduce the effectiveness of the HFE program.

2.3 Relevant HFE Standards

The incorporation of HFE design requirements into project specifications is absolutely crucial to the successful design and integration of HFE in any new system. It provides for technical guidance and compliance without which the HFE effort will remain a "nice to have" at best or will have to rely upon the good intentions of the contractor/vendor. The importance of early availability of specifications, standards and requirements is also crucial to the total and consistent implementation of their content. Ideally these documents will be available during awareness training to provide attendees with the information and familiarize them with the documents content.

It is also extremely important that the HFE design inputs be based on the relevant standards such as the following:

- American Society for Testing and Materials. (2000). *Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities* (ASTM F 1166 – 2000). West Conshohocken, PA: Author.
- American Society for Testing and Materials. (1991). *Standard Human Engineering Program Requirements for Ships and Marine Systems, Equipment and Facilities* (ASTM F 1337 – 2001). West Conshohocken, PA: Author.
- American Bureau of Shipping. (1998). *Guidance Notes on: The Application of Ergonomics to Marine Systems*. New York: Author.
- American Bureau of Shipping. (2002). *Crew Habitability on Offshore Installations*. New York: Author.
- NORSOK Standard. (1997). *Working Environment.* (S-002, Rev. 3)

Other project specific design requirements developed by HF Personnel.

Examples of such documents that have been developed for specific companies or projects in the past include the following:

- HFE Requirements for Offshore Living Quarters.
- HFE Requirements for Workplaces.
- HFE Requirements for Controls, Displays, Alarms, and Operator Panels/Consoles.
- HFE Requirements for Location and Orientation of Valves.
- HFE Requirements for Labels and Signs.
- HFE Requirements Ramps, Stairs, Vertical Ladders, Work Platforms, Walkways, and Railings.
- HFE Requirements for Computer Displays.
- HFE Guidelines for the Preparation of User Operational/Maintenance Manuals.
- HFE Specifications for Environmental Conditions in Enclosed Spaces.

Additional references are listed separately in Appendix A for use in obtaining information on specific topics. This list of references is not all-inclusive and only representative of the information available on HFE related topics.

2.4 Close Cooperation between Operations and HFE

The input of the end user, generally represented by Operations and Maintenance, is critical to the successful deployment of any new system and must be sought during every phase of the project cycle. By soliciting the opinions and knowledge of persons who have experience with systems, facilities, and equipment similar to that under design, many of the lessons learned by these individuals and information regarding strengths and limitations of the user population can be incorporated into the current design. It is also a commonly held belief that when users are involved in the design process their satisfaction with the end product is increased.

The cooperation between Operations and HF Personnel is the key in the determination of many design parameters and in the development of many project documents. The Operations personnel will provide HF Personnel with task information and data used to select appropriate HFE design guidelines and is integrated into competency profiles, staffing levels, procedure development, and other studies including HAZOPs and materials handling studies. HF Personnel are in turn advocates of Operations, providing them with support and guidance on issues pertaining to human capabilities and limitations. This information can influence the physical design of the facility as well as staffing levels, work scheduling, procedures, and materials handling as examples.

2.5 Early Focus on Known Problem Areas

The early focus should be on the analysis of known problem areas and lessons learned. Information sources that can identify these known problem areas include industry wide and company specific accident and incident reports and near misses, interviews with Operations and Maintenance personnel on similar existing facilities and equipment, and inputs from HF Personnel with offshore design experience. Where existing data is not available, a Front End Human Factors Engineering Analysis (FEHFEA) or a similar type of Gross Task Analysis should be conducted. This involves a multi-disciplinary team who identifies potential problems in the design of the human-machine-environment interface and ensures that these are addressed during the detail engineering design phase.

3.0 HOW TO INTEGRATE HUMAN FACTORS ENGINEERING (HFE) INTO THE PROJECT LIFE CYCLE, UP TO POST-COMMISSIONING AND START-UP

To ensure the effective integration and application of HFE design principles throughout the various life cycle phases of a capital project, a strategy is required which will establish management responsibility and accountability for HFE. The objective of this paper is to propose such a strategy. This can best be achieved by introducing HFE into existing project management systems with the prime objective of ensuring that the relevant HFE activities are executed effectively and efficiently at every stage of the project.

Once the appropriate level of HFE involvement in the project has been determined by project management, the critical points for bringing HFE activities into the project must be identified relevant to the project schedule. The attached Sample HFEP provides an overview of the high level activities associated with HFE and their relative time frames within a project. These activities follow the generalized life cycle model for HFE that requires the integration of analysis, design and verification, and evaluation.

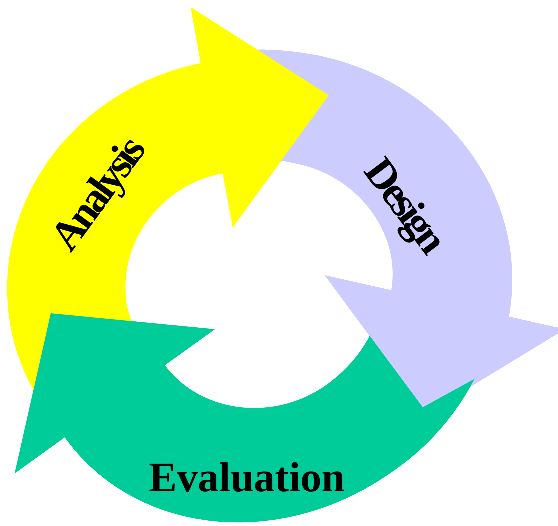

Figure 1. Life Cycle Model for HFE

Some of these activities have been expanded upon below:

3.1 HFE Vision and Policy Statement

The first step in the creation of a HFE Vision Statement is obtaining the approval and support for the implementation and integration of HFE into the new design project from senior management. This commitment on management's part should be included in a vision statement, which explains how

HFE will be addressed in relation to the project, within the company. This statement can be a stand-alone policy under its own HFE heading, or included as part of the Health, Safety, and Environment (HSE) policy statement.

The corporate or management level HFE vision statement should be related to a project level HFE mission statement. Similar to the corporate level statement, the project level statement will also require the approval and support of project management and discuss how HFE will be addressed in relation to the project.

A high degree of correlation between the two statements is required to ensure that the HFE desires of both levels of management are communicated compellingly throughout the project team and all phases of work. These two statements are supported by the project objectives.

Attached are Sample Vision, Mission and Objective Statements found in Appendix B. Note that these samples may not address all of the issues relevant to a specific project and that the terms of the project will also impact this statement.

3.2 Management and Project Team Orientation

Once the policy statement has been formalized, management and employees responsible for project execution need to be orientated to HFE, what it is and why it should be a part of a capital project. The Project Human Factors Engineering Plan (HFEP - Section 3.3.1.2), developed immediately upon management approval and support for HFE integration, should be introduced as part of this orientation as an outline of the required HFE tasks and how they integrate into the overall project. Such sessions are frequently called HFE awareness training sessions. Additionally, active support and involvement of line and project management is important to ensure successful implementation of the HFE strategy. Project managers, construction managers and line managers should be provided with knowledge about HFE principles and best practices and the added value of HFE as well as its tangible and intangible benefits.

Generally, the objectives of an awareness-training program are as follows:

- A basic knowledge of when and why human errors occur on offshore structures and onshore facilities
- A basic knowledge of HFE and why it should be applied during the project
- A basic knowledge of HFE design standards and how to use them
- Sufficient knowledge to recognize when and how to solicit HFE assistance when required.

The skill levels for different persons on the project team will generally be job specific and are addressed through the depth of training provided. A general overview for management training may require a two hour presentation to accomplish the objectives above, while a designer or engineer may require an eight hour training session to communicate the required level of understanding.

3.3 HFE Tasks/Activities

In the following paragraphs are listed typical activities performed by HF Personnel, from conceptualization to post-commissioning and startup phases of the project. These phases will obviously be different depending on the operating company or client. In order to perform some of these HFE Tasks/activities a number of HFE tools or techniques are mentioned. It is not the intention of this white paper to provide detail on these tools or techniques. The company is best served by having the techniques or tools applied by HF Personnel. .

3.3.1 Concept Phase (Define and Select)

3.3.1.1 Include HFE Requirements in the Project Specification(s)

During this phase detailed HFE design requirements that will accommodate the physiological, psychological and sociological characteristics of the anticipated end-user population must be included in the project specification(s) by those responsible for HFE on the project team. These specifications will also address the requirements that will initiate the HFE integration activities and tasks including operability assessments and verification. These requirements may take the form of calling out an HFE design standard such as ASTM F1166-2000 or the ABS Ergonomic Guidance Notes, or by developing and including company specific HFE design requirements in the project specification(s). The importance of early availability of specifications, standards, and requirements is crucial to the total and consistent implementation of these documents. Ideally these documents will be available during awareness training to provide attendees with the information and to familiarize them with the documents content. See Figure 2 and Figure 3 for examples of HFE requirements.

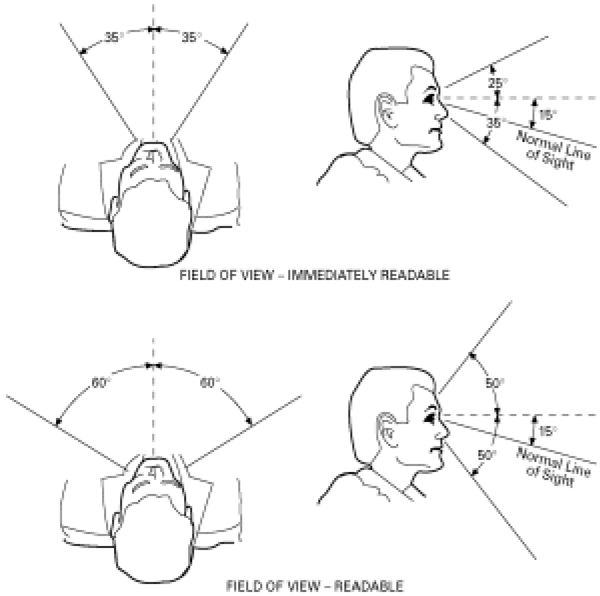

Figure 2. Operator Field of View

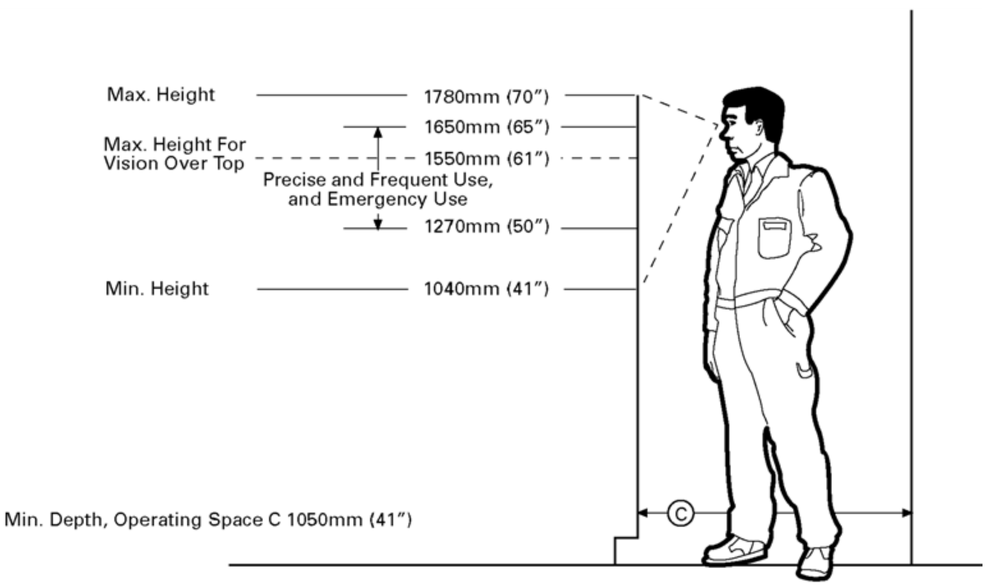

Figure 3. Multi-tiered Standing Console

(Figures used with the Permission of ABS)

Companies may also integrate (embed) specific HFE guidance and requirements directly into appropriate technical standards as opposed to separate HFE requirements or both. The project specifications should also include the scope of HFE work to be completed by the contractor as appropriate. It is important to have HF Personnel involvement during the project development as well as inclusion of HFE requirements into the project specification. This is largely because on any particular project there may be other factors that constrain the inclusion of certain HFE design requirements. Examples include: Operations may require the use of certain equipment, a specific process, or a design logic compatible with existing facilities, safety systems, etc. which may conflict with preferred HFE guidance (this most often happens when an existing facility is being expanded); contract terms, regulatory requirements, etc. may limit flexibility to implement certain HFE considerations, equipment choices, allowable suppliers, etc. It will therefore generally require HF Personnel to assist the project team in tailoring the HFE requirements for inclusion in the project specifications.

It should be noted that the importance of HFE integration activities, like operability assessments, are frequently underestimated and fail to be incorporated into the detailed design or feedback. Hazard and operability studies, which are commonly implemented in a project to address these issues, fail to cover the entire scope of operations in favor of review of the design philosophy that is easier to discuss. This failure has lead to the involvement of HF Personnel in other processes including 3D CAD and model reviews to address issues missed in the hazard and operability analyses.

3.3.1.2 The Project Human Factors Engineering Plan (HFEP)

The HFEP is a key part of the successful integration of HFE into a project. The HFEP should describe the scope of HFE work to be completed by each party, including the specific tasks and their relation to the project schedule, the deliverables, organizational structure, responsibilities of all parties involved, and vendor and subcontractor activities. Responsibility for developing the document can be assigned to the company, contractor or both parties depending on the contracting philosophy undertaken. In the case that the company assumes the responsibility for the HFE activities, the HFEP should be written by the company. In the case that the contractor assumes full responsibility for HFE activities, the contractor should write the HFEP as part of the bid package or as specified in the RFQ. There may also be the case where the company will develop an HFEP for the management of their own HFE activities that occur at a higher level than the contractor's HFE activities. In this case the company should define the concept for both HFEPs and the contractor should conform to the requirements therein. Irrespective of the author, the HFEP should be prepared as early as possible and upon management approval and support for HFE integration at the project level and assignment of the contract at the contractor level.

In any case the HFEP should be written prior to any awareness training. By having an approved HFEP prior to training, the implementation of the plan is secured and all members of the project team can be made aware of how HFE integrates into the project as a whole.

Attached is a sample HFEP found in Appendix C. It should be stressed that the HFEP does not include all of the topics covered by this white paper. The white paper addresses the strategy and philosophy for implementing HFE in a project while the HFEP is the process of implementing HFE in a project. In addition, there are topics covered by the white paper, which may be optional components of an HFEP, depending on the type and scope of a project.

3.3.1.3 HFE Participation During Conceptualization and Formulation of Philosophies

During this early stage of the project HF Personnel need to participate in all analyses that reach decisions and formulate philosophies regarding the health, safety and or environment of personnel as well as the operability, maintainability, and staffing levels of the facility. This may include control system, safety system, and emergency philosophies. HFE inputs must also be provided to the conceptual design and preliminary layouts in order to facilitate operability, maintainability, and to reduce the potential for human error.

3.3.1.4 Front End Engineering Definition (FEED)

During the Front End Engineering Definition (FEED), a Front End Human Factors Engineering Analysis (FEHFEA), Gross Task Analysis study (ASTM F1337 - 2001) or FEEEM® Design Analysis needs to be performed under the guidance of HF Personnel. The purpose of this task analysis and the analysis of lessons learned on similar existing facilities and operations input is to identify potential problems in the design of the human-machine interface with regards to the working environment. These analyses are also necessary to ensure that the potential problems previously identified are being addressed during detailed design. Certain critical facilities such as the Central Control Room, Driller's Control Cabin and the Offloading System will require a dedicated task analysis. Optimally studies such as these and operational and functional task analyses should begin shortly after the development of the process flow diagrams (PFD's). This timing will minimize the costs related to changes and schedule impacts and will allow the studies to continue smoothly during the detailed engineering design phase. Additional information on task analysis requirements is available in NORSOK S-002, Working Environment Standard (http://www.nts.no).

3.3.2 Detail Engineering Design Phase

3.3.2.1 Contractor Selection and Award

During the contractor selection and award process, the company, with the help of the HF Personnel, needs to evaluate contractor bid packages for the inclusion/integration of HFE requirements. The contractor should include in its bid package a Human Factors Engineering Plan (HFEP), when applicable, describing the scope of HFE work to be completed for the project, the deliverables, schedule, organizational structure and responsibilities of those involved including vendor and subcontractor activities. The information presented in these packages and the quality of the contractor HFEP provided (when applicable) is indicative of the contractor's capability in the area of HFE. The bid submittal should be reviewed for adherence to the HFE requirements included in the project specification. The evaluation must check the credentials of the contractor's proposed HF Personnel to ensure that they are qualified. Where HF Personnel are located within the contractor organization should also be considered and it is recommended that these persons be under the Engineering department, though Operations and HSE are also acceptable organizational locations. The physical location of this staff with regard to the remainder of the project team should also be considered. It is to the company's benefit for the HF Personnel to be co-located with the contractor's engineering staff.

3.3.2.2 HFE Champion

Project management must ensure that an HFE point of contact has been appointed within the company's project management team for each phase of the project. This point of contact is called the HFE Champion or HFE Accountable Person. The HFE Champion is most effective when this person has been appointed early in the project development and has approval authority covering most, if not all, items relating to HFE. Organizationally the HFE Champion and HF Personnel should be an integral part of the project team and they should be physically and organizationally located within the Engineering (preferred), or Operations (acceptable) department depending on the life cycle phase of the project. Past offshore project experience has shown that placing HFE Personnel in a support group, such as HSE, is not advisable but may work depending on where the HSE or support group representative reports to in the project organizational charts. Having HSE or the support group report to a project director will provide HFE with the support of senior project management.

3.3.2.3 Contractor HFE Awareness Training

Awareness training to contractor project management and an introduction to HFE training seminar to the contractor project management, engineering and design team must be provided before detail design begins. This training should include an introduction to all of the HFE activities to be performed during detail design and should describe what will be needed from the engineers and designers to accomplish those activities. Training should include presentations on the HFEP and design requirements, guidelines and checklists.

3.3.2.4 HFE Design Requirements, Guidelines and Checklists

The HFE design specifications included in the project specification are to be made available for use by designers and for inclusion in RFQs to vendors. It may be necessary to support these HFE design specifications with additional HFE guidelines and checklists subject to the approval of the company HF Personnel. HFE specifications may need to be tailored for specific vendor package RFQs. If required, company specific documentation such as standards, should be developed. Special documents should be developed prior to HFEP and awareness training for their inclusion in the appropriate documents.

3.3.2.5 HFE Action Item Tracking Database

HF Personnel should also document all HFE recommendations and design inputs made from the earliest point of HFE involvement and throughout all phases of the project. A database for keeping track of these HFE action items will allow for action item follow-up, closure, and for HFE progress reporting. Regular progress reports of HFE activities should be provided to project management.

3.3.2.6 Specific HFE Analyses and Studies

In order to properly support a design decision HF Personnel may be required to conduct specific HFE analyses. In some cases information is provided on human capabilities and limitations as input to studies conducted by Engineering, Operations and Maintenance (O&M), or other parties as required. Examples of such analyses and studies include:

- **Function allocation, task analyses and job descriptions** – The purpose of these HFE analyses is to identify which system functions are to be performed by equipment and which tasks are to be performed by personnel. For those tasks allocated to human operators, these analyses determine whether they are compatible with human physiological and psychological capabilities and limitations. Finally the tasks are grouped together and described as a single job or position, which serves as a major input for the determination of personnel competency profiles. HF Personnel will generally conduct these analyses though the data may be collected by other persons for analysis. Additional information on task analysis requirements is available in NORSOK S-002, Working Environment Standard (http://www.nts.no).
- **HAZOP's for key areas** – Hazard and Operability Studies (HAZOPs) are one of the most popular process hazard analysis techniques currently used in the offshore industry. The purpose of reviewing human factors within the HAZOP is to identify situations, equipment, or other factors which may result in human errors, thus creating process hazards, operational upsets, or maintenance problems. Once potential errors are identified, steps can be taken to control these deficiencies. The HAZOP team is composed of personnel representing the required engineering and technical disciplines who have experience with the primary hazards of the facility's processes. While human factors must be addressed during the HAZOP, it is not generally a required engineering discipline to be represented on the HAZOP team. The HAZOP team will be placed at a disadvantage if there is a lack of representation of HFE skills and knowledge on the team. This can result in the misapplication of training or procedural changes, or to the misapplication of equipment changes to control or correct for human error potentials and human performance related issues. HF Personnel should participate in the pre-HAZOP review of documentation such as layout drawings and piping and instrumentation diagrams/drawings (P&IDs). With the support of Operations and Maintenance personnel, HF Personnel will define the tasks that an operator would be expected to perform and which tasks would be assigned to equipment. During the HAZOP all issues that have HFE implications should be noted in the HAZOP record. An important mechanism to identify HFE concerns is the team's discussion of causes of deviations from the system intent along with the identification of the root causes of these deviations.

Whenever the potential for human error is identified during a HAZOP study, the team should discuss how and why such an error could occur and ensure that the HAZOP record documents the source(s) of such errors. HF Personnel should review the identified concerns as well as the suggested safeguards/controls and recommendations. This HFE activity is to ensure that the recommendations will reduce the probability of the error or reduce the consequence of the error to acceptable levels. Following the study HF Personnel may also need to perform additional analysis to evaluate the extent of identified HFE problems and their control.

- **Valve Criticality Analysis (VCA)** - The purpose of this study is to classify and then locate all valves used on a facility based on their criticality. The classification is based on a formal set of criteria agreed upon by all relevant members (disciplines) of the Engineering, Design, Operations, and Maintenance teams. The major benefit of the VCA is that it formalizes the decision process for determining the location (accessibility) of all valves. It also provides clear guidance to designers, speeds up the overall design review process, and alleviates unnecessary lengthy discussions on valve locations as the design progresses to completion. Additionally, the VCA ensures that operational and maintenance requirements are addressed when deciding on the location of a valve and this process generally reduces the cost of over-design. An example of this utility is the elimination of unnecessarily long piping in order to make valves accessible from deck level or the provision of stairway access and work platforms for access to non-critical valves. HF Personnel participates in all criticality discussions and provides guidance on acceptable locations for valves of different criticalities.
- **Emergency egress, escape and evacuation** – The purpose of this study is to review the HFE requirements during an emergency on an installation. This will include analysis of the escape routes, muster stations, and the integrity of the temporary refuge, the survival crafts/lifeboats and fast rescue crafts. During an emergency the most critical aspects of operations are the communications to personnel of the hazardous event and the design provisions that have been included to ensure the integrity and visibility of the egress routes. This includes HFE inputs on: the frequency, type and magnitude of the tones utilized for the alarms; the color, frequency/intensity, and location of alarm lights; and the markings, lighting, protection/shielding (plating, grating or heat shields) and clear width of escape routes (especially for stretcher access). After the egress routes, the next most critical location is the muster point. This would normally be located in a temporary refuge and is a designated point for verifying that all personnel are accounted for before the final decision to abandon and evacuate is made. The critical HFE aspects of this location include access/egress for the normal compliment of personnel on the

installation, the size of the muster station (adequate enough in size to minimize claustrophobic fears or stress with full evacuation equipment on), the communications in the refuge area (clarity), heat / carbon dioxide accumulation and stress, physical protection against the accidental event, and proximity to survival crafts/lifeboats. Generally, a secondary muster point is designated on the installation and would require the same HFE specification as the primary muster area. The final safety critical system is the HFE aspects of the survival crafts (lifeboats) and their boarding/staging locations. Designers should ensure that the survival crafts have incorporated HFE considerations during design, testing, maintenance, and operations of this equipment. This would include ensuring cultural calibration of the seats/entrance and critical pieces of operating equipment in the boat, stretcher access, recovery of overboard personnel and operations and control of the lifeboat. The study is normally performed by the HSE Specialist with significant input from HF Personnel.

- **Material handling study** – The purpose of this study is to define the requirements for material handling, either mechanically assisted or manually, on the facility. It is conducted by engineering with inputs from HF Personnel to interpret design standards and provide additional design guidance as needed on human capabilities and limitations. This study is conducted largely to prevent injuries from manual materials handling activities and to reduce downtime during scheduled and unscheduled maintenance activities. The scope of this study may include the evaluation of material handling equipment, selection of materials handling equipment, validation of paths of movement and clearance for this equipment, and accessibility to equipment.
- **Crane study** – The purpose of this study is to optimize drop zones or laydown areas based on crane operator viewing angles from the crane cab. This is conducted by engineering with input from HF Personnel on operator eye positions based on the appropriate anthropometric dimensions as well as other relevant information on human visual capabilities and limitations. Crane studies may also include review of the operator interface controls, work environment evaluations, accessibility issues including ladders and handrails and review of operational procedures.
- **Control room study –** The purpose of this study is to focus not only on the control room layout and ambient environment, but also on all types of activities to be performed under both normal and abnormal conditions. The aim is to further identify any factors that may negatively affect the operator and other designated personnel's ability to detect deviations, diagnose the situation, and take action following a given abnormal situation in the process and the subsequent sequence of events. The weak points identified by the study are then used as a basis for design recommendations. The Control Room Study group/team should consist of a control

room operator, instrument engineer, process engineer and HF Personnel. The group should be led by HF Personnel who is familiar with the techniques or tools needed for the analysis and with experience in control room design. Additional personnel from specialized disciplines; e.g., electrical, HVAC, telecom, HSE and Human Resources may be required to participate for short periods during special topics of the study. (ISO 11064: *Ergonomic Design of Control Centres* can be used as a guideline. Additional references include: A *Method for Reviewing Human Factors in Control Centre Design* developed by the Institutt for Energiteknikk in Norway and available on the web-site of the Norwegian Petroleum Directorate (www.npd.no); and Ingstad and Bodsberg's (1990) *CRIOP: A Scenario-method for Evaluation of the Offshore Control Centre.)*

- **HAZOP's of critical operating procedures** The purpose of this exercise is to identify potential human error during critical operations as a result of poorly written operating procedures. One example of such critical operating procedures is pig launching/receiving. The study is conducted in the same fashion as a traditional HAZOP. This study is generally conducted by HF Personnel with input from Operations, Maintenance, and Engineering.
- **Competency profiles** – The purpose of creating competency profiles is to specify the job performance requirements of the personnel who will be using a new system. This profile can also be used as a basis for personnel selection, training, qualification, and placement. The competency profile defines human performance requirements, and can be compared with an engineering specification for facility equipment. Using competency profiles as a basis for selection eliminates much of the uncertainty in the selection and training process, and subsequently reduces the technical and commercial risks associated with employee attrition, failures during training, and human error. The purpose of competency profiles is to minimize the effort required to select, train, qualify and potentially upgrade personnel prior to start-up. The competency profile establishes the entry and performance requirements for employees, but does not define the employee selection process, the training process, or the qualification process outside the establishment of performance limits. The competency profile is the minimum standard required for employees in each job/position. The competency profile identifies *what* the end product should be: a qualified, skilled employee with the appropriate physical capabilities (e.g., visual and auditory) for each specific position. It does not identify *how* to recruit, train and qualify personnel in order to reach the desired competency. This study is generally performed by Human Resources Personnel or HF Personnel with the relevant training and experience with input from Operations, Maintenance, and Engineering.

A responsibility matrix outlining several of the tasks that are part of integrating HFE into the project is included in the Sample HFEP. This matrix indicates accountability, responsibility, review and comment and technical support needs.

3.3.2.7 HFE Requirements in Vendor Specifications

During procurement HF Personnel must ensure that HFE design specifications, guidelines or checklists are included in RFQs to vendors. Furthermore, HFE specifications for specific vendor package RFQs must be tailored by HF Personnel, if necessary. If required, HF Personnel develop company specific documentation. HF Personnel participate during the evaluation of vendor bid submittals to evaluate bid packages for inclusion/integration of HFE requirements and for adherence to these requirements.

A list of equipment and equipment systems is provided in Appendix F that addresses the HFE priority for that equipment or system as well as the specific area of HFE concern. This listing, while extensive, may not be complete for all projects and the project scope of work and HF Personnel should be consulted.

3.3.2.8 HFE Design Inputs

HF Personnel provide HFE design inputs to project engineers and designers during detail design of workspaces and facility layouts; including, for example, areas such as the control/monitor room, accommodation facilities and human-machine interface workstations or those areas identified during the FEHFEA or FEEEM® Design Analysis. The reasons that these design inputs must come from HF Personnel are: 1) they may result from HFE analyses and studies that have been conducted, 2) because there is no direct criteria available from the design standards, or, 3) the designers are often uncertain how to interpret a general HFE requirement and need assistance from HF Personnel. Assistance is required especially where there is a conflict between different HFE requirements, or between HFE and other engineering requirements.

3.3.2.9 HFE Participation in Design Reviews

HF Personnel should be a required participant in reviews of most drawings produced by the company, contractor and vendor engineering personnel. This review will allow HF Personnel to review the drawings for operability, maintainability, and accessibility as well as workflow. The introduction of the three-dimensional computer-aided design (3D CAD) has become a powerful tool to be used in conjunction with the 2D CAD drawings for this purpose. Consequently, it is important that HF Personnel be involved in all the appropriate 2D and 3D CAD design reviews, particularly the detail design reviews held at 30%, 60% and 90% of design completion. While it is recognized that not every project will make use of the 3D CAD technology, in cases where the option is available, HFE involvement is crucial.

3.3.2.10 HFE Inputs to Personnel Selection and Training Criteria

HF Personnel can assist the Human Resources personnel and Operations and Maintenance engineers by providing competency profiles for use in employee selection. In the absence of competency profiles HF Personnel must assist these persons with the entry and performance requirements for each job or position that has been identified for the new system. Entry requirements would typically include basic performance requirements, physical and psychological criteria (such as aptitudes and abilities), personality preferences (e.g., team orientation) and basic life skills (such as reading, problem solving and decision making). Performance requirements will typically include requirements common to all positions such as HSE awareness, PPE equipment operation or emergency operations (such as survival craft operation for emergency evacuation etc.). Each position will also typically require specific knowledge, skills and abilities required for job performance and these are generally grouped into job classes or duties; e.g., system operation, maintenance, administrative and logistics, HSE, etc. Some HF Personnel may be capable of providing inputs on how to recruit, train and qualify employees in order to reach the desired competency required, but these activities are generally best performed by suitably trained and experienced Human Resource specialists. The use of competency profiles or any other selection tools should be only with approval of company legal staff.

3.3.2.11 HFE Inputs to Operations and Maintenance Documentation

HF Personnel should review and provide HFE inputs during the development of operation and maintenance documentation, training devices and instructional material to ensure they meet HFE principles for design and usability. HF Personnel can also serve as a valuable source of information for these documents, because task analyses conducted as part of the HFE evaluation will yield a great deal of the information for procedures. In addition, HF Personnel can provide guidance on the usability of the material including informational content, layout, location, size, use of symbols and pictograms, etc., to ensure information is presented based not only on visual capabilities but also on psychological principles for human information processing.

3.3.2.12 HFE Inputs to Signs and Labeling

In addition to the content and design of the documentation and manuals, HF Personnel should be involved in the content and design of hazard warning signs, labeling programs and job aids. HF issues related to the design and content of these items include color, informational content, layout, location, size, use of symbols and pictograms. As with documentation, signs and labeling must take advantage of research on human capabilities and limitations to ensure that the intended message is clearly received.

3.3.3 Construction/Fabrication Phase

3.3.3.1 HFE Awareness Training to Construction Staff

At the start of the construction phase, those responsible for HFE must conduct HFE awareness seminars and special training sessions for the construction field staff (especially on-site inspectors) to develop a general awareness for HFE, to familiarize them with HFE integration efforts performed during the design phase, and to introduce them to the HFE problems that often are created during the construction phase.

3.3.3.2 HFE Inspections

HF Personnel must visit fabrication yards and construction sites in order to audit compliance to HFE design requirements and ensure that the HFE requirements considered during the engineering and procurement phases have been implemented as per design. These inspections would generally be held in conjunction with other HSE audits and inspections.

3.3.3.3 "Field Run" or "Field Installed" Equipment

HF Personnel must provide support during the installation of "Field Run" or "Field Installed" equipment to ensure compliance with project HFE design requirements. Additional verification of the application of HFE to the final installation will occur during the safety walk through inspections in which HF Personnel should participate.

3.3.4 Installation through Startup Phases

The opportunity to be involved in the installation, hook-up, commissioning and start-up of the facility will allow HF Personnel to observe these activities and will allow for the verification of the tasks and operational and maintenance procedures that were developed. The presence of HF Personnel during this time will allow HFE to be considered in the correction of problems identified, provide an opportunity for the generation of lessons learned from HF Personnel experiences and provide a better understanding of the practical methods used for performing common operations and maintenance tasks and procedures.

3.3.5 Operate Phase

When the facility is in operation, generally some form of feedback is required. Typically the following activities can be performed by those responsible for HFE as part of the API requirements for tracking operability in the first year:

- Conduct operability assessments at six months and one year. These assessments should be planned and their scope outlined during the commissioning and startup phase to address common operational and maintenance issues as well as problems and concerns that arise during the commissioning and startup activities
- Obtain operator feedback via written and personal interviews regarding HFE successes and failures relative to operability and maintainability
- Monitor accident/incident reports for the identification of HFE design deficiencies
- Develop a lessons learned file or database
- Review problems identified or modifications made and improve upon solutions.

The importance of the information gathered during operations cannot be understated. This information is invaluable to the designers, engineers and HF Personnel as feedback on the process and outcome of their efforts and provides a loop of continuous feedback as these personnel move from project to project.

4.0 DETERMINING WHAT LEVEL OF HFE INVOLVEMENT IS REQUIRED FOR A PROJECT

The question often arises with project managers as to what level of HFE involvement is applicable to their capital project. This is a reasonable question since capital projects can range from simple (e.g., replacement piping system with no design changes) to intermediate (e.g., addition of a new system such as a chemical injection skid to an existing facility), to major (e.g., design and construction of a new offshore platform). The type and number of HFE activities on any single capital project should be appropriate to the size and magnitude of the project including its complexity, whether or not it has a predecessor facility, the degree of similarity between the new and existing facilities operated by the company, and which, if any, HFE activities were performed on the previous facilities.

Simple acquisition projects that represent only minor changes in design, technology, or operator/maintainer tasks would not require the majority of activities described in this paper but should still be reviewed by HF Personnel. These projects generally result in minimal change to personnel knowledge, skills, selection, training, or system operation and therefore most of these activities would not be appropriate. However, a new, major capital project will in most every case demand HFE participation, since the impact of the new design and the various design alternatives on the Operations and Maintenance personnel are not predetermined.

The questions below are representative of those that can be used to guide project management on the decision as to what level of HFE involvement would be most beneficial to a particular capital project:

- Will the type of personnel involvement or the philosophies related to the operation and/or maintenance of the new facility or equipment differ substantially from what is currently practiced by the company?
- Will the new facility, equipment, instrumentation, etc. introduce new technology or impose new tasks and skill level requirements on the operators and maintainers?
- Is one of the objectives of the new project to optimize staffing levels in the new facility?
- Will the new facility be used by a different user population than is intended in the design standards and specifications?
- Will the facility be designed by a U.S. engineering contractor using U.S. design standards, for use in another country and operated by local or third-country nationals? If so, the design will require some level of cultural calibration, which is a review of the unique cultural requirements of the user nation that differ from U.S. standards.

The answers to these questions and many others will help determine the appropriate level of HFE involvement in the design of the new project.

5.0 THE IMPORTANCE OF THE INVOLVEMENT OF HF PERSONNEL

The selection and assignment of HF Personnel to the design team, together with the relevant HFE design requirements, are crucial to the success of the project's HFE integration effort. The HF Personnel must have the necessary academic credentials and relevant experience in HFE to support the HFE integration process. The integration of HFE requires a particular academic background and expertise. Experience has shown that employing or contracting HF Personnel during a project is a critical factor for successful implementation and integration of HFE (Robertson, 1999; Sworn and Stirling, 1999).

5.1 Experiences Regarding Use of HF Personnel

Studies on two large-scale engineering design projects for topsides in the North Sea by Wulff et. al. (1999), recent experiences with HFE integration in Gulf of Mexico, and other projects indicate that the provision of HFE requirements by themselves are not sufficient to ensure compliance with HFE design principles. The primary findings of these studies were:

- Active HF Personnel integrated in the design organization was critical. Close personal contact appears important for a positive result. HF Personnel functions as a proxy representative of operators and maintainers to ensure that their interests are taken into consideration.
- Neither the personnel responsible for HFE nor the HFE design criteria were well known by project members. It was found that the designers on these projects did not assimilate all the HFE design requirements and transform them into an optimal design. The project documents did not make clear the criteria by which the design was to be optimized nor how to resolve situations where different criteria were in conflict. Due to time and cost constraints, HFE requirements were resisted and in some cases simply not recognized. An interaction between HF Personnel as the owner and the designers as receivers of the new HFE requirements seemed to be more important to the designer's recognition of HFE than the distribution of documents outlining the requirements.
- Design groups are traditionally organized along functional lines, which can make it difficult to develop an overall design with HFE considerations in mind. Workspace design becomes a by-product of the partial designs of these functional groups. Active participation by HF Personnel can help to overcome these organizational barriers. Such participation also creates recognition in different departments of the need for HFE information and an awareness of HFE in general.
- Designers preferred specific HFE requirements to general requirements and recommendations, though providing these requirements did not guarantee their implementation. General requirements have to be supported by procedures to ensure their interpretation in each specific design situation. Due to the sheer amount of documentation, HFE requirements were not always read, and even when read the requirements were not necessarily understood or implemented. In some circumstances requirements were simply not implemented as a consequence of a screening process or a bargaining process where implementation of some requirements won and some lost.

- It appeared that the designer and engineering culture formed by their technical education and previous engineering projects was not conducive to an emphasis on human factors. HFE is only one, and usually not the most important, consideration for design engineers. Schedule and cost are important constraints to the HFE requirements. Since the design is typically developed in parallel by different departments, any requirement that was not known to the designer who made the initial design might imply the need for change, resulting in a design delay. This points to the need to have HF Personnel involved in the design process from the beginning, especially during consideration of the layout.
- Designers were often uncertain how to interpret a general HFE requirement and needed assistance from HF Personnel. If such assistance was not provided, the requirement was not implemented. There was often a conflict between HF and "technical/engineering" requirements. A tight budget and strict time constraints enhanced these conflicts.
- Timing of HFE considerations was also a problem because these considerations were not introduced until the detailed design phase. The study found that the active participation of HF Personnel together with high legitimacy (strong emphasis on HF requirements by regulatory bodies, company and project management) would help to ensure a positive outcome of this conflict or negotiation process.
- Perhaps the most important finding of these studies is the emphasis on engineering design as a trade-off process. Various factors in the design have to be considered. Many times this means that one aspect of the design is made optimal at the expense of another area being made somewhat less then optimal. Often there are many potential choices in the design of a particular aspect. One role of the project engineers is to evaluate the overall effect of these potential choices and determine which provides the best overall solution to the problem both from technical and business standpoints. This process is one of understanding the "trade-offs" involved in the various options.
- It was found that implementation of HFE in such a setting was a matter of negotiation among project members. For HFE to be successfully implemented, a party with strong interests in the HFE aspects of the design is needed. This role is best served by HF Personnel with support from the Operations staff. In addition, the negotiating position of HF Personnel and Operations representatives in engineering design should be strengthened by organizational means.

- HF Personnel had a general quality assurance role and functioned as a resource when there was a need to interpret general requirements into design specifications. It was important to these projects to strengthen the HF Personnel's negotiating position by emphasizing HFE in general company policy documents, by placing HF Personnel high enough in the organizational hierarchy and by enlisting active senior management support. HF Personnel also had the important task of evaluating and to some extent authorizing deviations.

In summary, both recent experience on Gulf of Mexico deepwater projects and the studies by Wulff et. al. (1999) point out the need for HF Personnel involvement from the conceptual design phase through the project's commissioning and start-up.

5.2 Responsibility for Execution of HFE

The HFEP or HF integration strategy comprises certain typical HFE activities that need to be performed at pre-determined stages throughout the various phases of a project. These HFE tasks/activities take place concurrently with engineering activities throughout the project's execution. Some HFE activities are dependent on engineering decisions and in other cases outputs from HFE tasks/activities influence engineering decisions. HFE and engineering activities are therefore interdependent.

Responsibilities for performing HFE activities are normally assigned to one of three individuals or groups. First, there is the HFE Champion within the company project management team who will be assigned HFE approval authority on most if not all matters concerning HFE. The HFE Champion must be assisted by HF Personnel (as defined above) to support the HFE Champion on technical and other matters as needed. These two individuals or groups will represent the company in all matters relating to HFE on the project. They will be responsible for all HFE activities performed prior to the award of the contract as well as activities identified as being outside the scope of work of the contractor's HF Personnel. These two company positions can be combined if a person with the relevant HFE training and experience can be identified.

The third group of individuals are those HF Personnel, Health and Safety and other personnel within the company, contractor, and occasionally vendor, organizations who will be responsible for all HFE related activities to be performed as required by the Project Specification during all project phases. More responsibility and activities assigned to the company HF Personnel would necessarily result in fewer activities being performed by the contractor's HF Personnel, and vice versa. Past experience has shown that it is more important and beneficial to the end product, if the majority of the HFE activities are taken up by HF Personnel representing the company rather than the contractor. Regardless, HF Personnel, whether company or contract, must be viewed and utilized as an integral part of the design team and have the project management's commitment and support for their activities. These critical success factors for an HFE integration strategy are discussed in Section 2.0.

Examples of specific responsibilities for some of the HFE activities generally performed are provided in the responsibility matrix included in the Sample HFEP. The responsibilities and titles used may vary depending on the contracting strategy as well as what phase of the life cycle the project is in. The contracting strategy will determine who is responsible for the execution of HF activities, specified as the company HF Personnel, contractor HF Personnel or possibly both. The project life cycle phase will determine whether the HFE Champion role is taken up by the Engineering, Construction, Commissioning or Offshore Installation Manager.

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International Standards Organization. (1999e). *Ergonomic Design of Control Centres – Part 6: Environmental Requirements for Control Rooms*. Geneva: ISO (International Standard ISO 11064-6).

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Acknowledgements

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Appendix A - Additional References

Reference	Title
33 CFR	Navigation and Navigable Waters
33 CFR 127	Training requirements - General
33 CFR 155	Training requirements - Navigable waters
33 CFR 95	Operating a vessel while intoxicated
46 CFR	Shipping
46 CFR 10	Licensing of maritime personnel
46 CFR 16	Periodic testing for drugs
46 CFR 5	Maritime Investigation requirements - personnel/drugs/alcohol
ABS	Guidance Notes on the Application of Ergonomics to Marine Systems, American Bureau of Shipping
ANSI/ IESNA RP-1	American National Standard Practice for Office Lighting
ANSI/HFS100-88	American national standard for human factors engineering of visual display terminal workstations
ANSI-S3.2-89	Method for measuring the intelligibility of speech over communication systems
ARI 575-87	Method of measuring machinery sound within an equipment space
ASHRAE 55-66	Comfort standard
ASHRAE 62-1989	Ventilation for Acceptable Indoor Climate
ASTM F1166	Standard Practice for Human Engineering Requirements for Ships and Maritime Systems, Equipment, and Facilities
ASTM F1337	Standard Practice for Human Engineering Program Requirements for Ships and Maritime Systems, Equipment, and Facilities
BS 4884 Part 1	Technical manuals, Specification for presentation of essential information
BS 4884 Part 2	Technical manuals, Guide to content
BS 4884 Part 3	Technical manuals, Guide to presentation
BS 4899 Part 1	Users requirements for technical manuals – Content
BS 4899 Part 2	Users requirements for technical manuals - Presentation
BS 6841	Measurement and evaluation of human exposure to whole body mechanical vibration and repeated shock
BS 95/201899	Lighting Applications - Emergency lighting
Defense Standard 00-25: Parts 1-13	Human factors for the designers of equipment. Directorate of Standardization: Glasgow, Scotland. United Kingdom Ministry of Defense (1988)
DOD-HDBK-743A	Anthropometry of U.S. Military personnel (metric)

Reference	Title
DOT/FAA/CT-96-1	Human Factors Design Guide for Acquisition of Commercial-Off-the-Shelf Subsystems, Non-Developmental Items, and Developmental Systems—Final Report and Guide
EN 292-1	Safety of Machinery - Basic concepts, general principles for design - Part 1- Basic terminology, methodology
EN 292-2	Safety of Machinery - Basic concepts, general principles for design - Part 2 - Technical principles and specifications
EN 349	Minimum gaps to avoid crushing parts of the human body
EN 563	Safety of Machinery - Temperatures of Touchable Surfaces - Ergonomics Data to establish TLV's for hot surfaces
EN 614-1	Safety of Machinery - Ergonomic design principles Part 1 - Terminology and general principles
EN 894-1	Safety of Machinery - Ergonomic requirements for the design of displays and Control Actuators. Part 1 General principles for human interactions with displays and control actuators
FAA	Human Factors Design Guide
IACS	Unified Interpretation SC82 Protection against noise, 1993
IACS	Requirements concerning NAVIGATION. Unified requirements for One Man Bridge Operated (OMBO) Ships. International Association of Classification Societies. 1992
IACS N1	Requirements concerning Navigation
IEC 225	Octave, half-octave and third-octave band filters intended for the analysis of sound and vibration
IEEE85-72	Airborne sound measurements on rotating electric machinery
IESNA RP-12-97	Illuminating Engineering Society of North America, Recommended Practice for Marine Lighting
ILO	International data on anthropometry. Occupational Safety and Health Series: No. 65, (1990)
ILO Convention 133	Convention concerning crew accommodation on board ship (supplementary provisions)
ILO Convention 147	Convention concerning minimum accommodation standards in merchant ships
ILO Convention 155	Recommendations concerning the improvement of accommodation standards in merchant ships
ILO Convention 92	Convention concerning crew accommodation on board ship (Revised 1949)
IMO	International Safety Management Code

Reference	Title
IMO 343 (IX), Agenda item 7	Recommendation on methods of measuring noise levels at listening posts
IMO A.19(830)	Code on Alarms and Indicators
IMO A.468(XII)	Code on Noise Levels on Board Ships
IMO DE 38/20/1	Role of the Human Element in Maritime Casualties - Engine Room Design and Arrangements
IMO DE 38/20/2	Role of the Human Element in Maritime Casualties - Guidelines for the on board use and application of computers
IMO DE 40/WP.5	Draft MSC Circular, Guidelines for engine room layout, design and arrangement
IMO NAV 43/6	Ergonomic Criteria for Bridge Equipment and Layout
IMO NAV 45/6	Ergonomic criteria for bridge equipment and layout
IMO RES. A.686 (17)	Code on Alarms and Indicators
IMO RES. A.708-17	Navigation Bridge Visibility and Functions
ISO 10075	Deals with ergo principles related to mental workload
ISO 10551	Ergonomics of the thermal environment—Assessment of the influence of the thermal environment using subjective judgment scales
ISO 11064-1	The Ergonomic Design of Control Centers Part 1 Principles for the design of Control Centers
ISO 11064-2	The Ergonomic Design of Control Centers Part 2 Principles of Control Suite Arrangement
ISO 11064-3	The Ergonomic Design of Control Centers Part 3 Control Room
ISO 11064-4	The Ergonomic Design of Control Centers Part 4 Workstation and Layout Dimensions
ISO 11064-5	The Ergonomic Design of Control Centers Part 5 Displays and Controls
ISO 11064-6	The Ergonomic Design of Control Centers Part 6 Environmental Requirements for Control Rooms
ISO 11064-7	The Ergonomic Design of Control Centers Part 7 Principles for the Evaluation of Control Centers
ISO 11064-8	The Ergonomic Design of Control Centers Part 8 Ergonomic Requirements for Specific Applications
ISO 11399	Ergonomics of the thermal environment—Principles and application of relevant International Standards
ISO 13731	ISO/CD Ergonomics of the thermal environment - vocabulary
ISO 13732	ISO/NP Contact with hot, moderate, and cold surfaces
ISO 14612	Ship's bridge layout and associated equipment - Requirements and Guidelines

Reference	Title
ISO 14726-1.	Ship and marine technology—Identification colors for the contents of piping systems—Part 1: Main colors and media
ISO 1999	Acoustics -- Determination of occupational noise exposure and estimation of noise-induced hearing impairment
ISO 2041	Vibration and shock - vocabulary
ISO 2631	Guide for the evaluation of human exposure to whole-body vibration
ISO 2923	Acoustics - Measurement of noise on board vessels
ISO 4867	Code for the measurement and reporting of shipboard vibration data
ISO 4868	Code for the measurement and reporting of local vibration data of ship structures and equipment
ISO 6385	BSI/ISO standard - Ergonomic Principles in the design of Work Systems
ISO 6954	Mechanical vibration and shock - Guidelines for the overall evaluation of vibration in merchant ships
ISO 717/1	Acoustics - Rating of sound insulation in buildings and of building elements: Part 1: Airborne sound insulation in buildings and interior elements
ISO 717/1	Acoustics - Rating of sound insulation in buildings and of building elements: Part 2: Impact sound insulation
ISO 7243	Hot Environments - Estimation of the Heat Stress on Working Man, based on the WBGT Index
ISO 7250	Basic Human Body Measurements for Technological Design
ISO 7547	Shipbuilding - Air conditioning and ventilation of accommodation spaces on board ships - Design conditions and basis of calculations
ISO 7726	Thermal environments - Instruments and methods for measuring physical quantities
ISO 7730	Moderate Thermal Environments - Determination of the PMV (Predicted Mean Vote) and PPD (predicted percentage dissatisfied) Indices and Specification of the Conditions for Thermal Comfort
ISO 8041	Human response to vibration - Measuring Instrumentation
ISO 8468 (E)	Ship's Bridge layout and Associated Equipment - Requirements and Guidelines
ISO 8861	Shipbuilding—Engine-room ventilation in diesel engine ships—Design requirements and basis of calculations
ISO 8862	Shipbuilding - Air-conditioning and ventilation of machinery control rooms on board ships - Design conditions and basis for calculations
ISO 8864	Shipbuilding - Air-conditioning and ventilation of wheelhouse on board ships - Design conditions and basis for calculations

Reference	Title
ISO 9241-1	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 1 A General Introduction
ISO 9241-10	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 10 - Dialog Principles
ISO 9241-11	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 11 - Guidance of Usability Specification and Measures
ISO 9241-13	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 13 User Guidance
ISO 9241-14	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 14 Menu dialogs
ISO 9241-2	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 2 Guidance and Task Requirements
ISO 9241-3	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 3 - Visual Display Requirements
ISO 9241-4	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 4 - Keyboard Requirements
ISO 9241-5	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 5 - Workstation Layout and Postural Requirements
ISO 9241-6	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 6 - Environmental Considerations
ISO 9241-7	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 7 - Display Requirements with Reflections
ISO 9241-8	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 8 - Requirements for Display Colors
ISO 9241-9	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 9 - Requirements for non-keyboard input devices
ISO DIS 13407	Human-Centered Design Processes For Interactive Systems
ISO/DIS 9241-12	Ergonomic Requirements for Office Work with Visual Display Terminals (VDT's) Part 12 - Presentation of Information
MIL-HDBK-1908B	Definitions of human factors terms
MIL-HDBK-46855A	Human engineering program process and procedures
MIL-HDBK-759C	Human engineering design guidelines
MIL-STD-1472F	Human engineering design guidelines
MIL-STD-1474D	Noise limits

Reference	Title
MIL-STD-740/1	Airborne sound measurements and acceptance criteria of shipboard equipment
NASA 1024 Vol. 1-3.	Anthropometric source books, 1978, National Aeronautics and Space Administration
NASA-STD-3000	Man system integration standards, July 1995, National Aeronautics and Space Administration
NORSOK S-002	Working Environment
NORSOK C-CR-002	Common Requirements - Architectural Components and Equipment
OSHA 3123	Ergonomics Program Management Guidelines for Meatpacking Plants. Occupational Health and Safety Administration publication (1991)
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Reference Book	Meister, D. (1989). *Conceptual aspects of human factors*. Baltimore: The Johns Hopkins University Press
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Reference Book	Van Cott, H.P., Kinkade, R.G. (eds.) (1992) Human engineering guide to equipment design. McGraw-Hill Book Company: New York, NY
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SAE-HIR1622A	Noise control in fluid power systems of marine Vehicles
SAE-J1050-94	Describing and measuring the field of view

Reference	Title
SAE-J209-71R87	Design and location for construction and industrial equipment, instrument face
SAE-J833-89	Human physical dimensions
SAE-J88-95	Machines, off-road work, -exterior, sound measurement
SAE-J899-88	Seat dimensions for work machines, off-road self-propelled, operator's
SOLAS II-1/36	Protection against noise
STCW 95	Standards, Training, Certification for Watch Standing, 1995
VDI 2056	Criteria for assessing mechanical vibrations of machines, Verein Deutschen Ingenieure

Appendix B - Sample Policy Statement

Vision. To improve overall system performance and reliability, by optimizing personnel performance, health, and safety through effectively integrating Human Factors Engineering principles into a project lifecycle.

Mission. To manage and integrate Human Factors Engineering through all the relevant phases of the project lifecycle in order to minimize the potential for human error and optimize operability and maintainability during facility operation.

Objectives. Objectives for HFE implementation include:

- Creating awareness of HFE at all levels of a project management team.
- Commitment for demonstrating the economic and health, safety, and environmental (HSE) benefits from applying HFE.
- Ensuring management and line responsibility exists for HFE implementation within a project team
- Ensuring HFE activities and tasks are effectively integrated into the project schedule for all major project phases.
- Establishing accountability for implementation of HFE within the project team.

Appendix C - Sample Project Human Factors Engineering Plan

HUMAN FACTORS ENGINEERING PLAN (HFEP)

1.0 Introduction

1.1 Overview

The COMPANY's commitment to Health, Safety and Environmental (HSE) performance is communicated through its mission statement. The mission statement commits the company to work towards the goal of "minimizing accidents, and to provide a safe and healthy work environment to its employees."

Hazard management will ensure that all HSE risks, appropriate to each phase of project activities, are satisfactorily addressed. One of the areas of hazard management, as addressed in the document "Hazard Management Design Philosophy" is Human Factors Engineering. The potential for human error is reduced through the application of Human Factors Engineering (HFE) design principles during the engineering phase of the project. The integration of HFE with the other engineering disciplines ensures that designs are created that effectively match the best of human and machine capabilities to create operational hardware and software which reduces the potential for human error, increases overall system availability and people satisfaction.

1.2 Scope

The purpose of this document is to define the HFE scope of work(activities), organizational structure, responsibilities and implementation plan for those responsible, within the project organization. These persons have been tasked with ensuring that HFE design requirements and principles are integrated during the detailed design and procurement, construction, hook-up and commissioning phases of this project.

The overall HFE design objectives, which also apply to vendor-supplied equipment, can be summarized as follows:

Operability – Ensure that the layout of equipment, including vendor supplied skid mounted packages, allows for easy access during the operation and maintenance of the units under all normal, upset/emergency and weather conditions by the full range of potential employees (i.e. 5^{th} percentile female to the 95^{th} percentile male, with personal protective equipment, cold weather clothing). The operability of the equipment also ensures the usability of display and control design including DCS console screens layouts and local control panels. This would mean that the placement and orientation of all controls and displays/instruments are appropriate to ensure safe and effective viewing, reach, and operation by COMPANY personnel.

Maintainability – Ensure the efficient and safe movement of equipment requiring maintenance without removal of other items such as piping, motors, etc. (This includes the provision of adequate space and laydown areas for the anticipated activities. Consideration should also be given to the provision and configuration of doors and access hatches.) Access/Egress – Ensure that all areas of the facility and equipment can be accessed and evacuated safely under normal, adverse weather and emergency conditions.

Manual materials handling – Ensure requirements for manual lifting, pulling, pushing, and carrying of equipment, with respect for the biomechanical and physiological capabilities and limitations of the personnel are included during design. Associated needs include the availability of mechanical lifting aids for assisted lifting and appropriate storage or placement of lifting aids for safe reach and effective operation.

Communication/Labeling – Ensure the clear communication of information and equipment identification, including effective viewing, reading, and understanding of instructions, signs, labels, operations and maintenance manuals.

Environmental – Ensure that environmental requirements regarding noise, lighting, vibration, climatic conditions and proximity to hot, cold, hazardous and contaminated equipment or areas have been addressed.

Habitability – Ensure the provision of acceptable personnel accommodations and recreational facilities, and minimize psycho-physiological stress effects of workload, fatigue, and social interaction.

Health and Safety – Ensure the provision of adequate medical facilities, non-restrictive personal life support and protection equipment.

2.0 PROJECT HFE DOCUMENTS

The detailed HFE design requirements for this project are referenced in the following documents:

- Human Factors Engineering Requirements for Workplaces
- Human Factors Engineering Requirements for Location and Orientation of Valves
- Human Factors Engineering Requirements for Controls, Displays, Alarms & User Panels/Consoles
- Human Factors Engineering Requirements for Labels and Signs
- Human Factors Engineering Requirements for Ramps, Stairs, Vertical Ladders, Work Platforms, Walkways and Railings
- Human Factors Engineering Requirements for Computer Displays

Other Related Project Specifications:

- Human-Machine Interface Design Guideline

3.0 ORGANIZATION AND RESPONSIBILITIES

Some of the key ingredients for the successful integration of HFE, during the various phases of a capital project's life cycle, are management commitment and the support of people at all levels of the project organization. An integration strategy is required which will establish line responsibility for HFE. This can best be achieved by introducing Human Factors into the existing project management systems with the prime objective of ensuring that HFE is executed effectively and efficiently at every stage of the project life cycle.

In order to ensure that HFE design requirements are addressed in time and integrated throughout the detailed engineering design and procurement, construction, hook-up and commissioning phases of a development project, the responsibility for implementation has been assigned to a number of people within the project organization. The organizational structure is shown in Figure 1 below.

The overall responsibility for ensuring that HFE design requirements are integrated during the detail design engineering and procurement is with the Engineering Manager. He will report to the Project Manager on all matters relating to HFE. HFE Personnel support, to ensure technical integrity and quality assurance, will be provided by a HFE Personnel. The HF Personnel with the assistance of other HF Personnel assigned by the Engineering Manager on an as needed basis, will be responsible for executing the HFE tasks identified in Section 4: HFE Scope of Work, and for providing Personnel support to the various disciplines and interpreting HFE requirements. The role and responsibility of HF Personnel in the execution of the HFE Scope of Work is summarized in the Responsibility Matrix provided in Appendix D. The functional disciplines will be responsible for day to day detail design activities and procurement and to ensure compliance with the appropriate HFE design requirements as referenced in Section 2: Project HFE Documents. A schedule for the execution of the HFE tasks/activities is included in Appendix E.

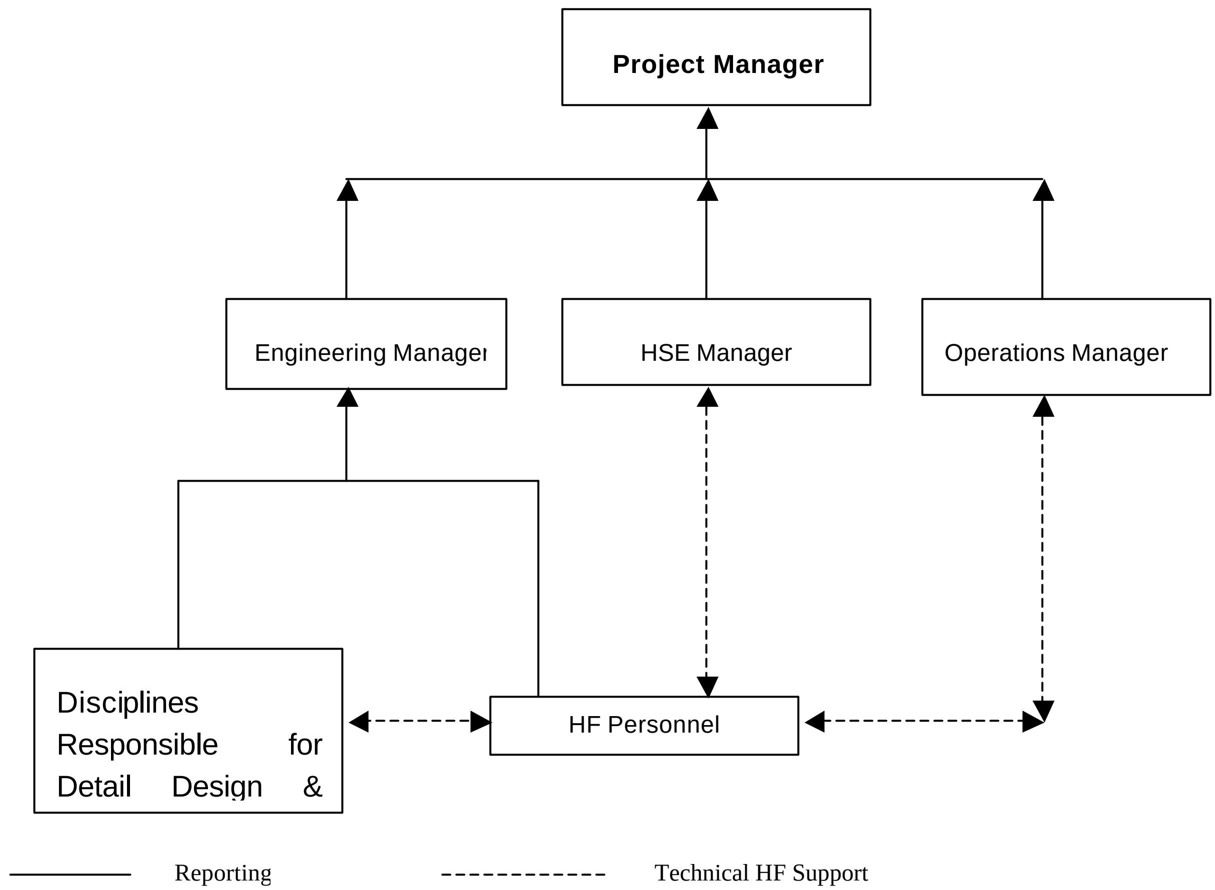

Figure 1: HFE organizational structure during detail design and procurement phases

4.0 HFE Scope of Work

A summary of the main HFE task activities to be performed by those responsible is as follows:

4.1 Conduct a Front End Human Factors Engineering Analysis (FEHFEA):

The purpose of this task analysis of future operations, maintenance activities, and of lessons learned on similar existing facilities, if applicable, is to identify potential problems in the design of the human-machine-environment interface and to ensure that these are addressed during the detailed engineering design.

4.2 Determine HFE Priorities:

Review deliverables (drawings and documents) and equipment lists to determine HFE review priorities and to identify and prioritize vendor packages, equipment, areas or procedures requiring HFE input or attention. Prioritization will be based on lessons learned from previous projects, equipment criticality, the potential for and consequence of human error, and the expected maintenance and Human-Machine interface (HMI) requirements. It is envisioned that only specific vendor packages, where the vendor is responsible for the package design, would be included.

4.3 Training:

Provide awareness training to project management and more detailed training to the project engineering and design team.

4.4 HFE Design Guidelines and Checklists:

Existing COMPANY HFE design guidelines will be utilized on the Generic Example Project. Additional HFE checklists as applicable for incorporation by designers and for inclusion in Request for Quotation's (RFQs) for previously identified vendor packages will be developed

4.5 Document all HFE Design Recommendations:

Document all HFE design recommendations and develop a database for keeping track of recommendations to allow for follow-up and closure as well as for reporting purposes to Project Management.

4.6 Valve Criticality Analysis (VCA)

Develop a set of criteria regarding location and means of access to be used when classifying valves with input from Engineering and Operations. These criteria will then be incorporated into the design and validated during subsequent review activities.

4.7 Review Engineering Drawings and Design Documents:

Generate a list of drawings and documents requiring HFE review based on the prioritization mentioned in Section 4.2. Review drawings and documents to develop recommendations for HFE improvements. Document all HFE design recommendations in database for tracking.

4.8 Evaluate Vendor Bid Packages:

For the specific vendor packages identified in 4.2, as requiring detailed HFE review, evaluate the vendor bid submittals for inclusion of the criteria contained in the HFE checklists and provide any HFE bid clarification required. Vendor designs for the selected packages will be reviewed to identify opportunities for HFE improvements with respect to design, packaging, operations, and maintenance. All work on the vendor packages would be under the direction of the responsible package engineer.

Other vendor packages will be reviewed for HFE content as part of the bid evaluation and designs will be reviewed by engineering personnel who have received HFE training.

4.9 Formal Safety Assessments (FSA):

HFE will be a component in the various FSAs conducted on the project. HF Personnel will participate in these meetings as needed and address specific recommendations from the reviews.

4.10 HFE Input to special design studies:

Participate in design studies that address HFE concerns, for example, materials handling and maintenance access study, dropped object study, Emergency Evacuation and Rescue Study (EERS), acoustical study, long term inspection and maintenance requirements or any other study at the request of Engineering or Operations.

4.11 3D Model Reviews:

HF Personnel will attend and provide input at the various 3D model reviews. All HFE action items identified will be recorded in the minutes of the meeting for action and tracking until close out.

At the 30% model review, the HFE goal is to verify that there will be sufficient clearances and unobstructed paths for movement of people and equipment, as well as accessibility to critical items and valves. Additional HFE goals are to review the sufficiency of work areas for both operations and maintenance and sufficient and logical pathways and egresses for EER.

At the 60% model review, the HFE goals include verification of sufficient and proper access at elevations for operations and maintenance, further clarification on EER routes, preliminary materials handling review, evaluation of personal safety systems, and consideration of human interfaces.

The 90% model review allows for verification of the previous recommendations and further consideration of accessibility, operability, mobility and maintainability issues.

4.12 Design of Accommodation Facilities:

Identify HFE criteria for habitability of the accommodations facility (Living Quarters). Review engineering and layout drawings associated with the accommodations facility for compliance with habitability criteria and provide recommendations as needed.

4.13 Design of Control Room and MCC Buildings:

Work with Operations to identify task requirements and functions to be performed in the control room and MCC buildings. Participate in developing design layouts and review final design, alarm handling and equipment selected for HFE concerns.

4.14 Design of Fire & Gas, General Platform Alarm and Paging System:

Review the layout of panels, as well as the location of visual and audio alarms for compliance to HFE design guidelines.

4.15 Labeling:

Work with engineering to implement project wide labeling design guidelines. Review labeling,

instructions, warning signs, and pipe coding systems for compliance with labeling design guidelines.

4.16 Construction Team HFE Training:

Conduct awareness seminars and special training sessions to the construction field staff (Company and Contractors) to develop the general awareness for HFE and ergonomics.

4.17 Conduct On-site Visits to Contractor Fabrication Facilities:

Participate as part of Safety Review Team in selected contractor site visits. These visits will verify that the HFE recommendations during the engineering phase have been implemented as per design. Provide HFE Personnel support during the installation of “Field Installed” equipment to ensure the application of project HFE philosophies.

4.18 Development/Review of Training Devices and Materials:

Provide assistance to Operations in the development and review of training material, as needed.

4.19 Review Project O & M Documentation:

Review documents, job aids and Operations and Maintenance procedures and instructional manuals to make certain they meet HFE usability design principles.

4.20 HFE Report:

Prepare HFE reports for submission to Project Management at scheduled intervals. Reports should provide the status of HFE activities and recommendations made.

4.21 Installation, Hook-up and Commissioning:

Participate in the installation, hook-up, commissioning and start-up of the facility to observe those activities that will allow for the verification of the tasks and operational and maintenance procedures that were developed. The presence of HF Personnel during this time will allow HF to be considered in the correction of problems identified, provide an opportunity for the generation of lessons learned from the HF Personnel's experiences and provide a better understanding of the practical methods used for performing common operations and maintenance tasks and procedures.

4.22 Operation:

Participate in the following activities as part of the API requirements for tracking operability in the first year:

- Conduct operability assessment before the end of the first year of operation.
- Obtain operator feedback via written and personal interviews regarding HFE successes and failures relative to operability and maintainability
- Monitor accident/incident reports for the identification of HFE design deficiencies
- Develop a lessons learned file or database.

5.0 Implementation process

The implementation process will use the HFE design requirements as provided in the documents referenced in Section 2, as the basis for the design and the procurement of vendor supplied equipment or packages/skids. These requirements will be supplemented by HFE design information and checklists developed by HF Personnel to provide more detailed design guidance to design engineers and vendors where applicable.

In case of any non-compliance with an HFE design requirement or issue raised which cannot be resolved within the discipline or with a specific Vendor, it will be referred to the Engineering Manager. If resolved it will be executed and the result will be recorded in the HFE Tracking Database for close out and sign off by the HFE Champion for that stage of the project life cycle. The HFE Champion may be the Engineering Manager for the Detailed Design Phase, Construction Manager for the Construction Phase, Commissioning Manager for the Commissioning Phase and the OIM after start-up. If the issue is deemed a safety concern, it will be entered into the Hazard Management Process as defined for the project for resolution and execution. The result will be recorded in the database for close out and sign off.

Appendix D - Responsibility Matrix

Responsibility Matrix

	Description of HFE Activity	**HFE Champion**	**HF Personnel**		**Other Disciplines (Eng., Operations, HSE)**		
		Accountable	Responsible	Review & Comment	Responsible	Technical Support	Review & Comment
1	Front End HFE analysis	**X**	**X**			**X**	**X**
2	Determine HFE priorities	**X**	**X**			**X**	**X**
3	HFE training to project design team	**X**	**X**				
4	HFE design guidelines and checklists	**X**	**X**			**X**	**X**
5	Document all HFE design recommendations	**X**	**X**				
6	Valve criticality analysis	**X**		**X**	**X**		
7	HFE review of engineering drawings and design documents	**X**	**X**			**X**	**X**
8	HFE evaluation of Vendor bid packages	**X**	**X**			**X**	**X**
9	Formal Safety Assessments (FSA)	**X**		**X**	**X**		
10	HFE input to special design studies	**X**		**X**	**X**		
11	3D Model reviews	**X**		**X**	**X**		
12	Design of accommodation facilities	**X**		**X**	**X**		
13	Design of control room and MCC buildings	**X**		**X**	**X**		
14	Design of fire & gas, general platform alarm, and paging system	**X**		**X**	**X**		
15	Labeling program	**X**		**X**	**X**		

Responsibility Matrix							
	Description of HFE Activity	**HFE Champion**	**HF Personnel**		**Other Disciplines (Eng., Operations, HSE)**		
		Accountable	Responsible	Review & Comment	Responsible	Technical Support	Review & Comment
16	HFE training to construction team	**X**	**X**				
17	HFE review during on-site visits to contractor fabrication facilities	**X**	**X***			**X**	**X**
18	HFE assistance during development of Training devices and material	**X**		**X***	**X**		
19	HFE review of project O & M documentation	**X**		**X***	**X**		
20	Generate HFE status reports	**X**	**X**				**X**
21	HFE support during installation, hook-up and commissioning	**X**		**X***	**X**		
22	HFE support during Operational Assessment	**X**		**X***	**X**		

Appendix E - Schedule of HFE Tasks/Activities

Schedule of HFE Activities during Concept, Design, Construction, and Operation *					
HFE Activity		**Project Life Cycle Phase**			
		Concept	**Detailed Design**	**Construction to Commissioning**	**Operation**
1	Include HFE Requirements in Project Specification(s)				
2	Develop Human Factors Engineering Plan				
3	HFE input and review during concept design studies				
4	Front End HFE analysis				
5	Determine HFE priorities				
6	HFE training to project design team				
7	HFE design guidelines and checklists				
8	Document all HFE design recommendations				
9	Valve criticality analysis				
10	HFE review of engineering drawings and design documents				
11	HFE evaluation of Vendor bid packages				
12	Formal Safety Assessments (FSA)				
13	HFE input to special design studies				
14	3D Model reviews				
15	Design of accommodation facilities				
16	Design of control room and MCC buildings				
17	Design of fire & gas, general platform alarm, & paging system				
18	Labeling program				
19	HFE training to construction team				
20	HFE review during on-site visits to contractor fabrication facilities				
21	HFE assistance during development of Training devices and material				

Schedule of HFE Activities during Concept, Design, Construction, and Operation *					
HFE Activity		Project Life Cycle Phase			
		Concept	Detailed Design	Construction to Commissioning	Operation
22	HFE review of project O & M documentation			(shaded)	(shaded)
23	Generate HFE status reports	(shaded)	(shaded)	(shaded)	(shaded)
24	HFE support during installation, hook-up and Commissioning			(shaded)	
25	HFE support during Operational Assessment				(shaded)

* = Shaded area indicates when the HFE activity is performed.

Appendix F - Equipment and Systems Listing

System	HFE Priority	HFE Areas of Concern
Safety Systems Related Equipment		
Temporary refuge	High	Physical space, personnel and equipment survivability, ease of access in an emergency, location of refuge in relation to work stations, personnel movement flow during , evacuation, temporary increases in POB
Muster area and embarkation station	High	Physical space, personnel and equipment survivability, location in relation to temporary refuge and work stations, access to life preservers, marshalling of personnel, temporary increases in POB
Fire and Gas detection	High	Primary (and secondary if used) control and monitoring panel design, layout and location and computer display design
Emergency shutdown system	High	Local and central control Station, design, location, orientation, labeling and accessibility
Fire Fighting Systems	High	Location of equipment, control and display design and layout, adequate access for operability and maintainability (equipment removal and replacement), location of fire water pumps
Fire-main	Medium	Adequate access for operability and maintainability of isolation valves, labeling of main sections for easy identification during emergencies
Fire Sprinklers	Medium	Labeling and maintainability concerns
Passive Fire Protection	Medium	Adequate access for inspection and maintenance
Lifeboats and Evacuation Equipment	High	Confirmation that lifeboats will hold the rated number of offshore personnel, launch station control design, provision of adequate access for maintainability and operability, location of lifeboats and other evacuation equipment, route marking, equipment storage, stretcher access and training
Lifesaving and Escape Devices	Medium	Equipment storage and location, size, fit of lifesaving devices, equipment marking/labeling/instructions
Collision Avoidance Radar	High	Location and orientation of CAR in Control Room, CAR display and control design, control room interface, ease of access to CAR antenna for maintenance

System	HFE Priority	HFE Areas of Concern
Emergency generator	High	Generator skid placement and arrangement, local control panel design and layout, control room interface, ease of access to and around generator for maintenance and repair
Emergency switchboard	Medium	Color coding, indicator lights, equipment removal and replacement
UPS system batteries, inverter, and distribution	High	Display design, control design, lifting, devices to assist in equipment lifting/movement
Containment systems (liquid and gaseous hydrocarbons)	High	Adequate access for maintainability and operability, control room interface, control panel design, valve access, evacuation issues for injured personnel
Pneumatic supply system	Medium	Adequate access for maintainability and operability, valve access
Ventilation systems	Medium	Ventilation rate, breathable air volumes, air velocity, thermal comfort, humidity
Communication Related Equipment		
Navigational aids (e.g., foghorns, beacons, etc.)	Medium	Ease of access for maintenance (especially replacement of beacon lights)
Emergency Hotline telephone	Medium	Appropriate location and standardization of any audible alarms and/or messages
Radio communications – general	Medium	Standardize radio frequencies (e.g. one for crane, one for operations, etc.)
Telephone – VHF/UHF	Medium	Location with respect to noise and usage requirements
Intercommunication	Medium	Procedures, equipment, location of personnel
Structure Related		
Hull/Structure (including watertight devices)	Medium	Ease of access to voids and tanks for inspection or maintenance, manway and hatch dimensions, evacuation issues for injured personnel, identification of tanks and voids
Ballast tanks and control system	High	Local and Control Room control panel design, layout and orientation, adequate access for maintainability and operability, EER issues for injured personnel, proper labeling of all components
Towing devices	Low	Arrangement and placement of equipment for operability and maintenance
Mooring systems	Medium	Arrangement and placement of equipment for operability and maintenance

System	HFE Priority	HFE Areas of Concern
Crude oil cargo and slop tanks	Medium	Adequate access for maintainability and operability, design, orientation and location of transfer manifolds and/or control consoles, evacuation issues for injured personnel
Tanks hydraulic system	Medium	Equipment removal and replacement, filter removal and replacement, adequate access for maintainability and operability
Cargo tank washing systems	Low	Arrangement and placement of equipment for operability and maintenance
Inert gas	Medium	Local and Control Room control panel design layout, orientation, control/display design, training and sign posting
Environment monitoring system	Low	Design and layout of system controls, displays and the design control panel, computer screens
Production/Offloading Related		
Subsea pipelines risers and umbilicals	Low	Arrangement and placement of equipment for operability and maintenance
Subsea controls system and HPU	High	HPU skid layout and arrangement, local control panel design and layout, location of skid in relation to other equipment, adequate access for maintainability and operability, lifting issues associated with hydraulic fluid cylinders (HPU)
Wellstream handling and testing, wellheads and flowlines	Medium	Control panel design and layout, display design, valve access and maintenance
Oil stabilization and treatment	Medium	Skid placement and arrangement, control room interface, control panel design, valve access
Produced water and sand treatment	Medium	Skid placement and arrangement, control room interface, control panel design, valve access
Water injection	Medium	Skid placement and arrangement, control room interface, control panel design, valve access
Gas compression and distribution	High	Local control panel design, orientation and layout, adequate access for maintainability and operability, control room interface, skid placement and arrangement, tube bundle or filter removal, equipment removal and replacement, mechanical handling devices, manway size and location, noise and thermal protection, lighting
Gas dehydration and treatment		
Gas injection		
Glycol regeneration		
Fuel gas		
Heat Exchangers		

System	HFE Priority	HFE Areas of Concern
Separators		
Pig launchers/receivers	High	Design of Launcher/Receiver barrel, access for loading pigs, safety warnings, interlocks, operating instructions
Flare relief and blow-down	High	Access to Flare Tip for inspection, maintenance and Tip removal and replacement, Heat Flux (thermal radiation) exposure to personnel
Metering system	Medium	Local display design and layout, control room interface, graphical user interface (computer screen design), ease of access for loading meter prover ball
Offloading	Medium	Hose storage and lifting, ease of access to valves, offloading control console design, layout, location and orientation
Power and Utility Systems Related		
Instrument air compressor, air receivers, dryers, and distribution	Medium	Skid placement and arrangement, local control panel design and layout, control room interface
Main power generation and distribution	High	Skid placement and arrangement, ease of equipment removal and replacement, local control panel design and layout, control room interface
General lighting	Low	Drawing review for fixture arrangement and placement
Sewage and water disposal	Medium	Skid placement, layout, and arrangement, local and Control Room control panel design, orientation and layout, ease of maintenance (especially on sewage treatment system
Potable water	Low	Control panel design and layout, labeling
Seawater pumping and treatment	Low	Skid placement and arrangement, control panel design and layout
Diesel storage and distribution	Medium	Local and Control Room control panel design and layout, ease of maintenance (especially cleaning filters), control room interface
Chemical storage, distribution, and injection	High	Injection skid design and layout, skid location on facility, adequate access on skid for maintainability and operability, local control panel design, orientation and layout, control room interface
Accommodations Block Related		
Control room and equipment room	High	Layout, outfitting, ergonomics issues, spatial orientation, communication equipment, noise, lighting, ICS

System	HFE Priority	HFE Areas of Concern
Hospital and Medical Facilities	High	Location within accommodations module, layout and outfitting
Galley and Food Storage	High	Manual material handling activities, strike-down routes, layout, outfitting
Berthing and Recreation Spaces	High	Space size, layout and outfitting, berthing space location in regards to other spaces in accommodations
Workshops and Storage Areas	High	Location on facility, assisted lifting capability provided if needed, layout and outfitting of spaces, environmental control, access to deck cranes if needed
Machinery spaces	Medium	Adequate access for maintainability and operability, maintainability concerns, layout and outfitting
Laboratories	Medium	Location within facility, layout
Miscellaneous		
Cranes	High	Crane location, adequate access within machinery room for maintenance, location of crane(s) to provide maximum visibility of facility by crane operator, control and display design, dropped objects, provision of maximum visibility to supply boat, environmental control
Fixed hoisting equipment	Medium	Location of mechanical handling equipment, ease of access to lifting equipment, safety, ease of use, provision of sufficient laydown areas, reducing impact of dropped objects
Motorized trolley car		
Portable handling trolleys		
Rigging and slinging equipment		
Helicopter deck structure and surface, lighting, net, markings and fixtures.	High	Design of stairs leading to heli deck, portable safety barriers and location of helicopter refueling stations
Drilling and completions equipment, BOP and divert systems, mud systems	High	Driller's control panel design and layout, visibility, control room interface, control design, display design, adequate access for maintainability and operability, equipment removal and replacement, lighting
Stairs, ladders, escape routes and access platforms	High	Width, tread depth and riser height, handrails, landings, stretcher access, slip resistance material

WORKING GROUP 3

2ND INTERNATIONAL WORKSHOP ON HUMAN FACTORS IN OFFSHORE OPERATIONS (HFW2002)

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

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

1.0 INTRODUCTION

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

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

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

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

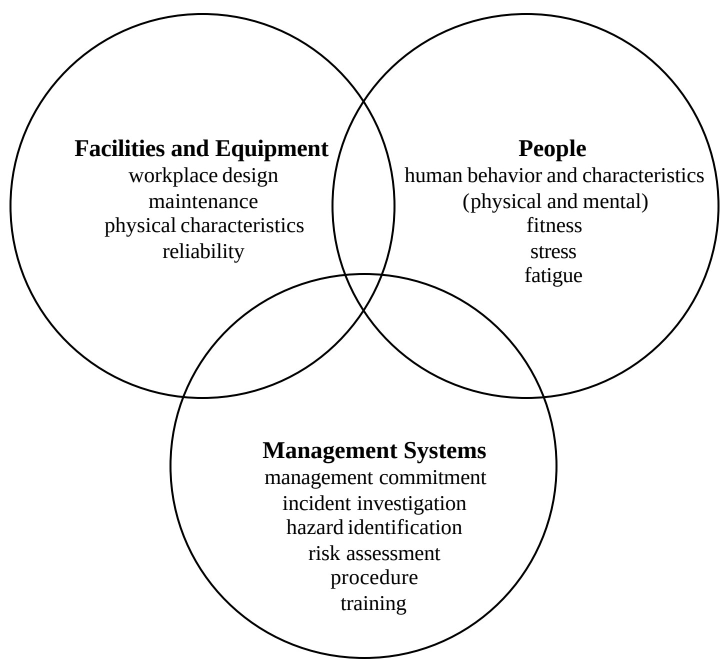

Figure 1. Human Factors and their Interactions

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

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

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

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

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

This paper discusses:

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

2.0 HUMAN PERFORMANCE ISSUES BY CLASSES OF HUMAN-MACHINE INTERFACES

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

2.1 Equipment Interfaces

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

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

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

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

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

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

2.2 Management Systems Interfaces

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

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

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

2.3 People Related Interfaces

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

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

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

2.4 Work Environment Interfaces

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

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

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

3.0 *UNDERSTANDING HUMAN ERROR IN EXISTING SYSTEMS*

3.1 Human Error as a Contributing Factor to Accidents

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

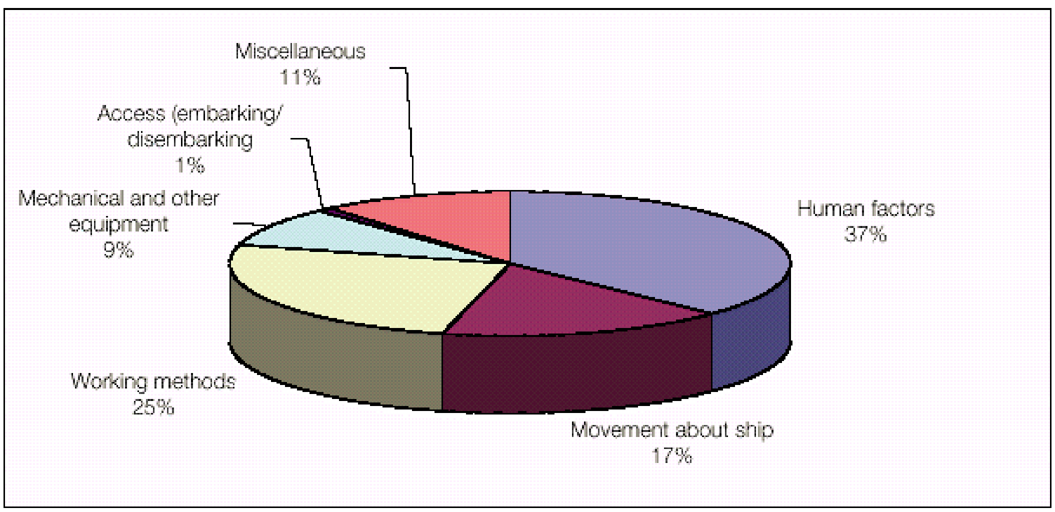

Figure 2. MAIB Allocation of Root Causes to Maritime Fatalities

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

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

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

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

3.2 Types of Human Error

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

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

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

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

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

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

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

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

3.3 Characteristics and Causes of Human Error

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

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

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

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

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

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

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

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

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

3.4 Human Error Offshore

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

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

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

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

4.0 HFE PROCESS FOR HUMAN ERROR REDUCTION IN EXISTING SYSTEMS

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

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

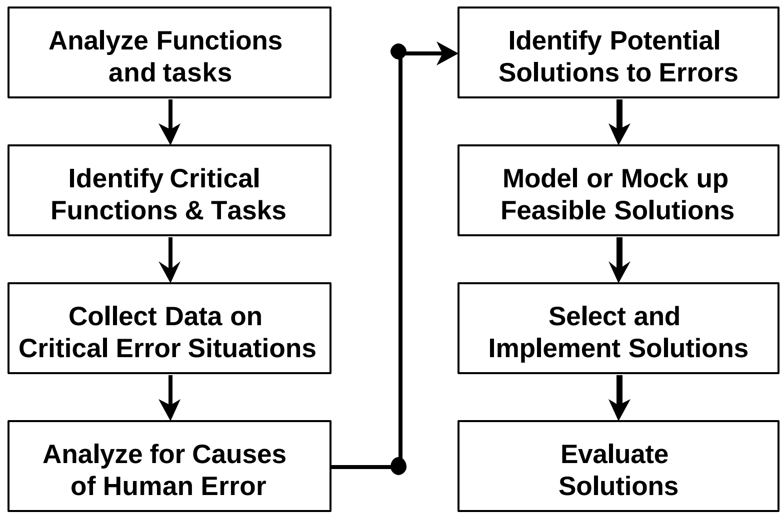

Figure 3. Process for Applying HFE Methods and Data for the Reduction of Human Errors

4.1 Step 1 - Analyze System Functions and Tasks

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

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

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

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

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

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

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

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

- Make error detection difficult
- Make error recovery difficult

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

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

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

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

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

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

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

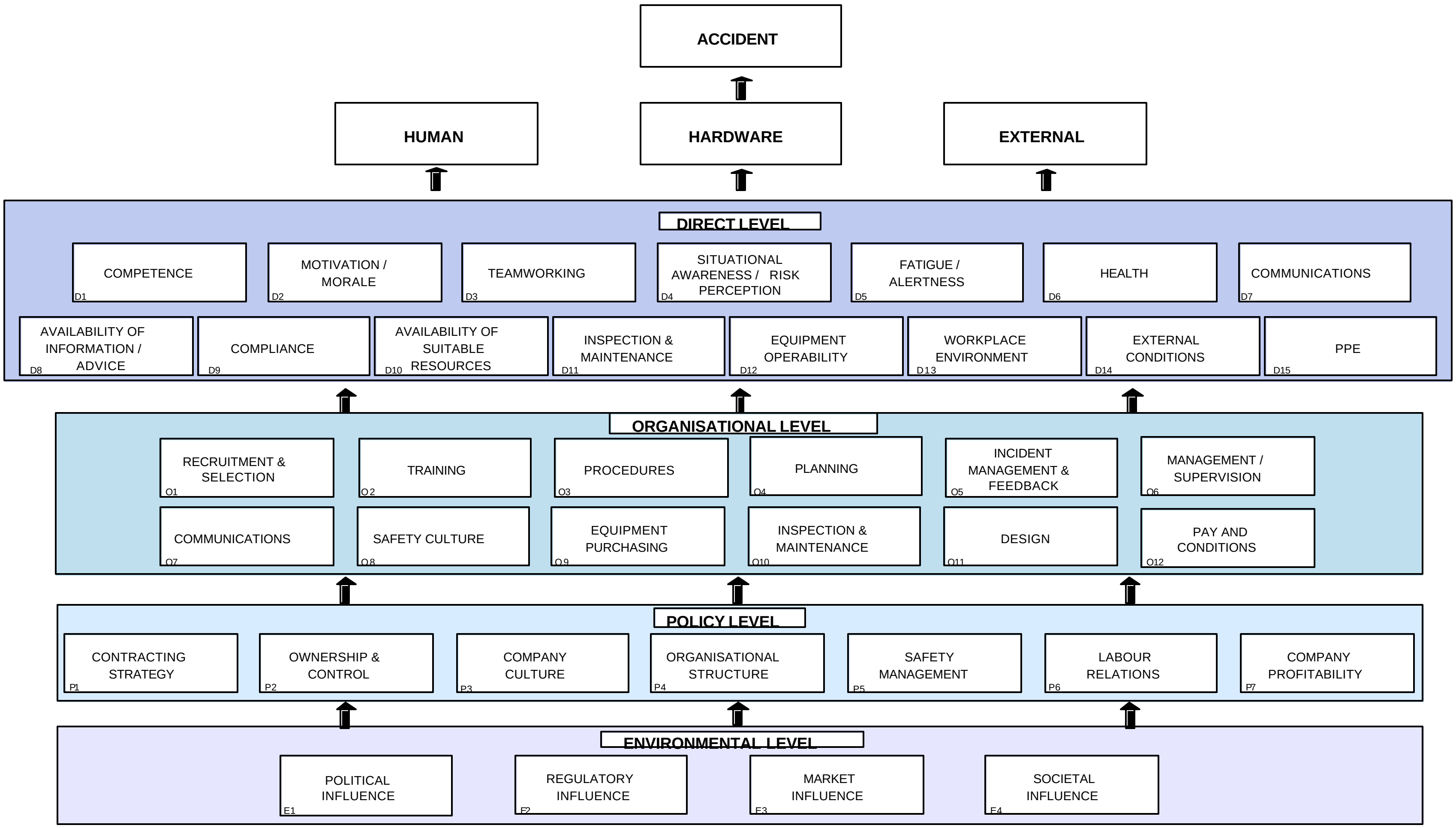

Figure 4. Generic Influence Network

Table 1. Example of a Hierarchical Task Analysis

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

4.3 Step 3 - Collect Data on Critical Error Situations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The primary constraints on error reduction include:

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

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

4.5 Step 5 - Identify Potential Solutions to Errors

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

Potential solutions will include:

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

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

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

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

4.6 Step 6 - Model the Feasible Error Solutions

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

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

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

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

4.7 Step 7 - Select and Implement Solutions

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

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

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

4.8 Step 8 – Evaluate Solutions

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

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

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

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

Specific HFE considerations in evaluations should include:

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

5.0 EXAMPLE ACTION PLANS FOR IMPROVING HUMAN PERFORMANCE ON EXISTING SYSTEMS

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

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

Process guidance is presented in Tables 2 through 8.

Table 2. Sample Process for Improvement of Communications

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

Table 3. Sample Process for Improvement of Labels and Signs

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

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

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

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

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

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

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

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

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

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

Table 8. Sample Process for Improvement of HFE Issues

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

6.0 VERIFICATION OF HUMAN PERFORMANCE ON EXISTING SYSTEMS

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

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

Evaluate the Assigned Role of the Human in Automation • Verify that each system function is allocated to human or machine or a combination of the two. • Verify that the role of the machine in manual tasks is defined. • Verify that the role-of-human in automated tasks is defined. • Determine that operator workloads are realistic.
Evaluate Training Concepts • Verify that the training analysis addresses training requirements based on job requirements. • Verify that the training analysis addresses all requirements for training devices, trainers, and part task and full task simulators. • Verify that training requirements are identified in time to allow for development of any new training devices (such as simulators). • Verify that the analysis addresses lessons learned from similar system training evaluations.
Evaluate Training Concepts • Verify training requirements include specific knowledge and skills to be acquired. • Verify training requirements include criteria for judging skills are learned. • Verify that training requirements include performance measures.
Evaluate Human Machine Interface Requirements *Evaluate Human-Machine Interface (HMI) Design* • Verify that standardization and commonality are addressed in the design of human-machine interfaces. • Verify that unique human interface requirements, documentation needs, and special software certifications are identified. • Verify that characteristics of automated decision support systems are identified. • Verify that human workloads and human performance requirements are assessed through human performance and task modeling, task network simulation, and human-in-the-loop simulation.

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

Evaluate Design for Operability *:*

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

Evaluate Design for Usability

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

Evaluate Communications Concepts

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

Evaluate Design for Habitability

- Have facility human functions and associated facility requirements been identified?
- Has the design effort identified access safety requirements?
- Have requirements for inhabiting the facility been identified?
- Verify that environmental controls are included in facilities (e.g., noise, lighting climate).

Evaluate Design for Maintainability

- Does design for maintainability include requirements for maintenance information requirements?
- Does design for maintainability include design for accessibility?
- Does design for maintainability include equipment arrangement to facilitate maintenance?
- Does design for maintainability include procedures-number and simplicity?
- Does design for maintainability include troubleshooting diagnostics and decisions?
- Does design for maintainability include built in test and automatic test equipment?
- Does design for maintainability include requirements and approaches for tools and test sets?
- Does design for maintainability include requirements and approaches for equipment identification and marking?

Evaluate Design for Safety

- Have hazards previously identified been eliminated or the associated risks reduced to an acceptable level?
- Are approaches for guarding the hazard adequate?
- Are approaches for labeling the hazard adequate?
- Are approaches for alarming the hazard adequate?
- Are approaches for safety training/procedures adequate?

Evaluate Installations

- Have equipment location requirements been identified?
- Has space layout for equipment installation been identified?
- Have equipment configuration requirements been identified?
- Have access/egress requirements been identified?
- Has an HFE design evaluation been conducted?

Evaluate HFE inputs to Change Proposals (ECPs)

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

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WORKING GROUP 4

2ND INTERNATIONAL WORKSHOP ON HUMAN FACTORS IN OFFSHORE OPERATIONS (HFW2002)

SOLVING HUMAN FACTOR ISSUES AS APPLIED TO THE WORKFORCE

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SOLVING HUMAN FACTOR ISSUES AS APPLIED TO THE WORKFORCE

1.0 INTRODUCTION

This paper aims to capture a range of current approaches to the management and delivery of safety by means of addressing workforce human factors issues. The paper is divided into a number of sections and each section is the product of the facilitated debate and discussions around the original discussion paper.

2.0 HOW DO YOU ESTABLISH THE CORRECT MANNING LEVEL?

Crew numbers were cut during the $12 barrel period with many offshore operators adopting long term plans to operate profitably in the $11 barrel range. Now that prices are higher, the companies are taking considerable profits but there remains a degree of sentiment that the low prices could yet return.

Many organisations have attempted to develop methods for determining ideal crew sizes. Some have been more successful than others. Some petrochemical companies have linked manning levels to the types and number of pieces of equipment, e.g. compressors, exchangers or reactors that are operated or maintained. The results have reportedly lead to under- rather than over-staffing. Attempts have been made to apply analyses developed for establishing crew compliments on Royal Naval vessels or manning levels on manufacturing plant. A number of defence contractors have produced methodologies for determining crewing levels for military ships and also ship naval ship repair yards. These methodologies are based on detailed task analysis and work planing theory.

The above approaches work satisfactorily when applied to a war ship as roles and responsibilities are very clearly defined. They do not appear to work when applied to repair yards and reports from offshore operators who have engaged defence contractors to analyse manning levels are that these projects have not been successful. These failures are not in the public domain but tend to come to light in discussions between HSE Inspectors and operating offshore company staff when the latter are explaining how the current staffing was determined.

Naval crew levels have been much higher than commercial ones as war ships are usually over-manned to cover for the additional requirements of battle conditions. Because tasks and roles are very tightly defined with clear hierarchies a considerable body of past analyses can be called upon to reduce the costs of undertaking a new assessment, additionally the costs can be amortised over a number of identical vessels. Similar arguments apply to the work and job analysis methods when applied to the staffing of manufacturing plant. The work in manufacturing is made possible by clearly defined tasks to a degree that cannot be related to the typical offshore environment.

In our experience detailed task analysis of offshore crew levels always results in a recommended crew level that is higher than the current compliment. As mentioned above, this experience comes to light only in discussion with offshore operators who are often quite disappointed with the poor outcome of an expensive consultant's project and as a result such analyses tend to be ignored. There is a clear case for more open sharing of experience between operators with a forum for bench marking techniques and approaches to staffing levels.

We have found that the staffing levels for emergency response are easier to assess than those for a normal or abnormal operating regime. The latter is probably the most difficult. The UK regulatory framework requires a Duty-holder to provide a demonstration of an adequate emergency response plan. The requirement for demonstration is the key and is the area where shortages of staff will become apparent. It has not been uncommon to find plans in which the same individual is required to treat the injured in the role of first aid medic and provide regular status reports as radio operator at one and the same time!

HSE has recently taken enforcement action with regard to inadequate manning on an offshore installation. The operator did not contest this action as the number of fatigue-related problems and rise in human error had led them to the reach the same conclusion. We have a 22 item question set to assess down manning (see Appendix 1) which the author has found to be effective but which has yet to be formally evaluated. The approach taken in the question set to require a demonstration that the operation at the current manning level is not subject to problems know to be caused by insufficient personnel. There are a number of benefits to this approach:

1. It removes the dependence on synthetic data as the operators and jobs are available for direct assessment.
2. There is no legal defence against reducing staff numbers when problems due to insufficient staff are already apparent (prior knowledge).
3. If manning levels are already too low the assessment of the current these manning levels and past accidents will invariably draw the senior management's attention to the cost of down time and accidents resulting from insufficient staff.

The methodology does require the operating company to have a record of past accidents, incidents and ill health in sufficient detail to analyse for workload related problems, however as a Regulator we would argue that no organisation should contemplate reducing staff unless it had these basic monitoring mechanisms in place.

Benchmarking manning levels with similar facilities in your own or another organisation can be effective. It is better to benchmark within your own organisation as more variables will be the same. Or course it is easier to benchmark when an installation is similar to others. If the work site is new or novel then it may be necessary to turn to outside consultants who may have experience of this type of plant.

In such a situation in which the plant or installation represents a departure from traditional or historic practice, the process of HAZOPS can be used to arrive at estimates of emergency manning levels based on the HAZOP scenarios. This can be very effective as the emergency scenarios represent the situations in which the manning level is most critical. When using the HAZOP/scenario approach it is important to select a range of representative scenarios. These should include such elements as (for example) critical tasks, simultaneous operations, and combined operations with other organisations.

Ongoing monitoring can provide a validation of manning levels in the form of periodic interviews with staff or discussions when jobs or task are planned. It may be tempting to raise workload issues during annual staff appraisals or reviews but it is improbable that workers will complain to too much work when bonuses are being discussed. In any review or HAZOP process it is important that those undertaking this work are fully conversant with the details of the tasks and activities. One way to monitor manning levels is to establish a set of performance indicators which can be tracked.

Lastly remember that problems can occur outside your work site as well as in it: is also important to monitor contractors to ensure that they are not aggregating additional hours while away from your site, by working on another contract for example.

3.0 CHANGES IN WORK ORGANISATION

The reduction in staffing has lead to the introduction of multi-skilling and multi-rolling to the extent that many of the old trade and craft demarcations have gone. Supervisors have given way to team facilitators and technicians now manage delivery assets. These changes are having a number of knock-on effects. The old common taxonomy for describing jobs no longer applies so that workers find it difficult to know what job they do. This makes applying for jobs very difficult as it does matching staff to jobs.

These changes have also introduced something of a split between those amongst the UK workforce from the old “smokestack” industries and those who only recently joined the labour-force. The older generation raised on rigid hierarchies and organised labour representation find it difficult to speak up in the new flat and “open-door ” organisational settings, a factor that could be very significant for the success or failure of any work-force involvement programme.

Many organisations are adopting semi-autonomous work teams, team based working or “self-managing” teams. These changes are associated with significant cost reductions and improvements in productivity when properly introduced. If the implementation is good than significant safety improvements can also occur due to such features as greater employee ownership of safety and employees discretion to allocate the required resources quickly[1]. These changes and the greater range of the jobs that result can require a heavy off-the-job training demand that can be difficult to meet when crew levels are cut to marginal levels. We now believe that non-attendance at training (typically for multi-skilling) is a key performance indicator for an excessively low crew level. Where staff are multi-rolled regular practice will be required for each of the roles, often with a greater emphasis on the less frequently applied skills[2].

Like most in the industry we are concerned about the impact of organisational change on safety performance. An example of industry practice is attached at Appendix 2. The approach taken is to ensure the maintenance of the normal management of risk processes throughout the change period. In practice this simple object masks a number of problems. Interestingly BP have been at the forefront of developing approaches to maintaining safety during change but the two key elements to their success do not appear in the attached materials from BP. These two elements are temporary over provision of expert staff during the change process and very fast and open communication paths from the workforce to the management to enable managers to identify and resolve problems before they become serious. One successful change used dedicated telephone hot lines to provide progress reports to staff working on the plant and allow these staff to provide feedback on problems as they occurred.

The additional variety brought into the work-site by multi-skilling can make for more interesting and rewarding jobs so long as the process is well managed. Delegating some authority to a work team does not mean that no one is in charge. Decisions still have to betaken, getting the job done safely is still someone's responsibility and management remains accountable. It is particularly important to be sure who is responsible for taking charge in an emergency, the best way to be sure is to run regular and varied emergency response drills. Even straight forward emergency response tasks such as raising the alarm have been known to be forgotten in a poorly organised team in which no one took charge.

Remember that changes is work organisation and the deployment of staff are as significant and critical to the safe productive operation of a site as are changes in technology or plant. As such they need to be planned with the same rigor and checks and balances as would be usual for engineering changes.

[1] HSE contract research report : OTO (?) Safety Implications of Self Managed Teams
[2] Oil Industry Advisory Committee publication “Multi-skilling in the petroleum industry” HSE books.

4.0 COMPETENCE

The change from job based to role, task or team-based working has introduced a number of problems for traditional approaches to competency based on the assumption of defined jobs with linear career development. Many HSE regulations require a “competent person” however the working definition of such an individual tends to contain insufficient information to establish a clear definition of the level of knowledge or skill required. Major duty-holders usually have well defined competence assurance programmes in place however it is not uncommon to find little or no mention of sub-contractors in these despite the significant proportion of such staff working on the same company’s installations.

The UK National Vocational Qualification (NVQ) system attempts to break all of the required competencies down into discrete observable elements with a recording and assessment system. However required level of detail renders the NVQ process cumbersome and open to abuse and its adoption therefore patchy.

As a regulator we have experienced particular difficulty inspecting for competence and as a consequence we are about to embark on a programme of work to attempt to identify the key enforcement issues. The poor coverage of task and job analyses in the UK offshore sector that is a contributor to the problems of determining manning levels is also a barrier to establishing detailed skill and competency matrices.

One area that is worth developing is the linking of the hazard assessments and safety barriers detailed in the operational Safety Case to a set of core competencies for staff whose work is critical to the integrity maintenance of these barriers and defences.

A common error is to assume that "training" = "competent" whereas of course training is important part of becoming competent but experience and learning are also vital. Programmes for mentoring which work by assigning experienced staff to guide the less experienced can be very effective. This applies to both new-hires and staff new to a specific task or job. The mentoring approach is very compatible with, and appropriate to, a well managed change process. Remember to provide ongoing management support for the staff doing the mentoring to ensure they have the additional time to take on this extra responsibility. Provide clear corporate support for the 'right way of doing things' so that the mentors do not get diverted into bad habits by less experienced staff. Mentoring programmes can fall victim to cost cutting; if such a programme is working well be sure to collect performance data to support the programme.

The US approach of working with local colleges to establish skills based foundation programmes is a good one as it sets an agreed and validated base line for workers coming on to a high hazard plant to work. If such a programme is running in your area then participate in it, if it is not then use your industry networks to set up a local programme models on successful approaches elsewhere.

5.0 SHIFT WORK AND FATIGUE

Workers on offshore oil installations appear to be the only major UK employee group who routinely adjust their circadian rhythms (by up to 12 hours) to adjust to their working schedule. This has many consequences, some beneficial, some not so. The primary benefits are significantly increased night shift performance. However this comes at the cost of a period of poor performance during adaptation to nights at the start of the tour and back to days after a roll-over (on a 7N/7D schedule) or at home at the tour end (on a 14N schedule).

A number of issues have come together to provoke considerable heated debate around the removal of the mid-tour rollover so that workers do a tour of 14 days with the next tour being one of 14 nights. We believe this to be safer and healthier for a number of reasons, however it van be very unpopular with some members the workforce. Objections centre on two factors, firstly workers prefer to adjust back to days while offshore rather than have this eat into their leave time, secondly they cite increased travel risk due to fatigue when coming off 14 nights. We are receptive to these arguments but note that as safety regulator we cannot condone tiredness at work in preference to tiredness at home, even when the consequences are domestic disharmony (the biggest single complaint)!

We have an extensive programme of research on shiftwork and we are currently investigating the issues around adjustment offshore versus adjustment onshore. The recent data does not support the workers proposition that adjustment back to days is faster in the regimented regime offshore. Quite the reverse appears to be true, however more data points are required before we can make any definitive statements. The road accident research would also predict that fatigue related driving accidents would be more likely to occur when driving from home to an early morning check-in at the heliport than when driving home at night at the tour end while still night adjusted. We have not been able to collect detailed information to support this proposition but a small pilot study found only one fatigue related offshore commuting accident and that was an early trip to the check-in.

We are concerned about fatigue as a result of excessive hours in cases where overtime is worked beyond the 12 hours. We now believe that overtime is another one of the key indicators for insufficient manning. A recent paper on this topic is appended[3].

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[3] *Shift-working offshore: roll-over vs. permanent nights*: Robert Miles; Offshore Safety Division, HSE. ERA conference proceedings, London 2001.

There is a wide variation between countries with respect to the extent to which working hours are regulated by national legislation and this is an important factor in determining the way that shift work is organised. For examples some countries apply a maximum day or night shift length, typically 12 hours, although some may alone one or more hours overtime under specified circumstances. A total number of days offshore may be specified, as may be a total maximum number of workdays per year. Some countries apply a waiting to permissible hours worked that takes into account the nature of the work or the harshness of the work environment. This seems a sensible approach and one that could be applied as a matter of good practice, regardless of the extent to which is was required by specific regulation.

In the European Community and Norway the trend has been for greater formal regulation of working hours on the grounds of improved safety, long term health and quality of life. However in practice such regulation often has ambiguities, or opt out clauses that can be exploited by less scrupulous employers and as with all regulation it is only of value if enforced. In practice it can be difficult to obtain accurate figures for hours worked as employees and managers may work together to conceal the true length of hours worked. A useful approach is to consider the worker as the critical component in a socio-technical system. As with all components the operator also needs maintenance and repair and has to be 'fit for the task'. It is sometimes hard to understand why a major company will pay the full rate for staff in critical posts who are close to sleep due to long hours when they could have someone alert if hours were cut slightly.

6.0 WORKFORCE INVOLVEMENT

There is now considerable evidence from a number of major accident investigations that greater workforce involvement is associated with improved safety. The key knowledge and experience required to recognise and identify a dangerous situation is usually to be found in those who have the most experience, often the front line process operators and maintenance staff. There are safety and performance benefits to gaining their involvement is the design / procurement process as a means of preventing the implementation of difficult to use or dangerous equipment and procedures. Evidence of the benefits of this approach are to be found in the work on Human Factors Engineering with some excellent cost benefit material collected by advocates of this approach which has been more widely adopted in the US than the UK[4].

There are a number of barriers to greater workforce involvement; the recent lay-offs have produced a climate of distrust in some companies and workers need to be equipped with sufficient knowledge to participate constructively. In addition managers need to be secure and competent so that the process is not taken by them to be a threat to their authority.

[4] GE Miller: Human factors engineering, what it is and how it can be used to reduce human factors errors in the offshore industry. OTC 10876.

One theoretical approach to work-force involvement it to look at the process from the perspective of distributed knowledge. The managers, engineers and technician/operators all hold some of the knowledge required to fully assess the risks of an activity and how best to mitigate them. Not until their knowledge is pooled can a real picture be assembled[5].

Some three years ago the UK offshore industry introduced their STEP Change in Safety Initiative. This has been a great success with demonstrable and considerable improvements in safety performance in a number of areas. The STEP initiative merits a paper in its own right and is too large to covering detail here but full information is available on an excellent web site at www.stepchangeinsafety.net.

One part of STEP is the setting up of a number of safety networks, one of which is the Workforce Involvement Network or WIN. WIN has recently undertaken a survey of offshore workers and produced a report on the findings[6] in which issues raised by the workforce are responded to by Offshore Installation Managers (OIM's) and other senior mangers within the industry.

7.0 DESIGN

HSE is concerned about the number of incidents in which poor design is identified as a causal or underlying factor. Historically poor design has been grossly underreported with many incidents involving unusable or dangerous equipment being attributed to "human error."

Recent HSE funded research has concentrated on the development of performance indicators for the design process so that a major operator could be equipped to audit the management of the design of a new installation. The outcomes from this research are two new methodologies, the Design Safety Performance Indicator (DSPI) and the Design Capability Maturity Model (DCMM). Both of these methodologies are described in detail in HSE contract research reports[7]. The DSPI provides a means of associating and tracking the relationship of each component of a design process to the overall safety performance and identify areas of the design process that are weak. The DCMM provides a means of assessing an organisation's high level capability to produce a design that is likely to be safe.

The fractured nature of the supply chain with many suppliers and sub-contractors means that bringing together designers and users is problematic. Offshore workers tend not to consider poor design as one of the underlying causes of accidents and so poor design is greatly underreported in past accident investigations and reports. When human factors experts and users participate in accident investigations more examples of poor design are found.

[5] Busby et al: Distributed cognition and human factors failures in operating and design processes. 2002 in press.
[6] Step change in safety. Workforce involvement network; Year end report and feedback survey, Southern North Sea, 2000 - 2001
[7] Copies will be provided for the workshop

One of the major benefits of isolating design causes is that remedial work can then be identified in the form of equipment improvements so reducing the probability of a repeat accident. Anyone responsible for safety will recognise and share the disappointment and frustration that comes with seeing workers killed and injured in repeats of known and preventable accidents.

Operators report that preferring to use design teams with direct offshore work experience produces safer and more usable designs of installations and plant. Where the availability of such staff is limited there will still be benefits in sending the design team to similar installations on observation tours. Some operators also use 'surveillance engineers' to observe plant in operation and capture the workforce experiences and suggestions so closing an important feedback loop.

The use of 'design, build and operate' contracts in which the design team are closely involved in the commissioning also leads to better design as does the US practice of keeping design teams together between contracts when possible.

8.0 FITNESS FOR WORK

The average age of the workforce offshore is increasing rapidly. The average in the UK sector is now in the region of 45 years of age. Offshore work is not seen as attractive as it was by those in the younger age ranges that need to come into the industry to take it forward. There will need to be a greater emphasis on understanding the exact physical requirements of offshore tasks so that staff can be selected or assessed. Wherever possible tasks will need to be redesigned and or automated so those older employees can carry them out. The nature of the offshore work environment with many heavy components, limited space and a general lack of crane cover below deck means that there is a lot of manual handling with the resulting musculo-skeletal injuries. Some companies estimate that up to two thirds of their employees leave offshore employment prematurely because of work related health problems.

In the UK these and related problems have come to be labelled under the catch-all title of occupational stress. This has now become a hot topic in the UK with a great deal of media attention and subsequent pressure to “do something.” Our own research does not indicate any particular cause for concern in the offshore sector for stress, however the reduction in manning levels and increasing work-load does give cause for concern in the future and the rate of musculo-skeletal injury remains high.

There are considerable benefits to be gained from simple and straight forward improvements in manual handling and job design to reduce the physical job demands. Successes that have reduced lost time injuries and improved productivity include[8]:

- Setting a maximum weight limit for individual luggage items (typically 20kg)
- Using a luggage trolley on the helideck
- Ordering lube oil and paint in 2.5 or 5 litre (1/2 or 1 gall) tins as a bulk palletised load (this cuts lifting injuries and reduces waste and fire hazard from part used open containers.
- Ordering frozen food in 5 or 10 kg packs not 50 kg as is sometimes the practice. We have seen a number of LTI's on FPSOs occurring when the vessel rolls while someone is carrying a 50kg potato sack.
- Storing heavy items near where they are needed.
- Providing wheeled trolleys and guide rails between lay down area and stores on FPSO's

Current HSE research in the offshore sector has focussed on the development of a simple to use stress risk assessment workbook for completion by workers. The trials so far have been a great success and have made the process of stress risk assessment manageable[9]. The approach taken is to avoid assessments of harm or mental ill health as these are emotive and can be seen as threatening by managers. The process centres on identifying problem areas and eliciting suggested improvements[10]. Tests so far indicate that operators like this approach and can embody it into their existing continuous improvement programmes.

One interesting outcome has been the ability of the method to identify a number of issues that have been missed by normal management means such as poor maintenance and poor reliability of equipment as major causes of stress and increased workload. It may be that the work book approach creates space for these ongoing problems to be raised, the importance of stress as a topic may also raise expectations about the problem being solved and so increase participation. As the assessment does not assess harm the element of “guilty knowledge” is removed and the continuous improvement focus allows the risk assessment to be used before there is any evidence of a major problem. In practice the process of using the workbook to elicit solutions to workplace problems is a good one regardless of whether it takes place under a 'stress' banner or not.

[8] "Well Handled" Book of manual handling case studies available from HSE Books (www.hsebooks.co.uk)
[9] Briner: British Psychological Soc Annual Conference 2002.
[10] Copy of draft work book to follow.

9.0 CULTURAL ISSUES

A topic which has so far received very little attention but may turn out to be very important is that of culture. By culture we mean whatever personal cultural elements impact on the workplace. Examples include:

- Professional culture i.e. 'mariner' or 'oil worker'
- Socialisation i.e. unionised or non-unionised
- Domestic i.e. single, married, parent
- Residential i.e. city dweller or rural dweller
- National

Prof Bob Helmreich at the University of Texas has developed a three level model of employee culture that is proving very useful in the prevention of aviation errors in multi-cultural aircraft crews. There are very stable and repeatable cross-cultural differences between nationalities on such key safety issues as rule violations and attitudes to authority. The skill shortages in the offshore oil sector, the multi-national nature of the industry, and the demands to recruit local labour mean that we will mean that the offshore workplace will increasingly become a multi-cultural workplace. While many offshore installations are already experiencing this trend there is little evidence of any industry wide agreement on what this means and how best to manage it.

Increasing the percentage of females has improved safety performance and productivity in a number of industrial sectors not dissimilar to offshore, for example mining[11], air and rail transport[12]. The employment of females offshore varies very widely from one country to another being relatively common in the Norwegian sector and very uncommon in the neighbouring UK sector.

10.0 TO CONCLUDE

It is difficult to be sure how work in the area of workforce involvement will develop but my own assessment is that the most benefit will come from greater workforce involvement in design and procurement including working with suppliers. This will require specific training in the process of participation in addition to the technical knowledge required to underpin involvement. I believe the outcomes of this greater workforce involvement will be better decision making due to the greater diversity of experience included in the decision process and ultimately better engineering.

[11] Recent report from Prof Mark Scrimpton, Memorial University, Newfoundland
[12] recent UK rail operator reported rail driver near miss and attendance reports

The growing cultural diversity of the workforce will provide a new set of challenges and opportunities that could bring about major change in the way that work is organised and managed. Many features of the offshore working environment that have persisted unchanged may in future be reassessed and improved, for example the prevalence of manual handling, the use of written procedures (rather than pictographic) or the predominance of male employees.

APPENDIX 1

OFFSHORE DOWN-MANNING QUESTION SET

(Prepared by Robert Miles: HSE Team Leader Human & Organisational Engineering)

Introduction

The following set of questions are designed to provide the information on which to base a judgement regarding the safety of any organisational down manning programme. The questions draw on recent experience of Inspectors and Topic specialists, no claim is made for its completeness as knowledge in the area continues to evolve. It is probable that these questions are of greatest value when applied by a Duty Holder as a guide for assessing their own plans for reduced manning.

Existing Manning Level

Which analyses have been undertaken to demonstrate that the existing manning levels are sufficient?

a) In normal operation

b) At times of shut-down, unplanned maintenance or unusual operating conditions

c) In an emergency

What checks were made to demonstrate that these analyses covered all of the necessary activities in sufficient detail?

How can the confidence level of the results be demonstrated?

Existing Work Load

What monitoring is currently in place for high workload? For example are the following recorded:

a) Overtime

b) Live permits to work

c) Un-actioned maintenance

d) Work related stress or fatigue

What are the current limits for excessive work?

How were these limits for excessive work established?

Is there any evidence of work-related stress or ill health at current manning levels?

Role and Task Reallocation

How have the individuals to be down-manned, or posts to be combined, been selected?

What analyses were undertaken to determine which roles or skills can be combined?

Are the predicted workloads for these new roles or jobs reasonable and at or below 12 hours per day?

What improvements in automation or reliability are being introduced to enable the reduced manning?

Monitoring of the New Situation

What workforce health monitoring is planned?

What workload monitoring is planned?

What mechanisms are there to capture role conflicts or skill shortfalls?

Risk Assessment

What type of risk assessment has been undertaken for the proposed changes?

Have past incidents, accidents and near-misses been analysed for work-load, role conflict or competence related failures?

Corporate Knowledge

How are the key elements of knowledge or experience identified?

How will key knowledge or experience be “captured,” retained or transferred?

Do the proposed changes increase corporate dependency on third party expertise? If so how will the availability and continuity of this access be assured?

SMS and Procedures

Is the process of change being managed to the principles set out in HS(G) 65 Successful Health and Safety Management?

Are all procedures being reviewed and rewritten to be applicable to the new roles and manning levels?

Is the Safety Management System integrity maintained both during and after the changes?

See Also

Oil Industry Advisory Committee publication “Multi-skilling in the petroleum industry” HSE books.

The “Team Toolkit” produced by OPITO (links via the OPITO web site: www.opito.co.uk)

RWM.

APPENDIX 2

SAFETY MANAGEMENT SYSTEMS AND DEMONSTRATION
A PRACTICAL ILLUSTRATION
COLIN PINDER – BP CHEMICALS

The Control of Major Accident Hazards Regulations (COMAH) place a general duty on operators to take all measures necessary to prevent major accidents and limit their consequences to persons and the environment. The regulations also require a demonstration that a Major Accident Prevention Policy (MAPP) is in place and that there is a Safety Management System (SMS) to implement the policy.

This article describes the Health, Safety and Environment Management System Framework used within BP and how the requirements of COMAH have been integrated into the framework.

BP's HSE Management System Framework

BP's HSE Expectations are detailed within the thirteen elements of the HSE Management System Framework, which are summarised below.

1. Leadership and Accountability
2. Risk Assessment and Management
3. People, Training and Behaviours
4. Working with Contractors and Others
5. Facilities Design and Construction
6. Operations and Maintenance
7. Management of Change
8. Information and Documentation
9. Customers and Products
10. Community and Stakeholder Awareness
11. Crisis and Emergency Management
12. Incidents Analysis and Prevention
13. Assessment, Assurance and Improvement

Addressing the full set of HSE Expectations is mandatory for every activity across the entire BP organisation. The relevance, application and degree of implementation within a particular operation or Business Unit will be a function of:

- The operational risk profile
- Local and national regulatory requirements
- Any voluntary HSE management programmes

Managers are accountable for putting in place appropriate documented systems and processes for each Expectation, for ensuring continuous progress towards BP's HSE goals and targets, and for confirming that these are effective via the HSE Assurance process.

The content, format and terminology of HSE management and audit systems at the Business Unit or functional unit level is a matter of local choice, provided that these:

- Are Compatible With The Assurance Management System Assessments
- Are Appropriate To Operational Risks
- Are Relevant To Regulatory And Voluntary Codes Subscribed To By BP
- Can Be Referenced back to all relevant Expectations set out in this HSE Management System Framework

To illustrate how the expectations further define the requirements of each element, Figure 1 below includes the expectations for Element 7 - Management of Change.

Element 7: Management of Change

temporary and permanent changes to organisation, personnel, systems, procedures, equipment, products, materials or substances will be evaluated and managed to ensure that health, safety and environmental risks arising from these changes remain at an acceptable level. We will comply with changes to laws and regulations and take account of new scientific evidence relating to HSE effects.

Expectations:

7.1 The health, safety, security, environmental, technical and other impacts of temporary and permanent changes are formally assessed, managed, documented and approved.

7.2 Changes in legal and regulatory requirements, technical codes, and knowledge of health and environmental effects, are tracked and appropriate changes implemented.

7.3 Effects of change on the workforce/organisation, including training requirements, are assessed and managed.

7.4 The impact on product quality of changes in manufacturing processes is assessed, associated hazards are evaluated and risks are controlled.

7.5 The original scope and duration of temporary changes are not exceeded without review and approval.

Figure 1. Element 7 Management of Change

Relating detailed procedures within a safety management framework to a MAPP can be achieved by cross-referring sections of the MAPP to expectations within the framework. An extract from the MAPP is included below, demonstrating the links between the MAPP and expectations:

“BP will adopt and implement procedures and instructions for:

- Planning modifications to, or the design of new installations, processes or storage facilities (Element 7.1)”

For example, demonstration that this bullet point within the MAPP relating to modifications is being met requires following the audit trail to expectation 7.1 described in Figure 1 above. There would need to be a procedure for controlling changes in place and this procedure would have to be working effectively. There is flexibility within the expectations to write a procedure which is relevant and applicable to particular locations around the world. Using the United Kingdom as an illustration, a structure for writing such a procedure using the principles in the Health and Safety Executive publications HSG 65 and HSG 190 is given in Figure 2 below.

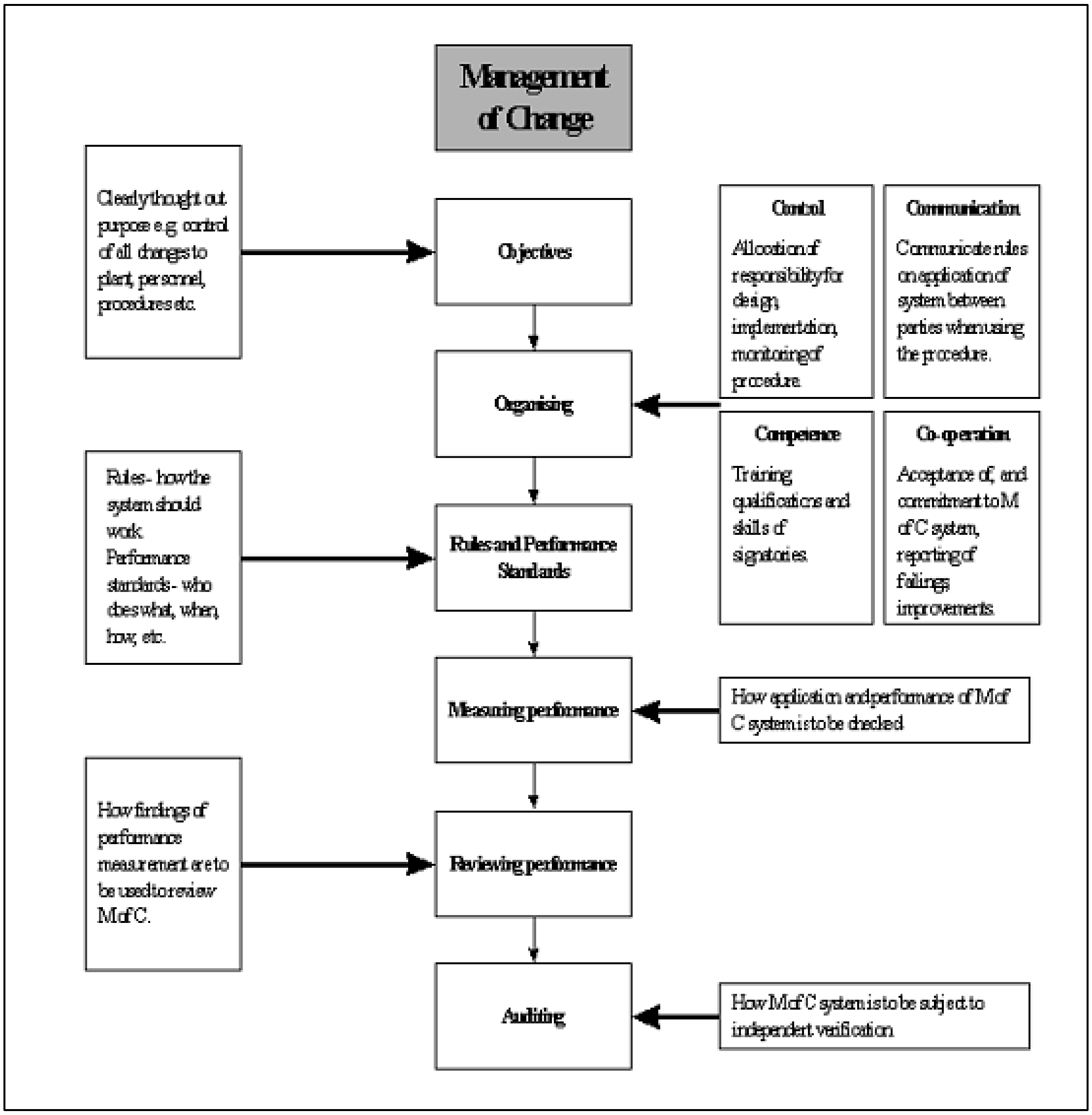

Figure 2. Document Structure

This article has tried to show how the requirements of COMAH can be integrated into the overall safety management system framework of an organisation. Important features about the SMS are:

- It Must Be Documented
- It Must Be Clearly Linked To Mapp
- It Must Have Clear Structure E.G. Hsg 65
- It Must Be Communicated To Personnel
- It Must Be Live

Significant resources are needed both to achieve demonstration of compliance with COMAH within the safety report and more importantly, to demonstrate that the safety management systems are actually being implemented in practice. The regulations provide the vehicle for both regulator and operator to work together, sharing best practice to prevent major accidents and limit their consequences to persons and the environment.

C. C. Pinder, Senior HSE Advisor, BP

APPENDIX 3

POSSIBLE PERFORMANCE INDICATORS FOR MANNING LEVEL

1. Overtime
2. Non-attendance at training
3. Outstanding number of preventive maintenance tasks
4. Fatigue -- as determined by asking people during incident investigations
5. Operator surveys -- ask will you be too tired to do this job?
6. Number and type of accidents
7. Presence of 5th shift system to compensate for training or maintenance
8. Risk assessments can be used to determine staffing levels
9. Use of buddy system during high risk tasks early in the morning (e.g. pig launching, prepping for maintenance tasks, rig repair during opportunities)
10. Number of unplanned call outs
11. Night manning of day person jobs as additional workload
12. Flexible / autonomous work scheduling
13. Absenteeism
14. Number of no-shows
15. Number of contractors and types of jobs that they do
16. How many people the original equipment was designed to be performed by

WORKING GROUP 5

2ND INTERNATIONAL WORKSHOP ON HUMAN FACTORS IN OFFSHORE OPERATIONS (HFW 2002)

EFFECTIVE INTEGRATION OF HUMAN (AND ORGANIZATIONAL) FACTORS INTO HEALTH, SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEMS

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ABSTRACT

It is common that offshore operating and drilling companies have policies, procedures, and practices that address Health, Safety, and Environmental (HSE) issues. It is less likely that such organizations will explicitly address (through written requirements) human factors (HF) concerns. Regardless, both HSE and HF are concerned with the same objectives: protecting people, property, and the natural environment from damage. The methods of each examine the job performed by the human, and compare work requirements to the design of hardware, software, and paper systems to allow safe and efficient performance. The perspectives of both disciplines are generally “user-centered” and act as the advocates for the human user to influence design so that hazards are limited and efficient and productive human performance is afforded. In the end, both are cost-effective in that efficiency is enhanced, and production losses due to injury or equipment damage are avoided. Despite the similarities, HF, including ergonomics, is rarely comprehensively addressed by HSE policies, practices, procedures, and personnel. A problem exists in that, while most offshore operators have integrated HSE programs, portions of which include occupational health and safety and process safety management systems, few companies are sure how to integrate HF concerns. In particular, such companies are not sure what the role of HF (including organization concerns) should be if managed within the overall HSE management system (HSE MS).

The objective of this paper is to explore means whereby appropriate HF concerns can be effectively integrated and managed offshore. The context of the paper is the *managed application* of HF principles and methods within offshore operations, rather than a presentation of the details of HF data and methods, or of the mechanical aspects of associated HF analysis tools and processes.

During the 1996 International Workshop on HF in Offshore Operations, the Management Systems Working Group generated a paper titled: “Application and Integration of Human and Organizational Factors into Management Policies, Procedures, and Practices to Reduce Human Error and Improve Safety and Productivity” (Moore, et al., 1996). That paper presented extensive background material on the management objectives and activities for both HF and safety management. This present paper builds on that foundation and expands the scope from HF within process safety to HF within overall HSE management programs. This will be accomplished by:

- Summarizing the offshore HSE management and HF approaches and recommended practices
- Presenting a notional life cycle process of HSE management systems appropriate for offshore application
- Identifying potential HF participation in the HSE management development process, thereby integrating HF issues and concerns with overall HSE MS objectives and processes.

DISCLAIMER

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1.0 INTRODUCTION

As defined by the International Association of Oil and Gas Producers:

> HF is the interaction of individuals with each other, with facilities and equipment, and with management systems. This interaction is influenced by both the working environment and the culture of the people involved. What may be a good system of work in one part of a organization may not be found in a region where the culturally driven attitude to risk taking may be significantly different. (International Association of Oil and Gas Producers, 2002).

Many industries, their related professional societies, or national governments, have recognized the importance of an effective HSE management system and so have developed their own HSE MS guidance tools to match the unique needs of their applications. Recent well known and widely used industrial HSE MS guidelines include:

- The American Petroleum Institute's (API) generated RP 75, *Recommended Practice for Development of a Safety and Environmental Management Program for Outer Continental Shelf Operations and Facilities*.
- The American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS) has generated *Guidelines for Auditing Process Safety Management Systems*.
- The Health and Safety Executive's Publication, HS(G)65, of the UK: *Successful Health and Safety Management*, has significantly altered thinking on occupational health and safety management in many organizations.
- British Standard 8800, *Guide to Occupational Health and Safety Management Systems*, has been developed to improve occupational health and safety management by integrating it other aspects business management.
- International Maritime Organization's International Code*, International Management for Safe Operation of Ships and for Pollution Prevention* (the "ISM Code") for the shipping industry.
- E&P Forum for *Guidelines Development and Application of Health, Safety, and Environmental Management Systems.* (Note: the E&P Forum is now known as the International Assocation of Oil and Gas Producers or OGP).
- OSHA 1910.119, *Process Safety Management of Highly Hazardous Chemicals*
- UK HSE's PFEER, *Prevention of Fire and Explosion and Emergency Response on Offshore Installations.*

- UK HSE's *Design Safety: Measurement of Performance and Organizational Capability*.
- The *Occupation Health and Safety Assessment Series* (OHSAS) 18001:1999 was developed to enable organizations to control health and safety risks.
- OHSAS 18002:2000 is *the Occupational Health and Safety Management Systems-Guidelines for the implementation of OHSAS 18001*.

All of the safety management guidelines mentioned above are set forth to assist organizations in creating their own HSE MS. Even those guidelines set as regulation, like OSHA 1910.119, and HSE's *Prevention of Fire and Explosion and Emergency Response* (PFEER), or those which are industry recommended practices, like API RP 75, have as their basis a need for organizations to create their own systems of safety management. Compliance to this guidance can only be proven through performance since none of these documents were created to be prescriptive in nature. Each relies on a company to set its own policies and objectives within the guidance framework. The organization is then expected to control its unique hazards and the possible effects of those hazards via its systems of work, auditing, policies, and practices.

The introduction of management philosophies has significantly changed the offshore industry view of controlling processes and improving quality, health, safety, environmental, and operational performance. Historically, the philosophy of *process* safety management (PSM) has been to aid in identifying, evaluating, and reducing operational risks -- with emphasis placed on the prevention and/or mitigation of uncontrolled flammable, explosive, and toxic releases. In this view, distinctions are made between *occupational health and safety (OHS) risks*, on one hand, and *process safety risk* on the other. Table 1, below, summarizes the safety distinctions between these approaches.

Table 1. Thrusts of Historic OHSMS and PSMS

OHSMS Thrusts	Process SMS Thrusts
Biomechanical analyses (lifting, etc)	Failure mode analysis (primarily hardware)
Ergonomic safety (repetitive stress injury)	Emergency planning
Behavior based safety (personnel)	Industrial process surveillance (system monitoring)
Mechanical safety (crushing wounds, etc.)	Fire, explosion, toxic release control
Electrical safety (electrocution)	Human error
Health hazards (toxins, poisons, etc)	Environment spill, effluent control and cleanup

There has been little interaction between these safety efforts, since OHS generally came under the purview of occupational health and safety departments, while PSMS was a responsibility of engineering departments. Further, environmental safety is often a separate organizational entity, responding to environmental protection initiatives. These organizational distinctions are unfortunate since the objectives and processes are highly similar. The overarching goal of an HSE MS should be to coordinate and integrate the activities of OHS, PSM, and environmental safety.

People within the offshore industry recognize this, as there is growing consensus of the need to identify, evaluate, and manage all forms of risks that lead to or contribute to the majority of offshore incidents. Indeed, many organizations have expanded the scope of the "safety" department to include all aspects of health, safety, and environment. This is often reflected in these now being called the HSE department (McCafferty and Baker, 2002).

Accidents, such as Piper Alpha, Flixborough, Three Mile Island, Bhopal, and Chernobyl have emphasized to all heavy industry that there are factors beyond engineering that can influence whether an accident occurs and the extent of damage from the accident. It has also been recognized that focusing only on engineering controls or technological improvements do not prove adequate nor result in the desired reduction in the probability of such events. As a result, the current view to hazard control is that hazards should be managed by the following approaches, in order of priority (modified from API RP 75):

- Elimination – eliminate the hazard or the task, if possible.
- Substitution – substitute a less hazardous material, energy source or task.
- Engineering Controls – use measures to restrict access to or contain the hazard.
- Administrative Controls – use measures to remind workers of the hazards.
- Personal Protective Equipment – use PPE to reduce the exposure to workers.

In all cases above, HF can and should be considered in the design and implementation of these controls.

1.1 Human Factors and Control of Human Error

It is often noted that most accidents offshore are the result of human failings linked to ineffective management systems, and that as a part of risk management, organizations must create comprehensive schemes for managing HSE that include emphasis on human and organizational factors. It has become understood that satisfactory performance can only be achieved by positive management approaches. Such approaches should be used to guide facility design, human interface design, safety reviews, operations, staffing levels, modifications, maintenance, inspections, and the training of personnel. Many organizations have been attempting this, but are still unsure how HF is or can be effectively integrated into their approaches. Miller (1999) has proposed a model for integrating human factors and ergonomics concerns in systems design. He visualizes control of human error as a pyramid with six (variously) layers (approaches) to insulating offshore operations from incidents related to the occurrence of human error (see Figure 1). Review of Miller's figure reveals that management commitment forms the foundation of human factors in design and human error control.

Figure 1. Pyramid Notion of Human Factors in Design

Understanding that management commitment serves as the foundation to integrating HF approaches with HSE is necessary in order to lower risks and the number of HF related incidents. Nothing makes this clearer than the sheer number of conferences, symposia, and workshops where the topics of OHS, process safety, safety management, and HF and ergonomics are discussed in terms of their: (1) commonalties of objectives, methods, and processes, and (2) combined potential to influence offshore safety and environmental protection. The 1996 International Workshop on HF in Offshore Operations addressed this quite thoroughly, as the Management Systems Working Group generated a white paper, and several support papers, that developed and produced a foundation for a cohesive HSE MS incorporating all these elements. Numerous similar symposia, workshops, and conferences have occurred since the 1996 conference, and more are in the planning stage.

The 1996 workshop presented the overall goals of an integrated HF and safety program, and discussed topics such as:

- Overall Management design
- Work processes
- Team development and organization
- Safety and environment protection policy
- Allocation of safety responsibility and authority
- Required resources and personnel
- Development of plans, procedures and documents requirements
- Discussion of shared analytic methods such as hazard analysis, risk analysis, root cause analysis, and human error analysis
- Control and management of change
- Personnel selection and training requirements
- Requirements and processes for continuous improvement.

Others have noted similar goals as being integral to achieving risk reduction through safety management. In their paper, "Incorporating HF into Formal Safety Assessment: The Offshore Safety Case," Bellamy and Geyer (1992) have defined safety management as the control of identifiable contributors to hazardous incidents and accidents. They state that the concept of control is central to safety management. The goal is to control hazardous processes and minimize the likelihood of loss of containment incidents and to establish mitigation systems to best control the consequences of such incidents where they occur. To accomplish this, it is necessary to assess and, where required, to alter the factors which shape those management processes that affect safety. According to Miller (1999), there are five basic approaches to control hazards. These are, in order of preference and effectiveness:

1. Generate designs that obviate risk
2. Provide physical guards or barriers to risks and hazards
3. Employ markings, placards, and labels to alert humans to the presence of a hazard
4. Train personnel to know, recognize, and avoid hazards or risky behavior.
5. Observe work behavior and provide feedback stressing problem identification and resolution.

1.2 HSE MS Models

Internationally, industry and government agencies have accepted a model by which HSE MS can be organized for effectiveness. The philosophy of HSE MS is that organizations need to apply the management principles of planning, organizing, implementing, and evaluating to all aspects of HSE. Such efforts should be based on principles that aid in identifying, evaluating, and reducing risks with the particular emphasis being placed on the prevention and/or mitigation of uncontrolled and toxic releases.

A graphical representation of this model is presented in Figure 2, Key Elements to Successful Health and Safety Management. This model is adapted from the UK HSE's publication "Successful Health and Safety Management." By using this model, an organization develops a policy for HSE, creates an organization to implement the policy, develops plans for controlling the company's activities, and sets out standards by which performance can be measured. The model also has monitoring and auditing functions to measure performance and ensure that the needs for improvements are fed back into the organization.

Further detail on how an organization might meet the proposed model is presented in the publication "Management at Risk" published by the UK Atomic Energy Authority (1991). It is stated in this publication that "Corporate management must continually develop and maintain a Safety, Health, and Environmental Program culture by demonstrating conviction and commitment through certain activities." These activities include:

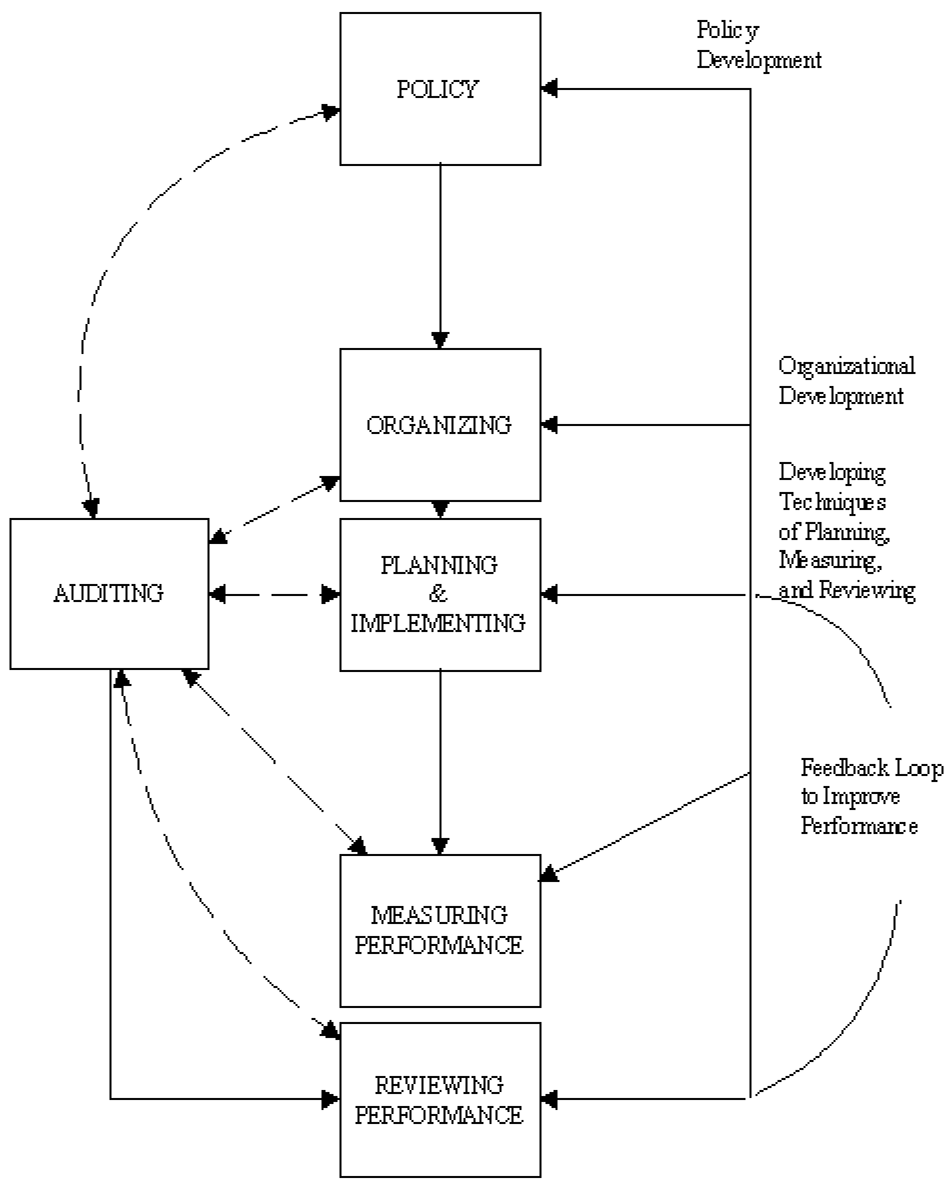
- Setting out written policy describing:
  - objectives
  - standards
  - priorities
  - authorities
  - decision reference points
  - management and communication structures that allow policy to be implemented and performance to be monitored.
- Implementing policy by
  - propagating and communicating policy
  - defining accountability
  - raising awareness and involvement of individuals
  - providing adequate resources
- Monitoring the performance of policy by
  - listening
  - taking proactive follow-up measures
  - eliminating deficiencies
  - taking initiatives (external auditing, training, analysis, assessment)
  - reviewing policy
  - rewarding good performance
  - auditing.

A key aspect of HSE MS is the creation of metrics for measuring where HSE goals are being met, and whether those standards are meeting their intended goal of minimizing risk. The performance criteria are used to monitor, audit, and review the HSE standards. Throughout the application of HSE MS, it is important not only that monitoring, auditing, and reviews occur but also that modifications are made to the HSE MS when deficiencies are noted, or when information on new ways of making improvements become known. The HSE MS must remain a living system where continual improvement is established as an objective. HSE MS improvements go hand in hand with Total Quality Management efforts. An excellent reference for describing how to integrate quality with HSE Management is provided in "*Integrating Quality, Environmental, Health, and Safety Systems*" by McDonald, Mors, Phillips and Phillips (2001),

Just as the basic model of planning, organizing, implementing, and evaluating has been accepted by many organizations worldwide, it is agreed that successful application of the model depends on human activities, including:

Decision making	Performance monitoring
Communicating	Feedback

People within an organization will be responsible for making decisions about what framework is to be used for establishing an HSE MS for an organization, as well as determining how the framework can be explained to others and how success or failure will be monitored. Taking a deeper look at HF within HSE MS, another goal of management is to reduce the potential for human errors, as well as to reduce equipment or system failures. Accordingly, Bellamy and Geyer (1992) have suggested the HF objectives presented in Figure 2 should exist within HSE MS.



Ref: Health & Safety Executive. Success for Health and Safety Management (HS(G) 65) London: HMSO, 1991.

Figure 2. Key Elements to Successful Health and Safety Management

The objectives of this approach are:

- To provide personnel with
  - a design that they do not have to fight
  - procedures which are not bureaucratically cumbersome, difficult to perform, or hazardous
  - necessary and unambiguous information
  - a working environment conducive to minimizing stress and discomfort.
- To select and train personnel such that their knowledge and skills are appropriate to the tasks which they have to perform, and to maximize personnel performance capabilities.
- To motivate people to perform safely and minimize pressure to do otherwise.
- To monitor performance, identify deviations from safety standards and to eliminate conditions conducive to error or procedure violations.

The Cullen Report (1990), which followed the Piper Alpha accident, identifies topics considered integral to an HSE MS. A significant conclusion was that a defective management system was the major issues. Specific factors mentioned by Cullen include:

- Organizational Structure
- Management personnel standards
- Training for operations and emergencies
- Safety assessments
- Design procedures
- Procedures for operations, maintenance, modifications, and emergencies
- Management of safety by contractors
- The involvement of the work force in safety
- Accident and incident reporting, investigation, and follow-up
- Monitoring and auditing of the operation of the system
- Systematic re-appraisal of the system in light of the experience of the operator and the industry.

Most organizations also agree that to assess HSE MS, an auditing approach should be used. This allows a way for different elements or factors to be quantified. Such quantification allows benchmarking, and thus a means for measuring performance and determining whether improvement is occurring. Some of the first people to suggest the use of some type of auditing scheme for evaluating safety management include Frank Bird (see Bird & Germain, 1985) and Dan Petersen (Petersen, 1982). The International Safety Rating System, ISRS, (Bird & Germain, 1985) has been developed as an auditing technique to provide a score on the quality of safety management. Petersen outlined accident causation models and mechanisms for system failures as well as assessment schemes for determining the quality of a company's safety management scheme in his book "Human Error Reduction and Safety Management" published in 1982. A third evaluation technique is the Instantaneous Fractional Annual Loss, IFAC, technique. It has been developed to indicate where there may be potential losses that could be attributable to safety management effectiveness (Whitehouse, 1987).

Other examples of SMS auditing approaches similar to those suggested by Bird, Petersen and Whitehouse include the following:

- The HSE safety auditing scheme (1985)
- Chemical Industries Auditing scheme (1977)
- DNV Technica's MANAGER Technique (Pitblado, et al. 1990)
- The Management Factor Technique (Powell & Canter, 1985)
- OSART programme (Bliselius & Franzen, 1985, Rosen 1988)
- OGP's Checklist for an Audit of Safety Management (1990)
- ABS Guide for Marine Safety, Quality and Environmental Management (April 2001).

A brief review of the elements of many of these techniques, as well as similar work by Boyen, Brandes, Burk & Burns (1987), Lees (1989) and Brian (1988) is provided in Harrison (1992). Further useful information about the origins of management system and the historical development of the associated concepts can be found in Bellamy & Geyer (1992).

From these early management systems, many industries or their related professional societies have developed their own guidance tools to match the unique needs of their applications. Given that different industries are served by different guidance and models, for the purposes of this paper, the E&P Forum (OGP) *Guidelines for the Development and Application of Health, Safety and Environmental Management Systems* approach has been chosen to explain how HF integrates with HSE MS. This model was chosen because it is an internationally accepted HSE MS approach for use by companies with offshore facilities. It combines the thought processes of both occupational health and safety (OHS) as well as process safety management (PSM) systems thinking.

According to the original document, the E&P Forum Guidelines for the Development and Application of Health, Safety and Environmental Managements Systems (1994) were developed to:

- Cover relevant HSE issues in a single document
- Be relevant to the activities of the E&P industry worldwide
- Be sufficiently generic to be adaptable to different companies and their cultures
- Recognize and be applicable to, the role of contractors and subcontractors
- Facilitate operation within the framework of statutory requirements
- Facilitate evaluation of operations to an international standard(s) as appropriate.

The Guidelines describe the main elements necessary to develop, implement and maintain an HSE MS. The detailed guidance can be obtained from the International Oil and Gas Producers website at www.ogp.org.uk. The elements, and a brief description of each, within the E&P Forum HSE MS are as presented in Table 2.

Table 2. E&P Forum HSE MS Elements

HSEMS Element	Descriptions
Leadership and Commitment	Top-down commitment and company culture, essential to the success of the system
Policy and Strategic Objectives	Corporate Intentions, principles of action and aspirations with regards to HSE
Organization, Resources and Documentation	Organization of people, resources and documentation for sound HSE performance
Evaluation and Risk Management	Identification and evaluation of HSE risks, for activities, products and services, and development of risk reduction measures
Planning	Planning the conduct of work activities, including planning for changes and emergency response
Implementation and Monitoring	Performance and monitoring of activities and how corrective action is to be taken when necessary
Auditing and Reviewing.	Periodic assessments of system performance, effectiveness and fundamental suitability.

The material above taken verbatim from the E&P Forum Guidelines document (1994).

The elements of the E&P Forum HSE MS model are very similar to the concepts of developing policy, organizing, planning and implementing; measuring and reviewing performance and auditing put forward in numerous OHS, SMS and TQM documents. This similarity further encouraged the authors to adopt the E&P Forum Model as a template for outlining the role of HF within HSE.

The graphical representation of the E&P Forum HSE MS is given is the Figure 3.

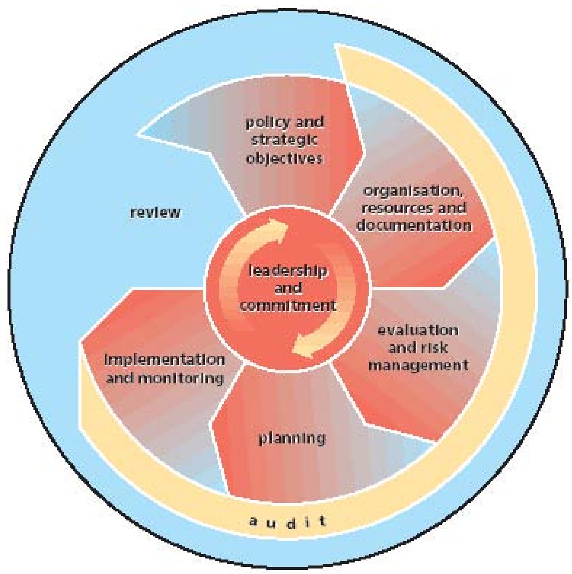


Figure 3. Graphic View of E&P Forum HSE MS Elements

2.0 INTEGRATION OF HF AND HSE MS

This paper introduces a notional life cycle process of HSE MS (see Figure 3) as presented in the E&P Forum Guidelines and then explains how HF principles and activities would integrate within that framework. Brief descriptions of the role of HF in each E&P HSE MS element are presented in Table 3:

Table 3. Role of HF in each E&P HSE MS Element

HSEMS Element	HF Role
Leadership and Commitment	The most important factor for the successful integration of HF within HSE MS is management leadership and commitment. It is through management declaring that integrating HF is an organizational goal and by providing the necessary resources for integration that success will occur. In addition, management must determine roles, responsibilities, accountabilities, and metrics in order that integration of HF in HSE takes place.
Policy and Strategic Objectives	Instilling Human (and Organizational) Factors objectives, principles, and processes through written policies and other high level documents with an HSE MS system design is necessary. The requirement associated with integrating HF as a part of HSE would also be documented here.
Organization, Resources and Documentation	Integrating HF principles within the HSE MS organization structure, ensuring adequate resources for HF will be provided and that HF requirements are documented is another important aspect of HF integration
Evaluation and Risk Management	Conducting ongoing assessments and measurements of HF within management processes is necessary for identifying, controlling, reducing the potential for human errors and for eliminating or mitigating their consequences.
Planning	In order for systematic identification and evaluation of human errors and their associated risks, human factors activities must be planned.
Implementation and Monitoring	Performing HF activities and monitoring HF functions during application of management processes is required to determine if efforts have been successful to reduce risks.
Auditing and Reviewing.	Utilizing HF processes for review, monitoring, and improvement of HSE MS is necessary to ensure continuous improvement.

The following tables discuss each of these major HSE MS elements in greater detail. For each HSEMS element, a table has been provided. Within each table, information from the E&P Guidelines is presented describing the intent of a particular HSE MS Element. The table is then sub-divided into sub-elements applicable to each HSE MS Element. For example, for the HSE MS Element of Policy and Strategic Objectives, the table is sub-divided into sections relating to the following:

- Policy Goals and Objectives
- Health, Safety and Environmental Policy
- Employee Participation.

For each sub-element, two questions relating to HF integration are posed, 1) How does Human Factors relate? And 2) What are the related Human Factors Tools/Activities? After such HF information is given, the final section of a table provides references for HF for the HSE MS element being discussed. The references are provided to allow the reader to seek additional information with regards to the integration of HF within particular HSE MS elements. The tables relating to how HF integrates within each E&P Forum HSE MS element are:

- Table 4, Leadership and Commitment
- Table 5, Policy and Strategic Objectives
- Table 6, Organization, Resources and Documentation
- Table 7, Evaluation and Risk Management
- Table 8, Planning
- Table 9, Implementation an Monitoring
- Table 10, Auditing and Reviewing.

Table 4. Leadership and Commitment

1.0 Leadership and Commitment, what is it according to the E&P Forum?
Senior management of the company should provide strong, visible leadership and commitment, and ensure that this commitment is translated into the necessary resources, to develop, operate and maintain the HSEMS and to attain the policy and strategic objectives. Management should ensure that full account is taken of HSE policy requirements and should provide support for local actions taken to protect health, safety and the environment. The company should create and sustain a company culture that supports the HSEMS, based on: • belief in the company's desire to improve HSE performance; • motivation to improve personal HSE performance; • acceptance of individual responsibility and accountability for HSE performance; • participation and involvement at all levels in HSEMS development; • commitment to an effective HSEMS. Employees of both the company and its contractors should be involved in the creation and maintenance of such a supportive culture.
1.1 HSE Vision and Mission
a. How Does Human Factors Relate to HSE Vision and Mission?
• Management influences safety culture (management/workforce attitudes) and attitudes about HFE integration and HFE integration into HSE including info engineering, design activities, incident investigation, management systems and procedures. • Management has responsibility to encourage safe behavior/discourage unsafe behavior. • It determines aims with regard to HFE in HSE. • Company leadership sets Policy and Goals, including those for HFE – including performance measures, reviewing corrective actions. It provides resources for implementing policy, plans, procedures, coaching with regards to HFE. • Management requires management responsibility for HFE and reporting on issues regarding HSE, as well as, assigns a champion (at highest level) with HFE responsibilities. • Management directs assessments to ensure the aim to integrate HFE into business practices is known throughout organization, and reviews results. The reviews include those related to audits, statistics, special study results.

b. What are the related Human Factors Tools/Activities for HSE Vision and Mission?

Inputs	HF Tools and Activities	HF Outputs
▪ Company's motivation to integrate HFE & HSE ▪ Previous HSE audit results ▪ HFE values and principles ▪ Principles of behavioral management ▪ Existing Senior Management leadership and commitment to HSE ▪ Existing HSE Policies and Strategies	▪ Needs Analysis for HFE in Company HSE Program	▪ Listing of HFE elements to be integrated in HSE ▪ Competent HFE resources ▪ Senior Management expectations ▪ HFE integration Vision and Mission

References for HF within Leadership & Commitment:

- Alexander & Pulat (1985)
- Chapanis (1996)
- Harrison (1992)
- Petersen (1982)
- Bird & Germain (1985)
- Geller (1995)
- Krause (1997)
- Schwartz (Ed., 2000)

Table 5. Policy & Strategic Objectives

2.0 Policy & Strategic Objectives, what are they according to the E&P Forum?

The company's management should define and document its HSE policies and strategic objectives and ensure that they:

- are consistent with those of any parent company;
- are relevant to its activities, products and services, and their effects on HSE;
- are consistent with the company's other policies;
- have equal importance with the company's other policies and objectives;
- are implemented and maintained at all organizational levels;
- are publicly available;
- commit the company to meet or exceed all relevant regulatory and
- legislative requirements;
- apply responsible standards of its own where laws and regulations do not exist;
- commit the company to reduce the risks and hazards to health, safety
- and the environment of its activities, products and services to levels which are as low as reasonably practicable;
- provide for the setting of HSE objectives that commit the company to
- continuous efforts to improve HSE performance.

The company should establish and periodically review strategic HSE objectives. Such objectives should be consistent with the company's policy and reflect the activities, relevant HSE hazards and effects, operational and business requirements, and the views of employees, contractors, customers and companies engaged in similar activities.

Sub-elements for Policy & Strategic Objectives include:

- Policy Goals and Objectives
- Health Safety and Environmental Policy
- Employee Participation.

2.1 Policy Goals and Objectives

a. How Does Human Factors Relate to Policy Goals and Objectives?

- Clearly defined goals and objectives for HFE in HSE should be documented (for all workers and managers).
- A policy is needed to set the tone, as well as, the requirement for integration of HFE.
- The objectives of HFE, including performance criteria, should be documented.

b. What are the related Human Factors Tools/Activities for Policy Goals and Objectives?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing HSE Policies and Strategies ▪ Previous HSE audit results ▪ HFE values and principles ▪ Human performance capabilities and limitations	▪ Develop HFE integration Vision and Mission statements ▪ Provide operational definitions for HFE integration elements • Define HFE/HSE integrated elements	▪ Written HFE integration objectives ▪ High-level management/employee expectations ▪ Human performance objectives ▪ HFE Implementation Plan (HFIP)

2.2 Health, Safety and Environmental Policy

a. How Does Human Factors Relate to Health, Safety and Environmental Policy?

- Clearly defined goals for HFE in HSE should be documented (for all worker and managers) within the HSE Policy.
- These goals will set the tone for integration of HFE.

b. What are the related Human Factors Tools/Activities for Health, Safety and Environmental Policy?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing HSE Policies and Strategies ▪ HFE Vision, Mission, and Objectives ▪ HF values and principles ▪ High-level personnel (management and employee) expectations ▪ Company's desire and motivation to incorporate HFE into HSE	▪ Operational definitions for HFE integration elements ▪ Determine HFE/HSE integrated elements ▪ Development of an HFE Implementation Plan ▪ Ergonomics/human factors engineering principles	▪ Specific HFE expectations by management/employees ▪ Input into roles, responsibilities, and accountabilities for HFE/HSE ▪ HFE performance goals and measures ▪ Credentials and Certification Information for HFE Personnel

2.3 Employee Participation

a. How Does Human Factors Relate to Employee Participation?

- Someone representing HFE should be included on HSE Committee.
- Employees on the HSE Committee should be made aware of the role, vision, mission, goals and objectives for HFE.
- Participation of both managers and employees in Behavioral-Based Safety (safe/unsafe acts) programs and also participate in risk, hazard, safety and environmental studies as team members or reviewers is needed to ensure input from management and employees with regard to HFE issues
- Suggestion Programs for HFE, as well as for HSE and productivity concerns.
- Employees should participate in Goal Setting activities for HFE in HSE.
- Employees are empowered to stop or refuse a task when HSE concerns, including those related to HFE, exists with the execution of a task.

b. What are the related Human Factors Tools/Activities for Employee Participation?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing HSE policies and strategic objectives ▪ HFE Vision, Mission, and Objectives ▪ Behavior based safety process feedback ▪ Incident and near miss data	▪ Roles, responsibilities, and accountabilities for HFE/HSE ▪ Review of HFE Performance Goals and Measures with regard to employee feedback, behavioral based safety program results, incident / near miss reports ▪ Working/safety culture assessment ▪ Interviews and questionnaires ▪ Suggestion programs	▪ Specific HFE expectations by employees ▪ Employee roles and responsibilities for HFE/HSE ▪ Defined feedback mechanisms for HFE/ HSE issues ▪ Updates to HFE Policies, Programs, Plans or to Behavior Based Safety Programs or Incident /Near Miss Reporting Schemes

References for HF within Policy & Strategy:

- Chapanis. (1996)
- Alexander & Pulat (1985)
- McSween (1995)
- Petersen (1982)
- Schwartz (Ed., 2000)
- Nordin, Et. Al. (1997)

Table 6. Organization, Resources and Documentation

3.0 Organization, Resources and Documentation, what is it according to the E&P Forum?
Successful handling of HSE matters is a line responsibility, requiring the active participation of all levels of management and supervision; this should be reflected in the organizational structure and allocation of resources. The company should define, document and communicate—with the aid of organizational diagrams where appropriate—the roles, responsibilities, authorities, accountabilities and interrelations necessary to implement the HSEMS, including but not limited to: • provision of resources and personnel for HSEMS development and implementation; • initiation of action to ensure compliance with HSE policy; • acquisition, interpretation and provision of information on HSE matters; • identification and recording of corrective actions and opportunities to improve HSE performance; • recommendation, initiation or provision of mechanisms for improvement, and verification of their implementation; • control of activities whilst corrective actions are being implemented; • control of emergency situations. The company should stress to all employees their individual and collective responsibility for HSE performance. It should also ensure that personnel are competent (see section 3.4) and have the necessary authority and resources to perform their duties effectively. The organizational structure and allocation of responsibilities should reflect the responsibility of line managers at all levels for developing, implementing and maintaining the HSEMS in their particular areas. The structure should describe the relationships between: • Different operating divisions • Operating divisions and supporting services (whether the services are provided on the same facility or from a larger corporate organization) • Onshore and offshore organizations • Employees and contractors • Partners in joint activities.

Sub-elements for Organization, Resources and Documentation include:

- Organizational Structure and Responsibilities
- Management Representatives
- Resources
- Training & Competency Systems
- Contractors
- Communications
- Documentation and its control.

3.1 Organizational Structure and Responsibilities

a. How Does Human Factors Relate to Organizational Structure and Responsibilities?

- Determines where responsibility for and reporting on HFE occurs in Management structure. HFE responsibilities and reporting requirements would be highlighted in the appropriate managers' job descriptions.
- To check if changes are needed for this area, periodic review of audit finding, incident / accident investigations, near miss reports, HFE tasks and progress should occur.
- The organizational structure should be such that there is an independence of HSE and production functions and reporting.
- As a part of this concern, command structure for incidents and accidents relating to HFE should be defined. Also authorities and responsibilities for HFE in HSE should be defined.
- In particular, areas of concern that fall under the organizational structure and responsibilities include chain of command, span of control, delegation of authority, responsibilities, staff accountability for safety at all levels (see Petersen, 1982).

b. What are the related Human Factors Tools/Activities for Organizational structure and responsibilities?

Inputs	HF Tools and Activities	HF Outputs
▪ HFE Mission, Vision, and Objectives ▪ HSE Policies and Strategies ▪ HFE Implementation Plan ▪ Roles, responsibilities, and accountabilities for HFE/HSE ▪ Feedback mechanisms for HFE/ HSE issues ▪ Personnel (management and employee) expectations	▪ Organizational communications evaluation ▪ Review / update HFE performance goals and measures ▪ Review/Update Human performance objectives ▪ Ergonomics/human factors engineering principles	▪ HFE Strategy ▪ HFE performance targets ▪ Assignment of HFE Objectives to various parts of the organization ▪ Defined HFE job functions, requirements and reporting responsibilities ▪ Job Descriptions for HFE Personnel

3.2 Management Representatives

a. How Does Human Factors Relate to Management Representatives?

- Determining human factors needs for managing work processes.
- Establishing and maintaining communications between employees and management.
- Verifying process planning, organizing, implementing and controlling activities that are a part of work processes.
- Identifying training needs.
- Identifying performance criteria for continuous improvement.

b. What are the related Human Factors Tools/Activities for Management Representatives?

Inputs	HF Tools and Activities	HF Outputs
▪ HFE Objectives of various parts of the organization ▪ Identification of a management representative for HFE Champion ▪ HFE Strategy ▪ HFE performance targets ▪ Specific HFE expectations by management	▪ Job task analysis of HFE Champion ▪ HFE job functions, requirements and reporting responsibilities defined ▪ Roles, responsibilities, and accountabilities for HFE/HSE determined	▪ Position Description for HFE Champion ▪ Assignment of HFE Objectives to various departments and managers ▪ HFE Champion job functions, qualifications, requirements and reporting responsibilities

3.3 Resources

a. How Does Human Factors Relate to Resources?

- Task analysis including Task dependencies analysis can be used to determine what individuals and department and other resources are involved in the conduct of HFE tasks, their responsibilities, risks.
- Some HFE concerns. under resources, include the number of daily shifts for a location, the length of shifts, the beginning and ending times of the shifts, as well as staffing levels for an installation. All are interrelated.
- Using task analysis for evaluating critical operations and maintenance tasks or emergency / contingencies plans, equipment, tools can be identified that would be required for safe, efficient conduct of tasks. This analysis would also identify the number of persons needed to complete the task, communications requirements, lifting needs where equipment mounted instructions might be required to aid in the conduct of tasks, etc.

b. What are the related Human Factors Tools/Activities for Resources?

Inputs	HF Tools and Activities	HF Outputs
▪ HFE Implementation Plan ▪ Job Descriptions for HFE Personnel, including Champion ▪ Credentials and Certification Information for HFE Personnel ▪ Reports of HFE activities and effectiveness ▪ HSE/HFE audit results ▪ Feedback mechanisms for HFE/ HSE issues	▪ Job task analyses for HFE personnel ▪ Incident, accident, and near miss data ▪ Human performance objectives ▪ Ergonomics/human factors engineering principles ▪ Personnel knowledge, skills, and ability standards	▪ Update/input into roles, responsibilities, and accountabilities for HFE/HSE ▪ Update/input into job descriptions for HFE Personnel ▪ HFE performance indicators ▪ Update/input into personnel knowledge, skills, and ability standards

3.4 Training/Competence System
a. How Does Human Factors Relate to Training/Competence System?
• For both identifying training needs and competencies, job / task analysis can be used. Analysis should be restricted to critical tasks. Results would be documented, preferably in a data-based system for tracking and updating purposes. • Using task analysis, training needs could be determined for Initial or Indoctrination training, HFE training, emergency training needs, including spills, fire, explosion, abandon platform, man overboard, weather contingencies as well as identifying operations and maintenance training. • This approach could determine who would be trained for different needs and the extent of that training. • The task analysis method could also help with identifying learning objectives associated with different types of training. • Using information about learning styles, from psychological research, training methods could be assessed to determine the method to use for different training needs (Classroom, computer based, lecture, on the job, in the laboratory or workshop, etc.) • Human factors principles could also be applied to determining what records should be kept and in what form. • Job / Task Analysis can be used to assess required competencies for different jobs. Such analysis can identify critical skills, knowledge, aptitudes, experience, decision-making abilities associated with a particular position, including human factors specialists. • Analyses of the requirements for particular jobs may also point out the need for including psychometric testing for certain positions. For example, test for color and depth perception for crane operators, hearing tests for persons using communications equipment, strength testing for jobs requiring heavy lifting, etc. Other positions may require testing for behavioral tendencies like risk taking. • Information from the Job / Task analyses can be used to create job descriptions. • Using information defined to establish competencies, review of performance for individuals is possible based on objective criteria. An appraisal method can be created based on such criteria. • A system should be created for tracking competencies. The system could allow self evaluation by employees as well as evaluation by supervisors and managers.

b. What are the related Human Factors Tools/Activities for Training/Competence System?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing company awareness training procedures and methodologies for HSE ▪ Existing company review/training procedures for the maintenance of HSE knowledge, skills, and abilities ▪ Human performance limitations/ capabilities ▪ Incident, accident, and near miss reports ▪ HFE Implementation plan ▪ HFE Strategy ▪ Feedback from training classes ▪ Performance evaluations of personnel	▪ Training requirements and needs assessment ▪ Gap Analysis for HFE training ▪ HFE awareness training goals ▪ Training needs analysis for renewal or refresher training ▪ Validation and verification exercise for training ▪ Instructional systems development process ▪ Psychometric and personality tests	▪ Update/input into human performance standards ▪ Learning objectives for HFE related to awareness training ▪ HFE training requirements and evaluations ▪ HFE competency assessment tools

3.5 Contractors (and Procurement)

a. How Does Human Factors Relate to Contractors (and Procurement)?

- In terms of HFE in HSE, it would be important to determine if contractors have systems for reducing the potential for human errors in their work processes. For example,
  - do they have an HSE policy?
  - Is there an incident / accident / near miss reporting system?
  - Is there a tracking system for these and also for injury statistics, fines, environmental violations?
  - Is there a log of overtime hours? Has analysis been done to determine if overtime increases, are accidents, injuries and near misses also increasing?
  - Another issue to examine is how are personnel selected for their jobs. Does a systematic means for evaluating skills and knowledge for various jobs exist?
- In choosing and procuring vendor-supplied equipment, a selection criteria for a vendor can be to choose a vendor that has used HFE in the design of equipment. An alternative is to have a staff member evaluate different equipment package for adherence to HFE criteria and then use this evaluation as an input to selecting equipment.

b. What are the related Human Factors Tools/Activities for Contractors (and Procurement)?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing Company procedures with respect to Contractor selection ▪ Existing Company procedures with respect to Contractor training requirements ▪ Existing Company procedures with respect to monitoring the Contractor's performance ▪ Existing Company procedures with respect to assessing the Contractor's performance ▪ Incident, accident, and near miss data ▪ Roles, responsibilities, and accountabilities for HFE/HSE	▪ Human performance standards ▪ Learning objectives for HFE related to awareness training ▪ HFE training requirements and evaluations ▪ HFE competency assessment ▪ HFE Vision, Mission, and Objectives ▪ HFE Implementation Plan ▪ HFE targets	▪ Contractor learning objectives for HFE related to awareness training ▪ Contractor HFE training requirements and evaluations ▪ Contractor HFE competency assessment tools ▪ Update/input into roles, responsibilities, and accountabilities for HFE/HSE with respect to Contractors ▪ Update/input into HFE Vision, Mission, and Objectives for Contractors

3.6 Communications

a. How Does Human Factors Relate to Communications?

- One means to reduce human error and communications problems is to create pre-planned communications protocols for both written and verbal communications. These protocols would exist for telephone, loudspeaker and radio communications. Report forms could be created for written communications, including things like daily operations reports, work permits, maintenance requests, order forms, drilling data, etc.
- For particular types of communications, there should be defined communications devices and channels. These would include marine, helicopter, crane communications. For these instances, defining terminology to be used in communications would be important. For example, IMO speak might be used for marine communications, aviation terms for helicopters.
- An organizational communications study could be conducted to track information flow and requests to improve forms and where possible reduce reporting requirements. This would include a review of shift logs, permitting systems, shift turnover practices/protocols, and other written request / reporting forms.

b. What are the related Human Factors Tools/Activities for Communications?		
Inputs	**HF Tools and Activities**	**HF Outputs**
Existing Company procedures for communications ▪ Incident, accident, and near miss data ▪ HSE/HFE audit results ▪ Constrained Language Lists IMO Speak for Communications with marine vessels ▪ Phonetic alphabets	▪ Job task analysis ▪ Link analysis ▪ Phonetic speech intelligibility tests	▪ Update/input into communication protocols ▪ Update/input into personnel evaluation and selection tools ▪ Update/input into personnel knowledge, skills, and ability standards
3.7 Documentation and its Control		
a. How Does Human Factors Relate to Documentation and its control?		
• Human factors evaluations should be integrated into all formal HSE/ hazard/risk studies. As part of these studies, potential human errors should be identified and analyzed and means for error reductions should be suggested. Implementation of results should be tracked. • Employees should be included in all HSE/hazard/risk studies as subject matter experts. • Where appropriate, human reliability analysis techniques should be applied to evaluate risks and hazards.		

b. What are the related Human Factors Tools/Activities for Documentation and its control?

Inputs	HF Tools and Activities	HF Outputs
Existing Company documentation control policies (this includes availability, distribution, and dissemination methodologies) Existing Company documentation maintenance policies (for example updates relating to changes in things like Company policies, procedures, or legislative/regulatory requirements) ▪ Incident, accident, and near miss data	▪ User interviews and questionnaires ▪ Information mapping techniques ▪ Feedback mechanisms for HFE issues	▪ Update/input into documentation format and visual presentation methodologies ▪ HFE value added to documentation accuracy and usability

References for HF within Organization, Resources, and Documentation:

- Chapanis (1996)
- Alexander & Pulat (1985)
- Schwartz, G. (Ed., 2000)
- Landy & Trumbo (1980)
- Karwowski & Marras (Eds., 1998)

Table 7. Evaluation and Risk Management

4.0 Evaluation and Risk Management, what is it according to the E&P Forum?

The company should maintain procedures to **identify** systematically the hazards and effects that may affect or arise from its activities, and from the materials which are used or encountered in them. The scope of the identification should cover activities from inception (e.g. prior to acreage acquisition) through to abandonment and disposal. The identification should include consideration of:
 	
• Planning, construction and commissioning (i.e. asset acquisition, development and improvement activities).
• Routine and non-routine operating conditions, including shut-down, maintenance and start-up.
• Incidents and potential emergency situations, including those arising from:
  - Product/material containment failures.
  - Structural failure.
  - Climatic, geophysical and other external natural events.
  - Sabotage and breaches of security.
• Human factors including breakdowns in the HSEMS.
• Decommissioning, abandonment, dismantling and disposal.
• Potential hazards and effects associated with past activities.
 	
Personnel at all organizational levels should be appropriately involved in the identification of hazards and effects.
 	
The sub-elements associated with Evaluation and Risk Management are as follows:
• Identification of Hazards and Effects
• Evaluation
• Recording of hazards and effects
• Objectives and performance criteria
• Risk reduction measures

4.1 Identification of Hazards and Effects

a. How Does Human Factors Relate to Identification of hazards and effects?

- Human factors evaluations should be integrated into all formal HSE/ hazard/risk studies. As part of these studies, potential human errors should be identified and analyzed and means for error reductions should be suggested. Implementation of results should be tracked.
- Employees should be included in all HSE/hazard/risk studies as subject matter experts.
- Where appropriate, human reliability analysis techniques should be applied to evaluate risks and hazards.

b. What are the related Human Factors Tools/Activities for Identification of hazards and effects?

Inputs	HF Tools and Activities	HF Outputs
▪ Incident, accident, and near miss data ▪ Communication protocols ▪ Existing Company HSE policies and strategic objectives ▪ Human performance limitations/ capabilities ▪ Human performance risks ▪ Behavior based safety feedback ▪ Principles of behavioral management ▪ Review of routine, non-routine, and emergency O&M procedures and policies	▪ Human error identification techniques ▪ Behavioral based safety programs ▪ Job task analysis ▪ Link analysis ▪ HFE Implementation Plan ▪ Ergonomics/human factors engineering principles ▪ Human performance standards	▪ Update/input into ergonomics/ HFE guidance and specifications ▪ Update/input into personnel evaluation and selection tools ▪ Update/input into personnel knowledge, skills, and ability standards ▪ Update/input into personnel job descriptions ▪ Update/input into hazard identification techniques

4.2 Evaluation

a. How Does Human Factors Relate to Evaluation?

- To assess hazard and risk controls, routine inspections and reporting on the inspections should be required – workplace, equipment, housekeeping. In additions, reviews of near miss and accident reports as well as behavioral based safety studies.
- A mechanical integrity program can help to control maintenance risks and failures. Periodic review of maintenance records and readings may also reveal potential problems.

b. What are the related Human Factors Tools/Activities for Evaluation?

Inputs	HF Tools and Activities	HF Outputs
▪ Incident, accident, and near miss data ▪ Communication protocols ▪ Existing Company HSE policies and strategic objectives ▪ Human performance limitations/ capabilities ▪ Human performance risks ▪ Review of routine, non-routine, and emergency O&M procedures and policies	▪ Human error analysis techniques ▪ Human reliability analysis ▪ Job task analysis ▪ Ergonomics/human factors engineering principles ▪ Human performance standards	▪ Update/input into ergonomics/ HFE guidance and specifications ▪ Update/input into personnel knowledge, skills, and ability standards ▪ Update/input into personnel job descriptions ▪ Update/input into hazard evaluation techniques

4.3 Recording of Hazards and Effects

a. How Does Human Factors Relate to Recording of hazards and effects?

- A hazard log can be used to record potential hazards including those related to HFE.
- Risk assessment reports and work sheets can be used to include use of HFE as a layer of protection.
- Include HRA in Risk Assessments.
- Hazards analysis recommendation to include HFE improvements.

b. What are the related Human Factors Tools/Activities for Recording of hazards and effects?

Inputs	HF Tools and Activities	HF Outputs
▪ Incident, accident, and near miss data ▪ Existing Company HSE policies and strategic objectives ▪ Existing Company hazard reporting and recording system ▪ Existing Company routine O&M procedures and policies ▪ Existing Company non-routine and emergency operating procedures ▪ Existing Company Risk Assessments, Reports, Analyses Data ▪ Hazards Analysis Worksheets	▪ User interviews and questionnaires ▪ Information mapping techniques ▪ Feedback mechanisms for HSE/HFE issues ▪ Learning objectives for HFE related to awareness training ▪ HFE training requirements and evaluations ▪ Layer of Protection Analyses including HFE ▪ HRA methods ▪ Program for HFE Recommendations, Resolutions and Follow-up	▪ Update/input into hazard recording procedures ▪ Update/input into hazard recording forms or checklists ▪ Update/input into documentation format and visual presentation methodologies ▪ Update / input Risk assessment worksheets and checklists ▪ Resolve PHA recommendations including HFE items

4.4 Objectives and Performance Criteria

a. How Does Human Factors Relate to Objectives and Performance Criteria?

- Performance standards setting for HFE
- Policy document developments for HFE
- Strategic planning for HFE

b. What are the related Human Factors Tools/Activities for Objectives and Performance Criteria?

Inputs	HF Tools and Activities	HF Outputs
▪ Incident, accident, and near miss data ▪ Human performance capabilities and limitations ▪ Performance evaluations of personnel ▪ Personnel (employee and management) roles and responsibilities for HFE/HSE ▪ Strategic Planning Objectives for HFE	▪ User interviews and questionnaires ▪ Job task analyses ▪ Human performance standards ▪ Personnel evaluation and selection tools ▪ Personnel knowledge, skills, and ability standards ▪ Policy documents for HFE	▪ Update/input into key performance indicators ▪ Update/input into procedures to set performance criteria ▪ Updated policies

4.5 Risk Reduction Measures

a. How Does Human Factors Relate to Risk Reduction Measures?

There are many ways that integrating HFE into HSE can reduce risks. The most appropriate application for HFE is the development of an HFE integration program that requires the systematic evaluation of interfaces and work processes for potential human factors concerns. Some factors that can be considered include:

- Designated smoking areas
- Lighting – night operations
- Program to reduce hazardous waste – labeling, handling instructions, methods
- Testing for depth, crane operations, labeling work permits, confined space, color vision
- Training and simulation for EER, spills, etc.
- Human Factors as part of design – anthrop – HMI – layouts – equipment/tool design
- HFE in risk studies
- Rules (mechanical integrity program)
- PPE selection, use, inspection
- HFE in design
- HFE in operations, maintenance
- HFE in procedures, labels, drills, SEMP, OHS, signs, labels
- Behavior based safety

b. What are the related Human Factors Tools/Activities for Risk Reduction Measures?

Inputs	HF Tools and Activities	HF Outputs
▪ Incident, accident, and near miss data ▪ Existing Company HSE policies and strategic objectives ▪ Existing Company hazard reporting system ▪ Existing Company procedures regarding risk reduction ▪ Existing Company routine O&M procedures and policies ▪ Existing Company non-routine and emergency operating procedures ▪ Behavior tendency data	▪ Behavioral based safety programs ▪ Psychological testing for personnel risk behavior ▪ Testing for depth perception and color deficiency ▪ Testing for hearing for those using voice communications equipment ▪ Human error analysis techniques ▪ Human reliability analysis ▪ Job task analyses ▪ Ergonomics/human factors engineering principles ▪ Human performance capabilities and limitations	▪ Update/input into ergonomics/ HFE guidance and specifications ▪ Update/input into personnel evaluation and selection tools/criteria ▪ Update/input into personnel knowledge, skills, and ability standards ▪ Specific HFE input into Company O&M, EER, HSE Documentation

References for HF within Evaluation and Risk Management:

- AicheE (1994)
- Gertman and Blackman (1994)
- Kirwan & Ainsworth (1992)
- Meister (1985)
- Reason (1997)
- Salvendy (1997)
- Wilson & Corlett (1990)
- Eastman Kodak (1983 / 1986)
- Grandjean (1988)
- Kirwan & Ainsworth (1992)
- Nordin, et. al. (1997)
- Salvendy (1997)
- Schwartz (Ed., 2000)

Table 8. Planning

5.0 Planning, what is it according to the E&P Forum?
The company should maintain, within its overall work program, plans for achieving HSE objectives and performance criteria. These plans should include: - a clear description of the objectives; - designation of responsibility for setting and achieving objectives and performance criteria at each relevant function and level of the organization; - the means by which they are to be achieved; - resource requirements; - time scales for implementation; - programs for motivating and encouraging personnel toward a suitable HSE culture; - mechanisms to provide feedback to personnel on HSE performance; - processes to recognize good personal and team HSE performance (e.g. safety award schemes); - mechanism for evaluation and follow-up. The sub-elements that relate to Planning are as follows: - General - Asset Integrity - Procedures and Work Instructions - Management of Change - Contingency and Emergency Planning.
5.1 General
a. How Does Human Factors Relate to planning in General?
• Treatment of safety critical items • Operations and maintenance of philosophies to include text requiring operability and maintainability be addressed by applying human factors engineering criteria to the design of equipment, skids, access/egress routes, alarms, announcements, etc. • Use of HFE in Quality Assurance Programs for procurement, fabrication, installation, production and decommissioning • Use of HFE attributes in qualifying contract personnel in the planning process.

b. What are the related Human Factors Tools/Activities for planning in General?

Inputs	HF Tools and Activities	HF Outputs
▪ Previous HSE audit results ▪ HFE values and principles ▪ Existing HSE Policies and Strategies ▪ Existing Company plan to achieve HSE objectives and performance criteria ▪ Existing Company policy to maintain HSE objectives and performance criteria	▪ HFE integration Vision, Mission, and Objectives ▪ Operational definitions for HFE integration elements ▪ HFE/HSE integrated elements ▪ HFE Implementation Plan ▪ Identify HFE requirements for Contractor Qualification Programs	▪ Update/input into management/ employee expectations ▪ Update/input into human performance objectives ▪ Update/input into HFE performance goals and measures ▪ Update/input into roles, responsibilities, and accountabilities for HFE/HSE ▪ Updated Contractor Qualification Programs

5.2 Asset Integrity

a. How Does Human Factors Relate to Asset Integrity?

- Documentation of Operations and Maintenance activities including HFE evaluations of interfaces, work processes, tools, procedures, etc.
- Inspection (routine and non-routine) of work areas for safety and ergonomics concerns
- Evaluation of procurement, fabrication and installation processes for checking that HFE as been addressed in these areas
- QA/QC include HFE checks

b. What are the related Human Factors Tools/Activities for Asset Integrity?		
Inputs	**HF Tools and Activities**	**HF Outputs**
Existing Company procedures relating to asset integrity (e.g., procedures to ensure that HSE-critical facilities/equipment are suitable for their required purpose) Existing Company procedures related to achieving HSE objectives ▪ Previous HSE audit results Incident, accident, and near miss data ▪ Existing Company routine O&M procedures and policies ▪ Existing Company non-routine and emergency operating procedures ▪ Existing Company QA program	▪ User interviews and questionnaires ▪ Ergonomics/human factors engineering principles ▪ HFE/HSE integrated elements ▪ Job task analyses ▪ Learning objectives for HFE related to awareness training ▪ HFE training requirements and evaluations ▪ QA checklist	▪ Specific HFE input into Company O&M, EER, HSE Documentation ▪ Update/input into ergonomics/ HFE guidance and specifications ▪ Update/input into personnel knowledge, skills, and ability standards ▪ Update/input into documentation format and visual presentation methodologies ▪ HFE value added to documentation accuracy and usability ▪ Update QA checklist to include HFE criteria

5.3 Procedures and Work Instructions

a. How Does Human Factors Relate to Procedures and Work Instructions?

- Coverage of documents with regard to tasks where human error potentials are high
- Reviews for quality of documents
- Written processes for updating, distribution
- Evaluation of procedures and work instructions for suitability for users. Procedures have requirements stating that there must be periodic reviews, revisions
- There should be a formal means for staff to comment procedures and work instructions
- Work permit system should be designed such that forms are easy to use, the work permit requirements are clear, and that an assessment for the potential for human errors is conducted in job planning associated with the permitted tasks
- Standards exist to set performance requirements on tasks. This would include criteria related to document layout, wording, type of instruction, flowchart use, prose guidelines, checklist use, etc.
- Procedures and work instructions should be up to date and written in a clear and usable format. (for example, use of information mapping to ensure tasks are broken into understandable portions)
- Verification and validation exercises should be required to test usability and validity of written procedures and instructions
- Revision cycle should be defined for all documents
- Procedures and Work Instructions should be updated in conjunction with Management of Change processes

b. What are the related Human Factors Tools/Activities for Procedures and Work Instructions?		
Inputs	**HF Tools and Activities**	**HF Outputs**
▪ Existing Company HSE policies and strategic objectives ▪ Existing Company routine, non-routine and emergency policies and procedures ▪ Incident, accident, and near miss data ▪ Previous HSE audit results ▪ Existing Company Quality System documentation	▪ User interviews and questionnaires ▪ Information Mapping Techniques ▪ Feedback mechanisms for HFE/HSE issues ▪ Training requirement's evaluation ▪ Human performance capabilities and limitations ▪ Behavioral based safety programs	▪ Update/input into existing Company HSE policies and strategic objectives ▪ Update/input into existing Company routine, non-routine and emergency policies and procedures ▪ Update/input into existing Company Quality documentation ▪ HFE value added to documentation accuracy and usability ▪ Update/input into documentation format and visual presentation methodologies

5.4 Management of Change

a. How Does Human Factors Relate to Management of Change?

- MOC Documentation, authorization and review procedures include HFE requirements
- MOC document tracking and monitoring includes HFE concerns

b. What are the related Human Factors Tools/Activities for Management of Change?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing Company procedures for planning and controlling changes ▪ Existing Company HSE policies and strategic objectives ▪ Incident, accident, and near miss data ▪ Previous HSE audit results ▪ Existing program to track, monitor and follow-up on changes	▪ User interviews and questionnaires ▪ Feedback mechanisms for HFE/HSE issues ▪ Identify HFE items for MOC checklists or forms	▪ Update/input into existing Company HSE policies and strategic objectives ▪ Update/input into existing Company change procedures ▪ HFE value added to documentation accuracy and usability ▪ Specific HFE input into Company O&M, EER, HSE Documentation ▪ Updated MOC checklists or forms to include HFE items

5.5 Contingency and Emergency Planning

a. How Does Human Factors Relate to Contingency and Emergency Planning?

Thorough consideration of HFE in Contingency and Emergency Planning is necessary to avoid human errors that could worsen the escalation or consequences of events during unusual circumstances. Some areas that should be considered include:

- Declaration of emergency (criteria) (method defined). Provision of an emergency control center for centering response activities. Protocols for contingencies and emergencies should be defined using operational terms and tests of these should occur to determine usability of the approach.
- Emergency response manuals should include clear and concise instructions for events such as man overboard, fire, explosion, collision, spills, etc. Other areas of operations that should be reviewed for potential HFE problems include:
    - Wave actions
    - Weather
    - Sea conditions
    - Marine operations
    - Drilling
    - SIMOPS.
- Exercises should be conducted to test the usability of the instruction and ensure that all necessary equipment has been defined and is available.
- Availability of information during emergencies should be assessed to determine if people have necessary info in a timely manner.
- Defined command structures should be include in response procedures.
- Job Task Analyses should be used to define roles, responsibilities, facilities and tools required.
- From the HFE literature, behavioral information on people in emergencies should be used as inputs to developing response procedures.
- Developing root cause analysis method should occur during planning in order to allow systematic evaluations of potential causes and also weaknesses in HSE, in case of incidents
- Simulation and monitoring of human behavioral response in emergency drills can be used to discover and address potential problem during emergencies
- Records of drills and notations of problems/concerns should be kept and periodically evaluated.
- HFE personnel should provide input on the location of platform shutdown and ESD stations throughout a platform, as well as on the design of Hydrogen Sulfide alarms and beacons.

b. What are the related Human Factors Tools/Activities for Contingency and Emergency Planning?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing Company non-routine and emergency operating procedures ▪ Personnel roles and responsibilities for HFE/HSE ▪ Feedback mechanisms for HFE/HSE issues ▪ Roles, responsibilities, and accountabilities for HFE/HSE ▪ Communication protocols ▪ Existing Company HSE policies and strategic objectives ▪ Incident, accident, and near miss data ▪ Previous HSE audit results ▪ Principles of behavioral management	▪ User interviews and questionnaires ▪ Personnel knowledge, skills, and ability standards ▪ HFE Design Standards ▪ Psychological testing for personal risk taking behavior ▪ Human performance capabilities and limitations ▪ Training requirements evaluation	▪ Update/input into existing Company non-routine and emergency operating procedures ▪ Update/input into roles and responsibilities for Company personnel ▪ Update/input into key performance indicators ▪ Update/input into procedures to set performance criteria ▪ Update/input into communication protocols ▪ Update/input into existing Company HSE policies and strategic objectives

References for HF within Planning:

- AicheE (1994)
- Karwowski & Marras (Eds., 1998)
- Schwartz, G. (Ed., 2000)
- Eastman Kodak (1983 / 1986)
- McSween (1995)
- Wilson & Corlett (1990)

Table 9. Implementation and Monitoring

6.0 Implementation and Monitoring, what is it according to the E&P Forum?
Activities and tasks should be conducted according to procedures and work instructions developed at the planning stage—or earlier, in accordance with HSE policy: - At senior management level, the development of strategic objectives and high-level planning activities should be conducted with due regard for the HSE policy. - At supervisory and management level, written directions regarding activities (which typically involve many tasks) will normally take the form of plans and procedures. - At the work-site level, written directions regarding tasks will normally be in the form of work instructions, issued in accordance with defined safe systems of work (e.g. permits to work, simultaneous operations - procedures, lock-off procedures, manuals of permitted operations). Management should ensure, and be responsible for, the conduct and verification of activities and tasks according to relevant procedures. This responsibility and commitment of management to the implementation of policies and plans includes, amongst other duties, ensuring that HSE objectives are met and that performance criteria and control limits are not breached. Management should ensure the continuing adequacy of the HSE performance of the company through monitoring activities (see section 6.2). The sub-elements related to Implementation and Monitoring are as follows ▪ Activities and Tasks ▪ Monitoring ▪ Records ▪ Non-compliance and Corrective Actions ▪ Incident Reporting ▪ Incident Follow-up

6.1 Implementation and Monitoring Activities and Tasks

a. How Does Human Factors Relate to Activities and Tasks?

- HFIP would describe HFE planned HFE activities for the various parts of the installation's life cycle.
- Simulations of emergency, spills, other emergency drills
- Awareness training for HFE
- Toolbox talks on HFE related topics

b. What are the related Human Factors Tools/Activities for Activities and Tasks?

Inputs	HF Tools and Activities	HF Outputs
▪ Personnel roles and responsibilities for HFE/HSE ▪ Feedback from mechanisms for HFE/ HSE issues ▪ Previous HSE audit results ▪ Existing Company policies and procedures including HSE ▪ Human performance objectives ▪ Existing Senior Management leadership and commitment to HSE ▪ Incident, accident, and near miss data ▪ HFE integration Vision, Mission, and Objectives	▪ HFE values and principles ▪ HFE Implementation Plan ▪ HFE Strategy ▪ User interviews and questionnaires ▪ Ergonomics/human factors engineering principles	▪ Update/input into Senior Management expectations ▪ Update/input into management/employee expectations ▪ Update/input into roles, responsibilities, and accountabilities for HFE/HSE ▪ Update/input into HFE integration Vision, Mission, and Objectives

6.2 Monitoring

a. How Does Human Factors Relate to Monitoring?

Monitoring is necessary to demonstrate that HFE activities are having the desired effects and results. One means is to require that performance standards and measures be periodically checked. HFE criteria should also be reviewed to ensure it is current and applicable or where gaps in criteria might exist.

b. What are the related Human Factors Tools/Activities for Monitoring?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing Company procedures for monitoring HSE performance ▪ Personnel roles and responsibilities for HFE/HSE ▪ Feedback from mechanisms for HFE/ HSE issues ▪ Previous HSE audit results ▪ Human performance objectives ▪ Existing Senior Management leadership and commitment to HSE ▪ Incident, accident, and near miss data	▪ HFE Integration Vision, Mission, and Objectives ▪ HFE values and principles ▪ HFE Implementation Plan ▪ HFE Strategy	▪ Update/input into existing Company procedures for monitoring HSE performance ▪ Senior Management expectations ▪ Update/input into performance evaluation metrologies of staff ▪ Update/input into management/ employee expectations ▪ Update/input into roles, responsibilities, and accountabilities for HFE/HSE

6.3 Records

a. How Does Human Factors Relate to Records?

- Records on contractors HSE, job performance, HSE programs to check for past HFE problems and current programs
- Records on drills, including timings, persons involved, problems could reveal HFE concerns
- Records must be kept on the progress of implementation of HFE into HSE matters. Performance standards, measures, as well as the success of HFE process and the validity of criteria should be

b. What are the related Human Factors Tools/Activities for Records?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing Company documentation regarding recording keeping ▪ Previous HSE audit results ▪ Existing Company HSE policies and strategic objectives ▪ Feedback from mechanisms for HFE/ HSE issues	▪ User interviews and questionnaires ▪ Information mapping techniques ▪ Ergonomics/human factors engineering principles ▪ HFE/HSE integrated elements	▪ Update/input into existing Company documentation regarding recording keeping ▪ HFE value added to documentation accuracy and usability ▪ Update/input into documentation format and visual presentation methodologies

6.4 Non-compliance and Corrective Actions

a. How Does Human Factors Relate to Non-compliance and corrective actions?

- There must be a method / procedures for identifying non-compliances with HFE criteria, programs, policies and intent. In addition, corrective actions for identified HFE non-compliances must be recorded, tracked, implemented or it must be explained why these actions were not taken or successful.
- Follow-up should occur within a specified time period
- Documentation must be completed and kept up-to-date.

b. What are the related Human Factors Tools/Activities for Non-compliance and corrective actions?

Inputs	HF Tools and Activities	HF Outputs
▪ Previous HSE audit results ▪ Existing Company HSE policies and strategic objectives ▪ Feedback from mechanisms for HFE/ HSE issues ▪ Existing Company Quality System ▪ Previous Quality System audit results ▪ Job functions, requirements and reporting responsibilities ▪ Performance evaluations of staff ▪ Communication protocols	▪ User interviews and questionnaires ▪ Ergonomics/human factors engineering principles ▪ Personnel knowledge, skills, and ability standards	▪ Update/input into existing Company Quality System ▪ Update/input into existing Company HSE policies ▪ Update/input into key performance indicators ▪ Update/input into procedures to set performance criteria

6.5 Incident Reporting

a. How Does Human Factors Relate to Incident reporting?

- Root cause analysis should include factors related to human errors and failures of management systems.
- Incidents are indications of weaknesses in management systems. As a result, all incidents must be investigated using a pre-determined assessment method. The results of the assessment should then result in changes to the management system.
- There must be criteria for specifying what encompasses an incident versus a near miss. The criteria should be documented. The incident or near miss itself should be investigated following a systematic methodology that will reveal a root cause associated with the incident. The incident investigation method should also set forth reporting requirements for incidents.

b. What are the related Human Factors Tools/Activities for Incident reporting?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing Company procedures concerning incident investigation and follow-up ▪ Incident, accident, and near miss data ▪ Existing Company HSE policies and strategic objectives ▪ Previous HSE audit results ▪ Feedback from mechanisms for HFE/ HSE issues	▪ Root cause analysis including human and organization factors ▪ User interviews and questionnaires ▪ Ergonomics/human factors engineering principles ▪ Personnel knowledge, skills, and ability standards	▪ Update/input into mechanisms and responsibilities incident reporting ▪ Update/input into incident reporting procedures ▪ Update/input into incident reporting forms or checklists ▪ HFE value added to documentation accuracy and usability

6.6 Incident Follow-up

a. How Does Human Factors Relate to Incident follow-up?

- For every incident, the investigation should document corrective actions. The incident investigation procedure should also require monitoring of statistics to determine any trend in incidents. Time frames / limits should be set for follow-up activities. Mechanism to check if all potential human errors and management systems failures have been identified in incident report scheme.

b. What are the related Human Factors Tools/Activities for Incident follow-up?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing Company procedures concerning incident investigation and follow-up ▪ Incident, accident, and near miss data ▪ Existing Company HSE policies and strategic objectives ▪ Previous HSE audit results ▪ Feedback from mechanisms for HFE/ HSE issues.	▪ Root cause analysis including human and organization factors ▪ User interviews and questionnaires ▪ Ergonomics/human factors engineering principles ▪ Personnel knowledge, skills, and ability standards	▪ Update/input into mechanisms and responsibilities for follow-up of incidents ▪ Update/input into incident follow-up procedures ▪ Update/input into incident follow-up forms or checklists ▪ HFE value added to documentation accuracy and usability

References for HF within Implementation and Monitoring:

- AicheE (1994)
- Karwowski & Marras (Eds., 1998)
- Schwartz (Ed., 2000)
- Eastman Kodak (1983 / 1986)
- McSween (1995)
- Wilson & Corlett (1990)

Table 10. Auditing and Reviewing

7.0 Auditing and Reviewing, what is it according to the E&P Forum?
The company should maintain procedures for audits to be carried out, as a normal part of business control, in order to determine: ▪ Whether or not HSE management system elements and activities conform to planned arrangements, and are implemented effectively. ▪ The effective functioning of the HSEMS in fulfilling the company's HSE policy, objectives and performance criteria. ▪ Compliance with relevant legislative requirements. ▪ Identification of areas for improvement, leading to progressively better HSE management. For this purpose, it should maintain an audit plan, dealing with the following: ▪ Specific activities and areas to be audited. Audits should cover the operation of the HSEMS and the extent of its integration into line activities, and should specifically address the following elements of the HSEMS model: ▪ organization, resources and documentation; ▪ evaluation and risk management; ▪ planning; ▪ implementation and monitoring. ▪ Frequency of auditing specific activities/areas. Audits should be scheduled on the basis of the contribution or potential contribution of the activity concerned to HSE performance, and the results of previous audits. ▪ Responsibilities for auditing specific activities/areas.

7.1 Auditing

a. How Does Human Factors Relate to Auditing?

- HFE is applied to documents technical correction, usability, and up to date. Procedures manuals checks on root causes compared to accident and near miss reports
- Types of applicable audits HFE criteria adherence with specs, HFE's process safety occupational
- Management must require periodic audits in order to ensure that all HFE activities are taking place, that benefit is being gained from the application of HFE, that all persons in the organization understand their role with regards to HFE implementation and also to identify and gaps in implementation. Audits are also necessary to ensure that planned activities are taking place and that targets with regard to HFE are being met.
- A method for conducting audits must be predetermined and documented. The audit procedure should also identify objectives, frequency and depth of the HFE audits. The procedure should also document who is responsible for the HFE audit function as well as reporting requirements.

b. What are the related Human Factors Tools/Activities for Auditing?

Inputs	HF Tools and Activities	HF Outputs
▪ Existing HSE Auditing procedures ▪ Existing Company HSE Auditing policies ▪ Previous HSE audit results ▪ Feedback from mechanisms for HFE/ HSE issues ▪ Existing Company Quality System ▪ Previous Quality System audit results ▪ Job functions, requirements and reporting responsibilities ▪ Performance evaluations of staff	▪ User interviews and questionnaires ▪ Ergonomics/human factors engineering principles ▪ Personnel knowledge, skills, and ability standards	▪ Identification of areas for improvement, leading to progressively better HSE management ▪ Update/input into audit protocols and procedures ▪ Update/input into key performance indicators ▪ Update/input into procedures to set performance criteria ▪ HFE value added to documentation accuracy and usability

7.2 Reviewing

a. How Does Human Factors Relate to Reviewing?

- Periodic review of audit findings is necessary to determine any issues that may be unresolved and also to identify trends in the audit findings. Audit results can also be reviewed together with other types of "management system" indicators, like the results of incidents and near miss investigations.
- Reviewing audit finding may point to area in the management systems that require changes or updates.

b. What are the related Human Factors Tools/Activities for Reviewing?

Inputs	HF Tools and Activities	HF Outputs
▪ Senior Management roles and responsibility ▪ Existing Company HSE policies and strategic objectives ▪ Previous HSE audit results ▪ Feedback from mechanisms for HFE/ HSE issues ▪ Existing Company Quality System ▪ Previous Quality System audit results	▪ User interviews and questionnaires ▪ Ergonomics/human factors engineering principles ▪ Personnel knowledge, skills, and ability standards	▪ Identification of areas for improvement, leading to progressively better HSE management ▪ Update/input into audit protocols and procedures ▪ Update/input into key performance indicators ▪ Update/input into procedures to set performance criteria

References for HF within Auditing and Review:

- AicheE (1994)
- Kirwan & Ainsworth (1992)
- Karwowski & Marras (Eds., 1998)
- McSween (1995)

2.1 Cost Benefit Analysis

The cost/benefit measures of HSE management systems are often incorrectly perceived as intangible. Formal management systems integrated with HF, properly designed, developed and implemented provide a foundation to measure process performance compared to criteria designed to meet end objectives. Trying to measure process performance in an informal management environment is very difficult, if not impossible, and is often characterized as "bottom line management" (i.e. "our bottom line is good, therefore our processes are performing well" or vice versa). Over time a false sense of security is formed around processes perceived by the bottom line to be performing well and various kinds of "fire fighting" are implemented for processes shown by the bottom line as not performing well. Formal management systems are used as a tool to manage and control each process, eliminate fire fighting and continuously improve performance. Management systems provide the information needed to pin point problem areas and data necessary to analyze each process such that corrective/preventive measures can be taken before they negatively impact the bottom line.

Cost benefits of integrating HF into management systems are process specific and must be measured in terms of costs saved through process improvements, such as design control, incident investigation, process controls, etc. Management systems have no cost benefit if they are not used as a tool to facilitate the management and improvement of each process. Applying formal management systems facilitates:

- Improving operating and safety conditions through the optimization and structuring of related processes.
- Establishing a common platform that can be used to evaluate and improve performance of all areas of operations (e.g. a management system that encourages sharing of strengths, correction of weaknesses and learning from mistakes).
- Improving performance and streamlining operations by analyzing performance data and making incremental refinements over time.
- Reducing risk, cost of operations, improving support services, lowering down time, fewer unplanned rework and manufacture / fabrication errors through improved control of processes and systems.
- Lowering costs associated with technological advancements, organization expansion, restructuring and change.

Hard data does exist on costs that can be saved in a variety of processes such as design control. (See the papers by Working Groups 2 and 3[1] for guidance on cost-benefits and tradeoff analysis for new, and existing, designs where this type of data has been documented.) In other processes where data has not been established, the cost/benefit relationships are not as clear.

Clearly the strongest tool available to maintain incremental improvements in operations and safety that result in significant cost and risk reduction is the use of management systems. To obtain a true picture of the overall costs and benefits a management system can provide, process improvement and related cost data must be established for all processes within an organization. When the costs of designing, developing, and effectively implementing a formal management system for all the processes are added together and compared to the cost of managing and controlling processes informally, the payback on the one-time cost for the management system is typically within four to eight months.

3.0 CONCLUDING REMARKS

Many industries, including the maritime and offshore oil and gas industries, agree that technological approaches are not sufficient to increase safety and reduce risk potential associated with hazardous operations. It is now recognized that organizations must be well managed and develop a system of HSE management which includes not only systems of work aimed at technical issues but which also include managing human and organizational factors. The management principles upon which HSE MS should be based are planning, organizing, implementing, and evaluating. It is also recognized that an effective HSE MS cannot be bought off the shelf since, as Whalley-Lloyd (1994) points out, an HSE MS has to be developed to suit a company and the people working in it. For success, an HSE MS must involve key individuals within the organization during the development of the HSE MS scheme and all individuals in the organization need to be committed to its implementation. Not only must a particular organization develop, implement, communicate, evaluate, and update its HSE MS, but that organization's management should ensure that the program contains elements similar to the guidance that is commonly accepted by its' industry and regulators.

[1] Actually WG3 doesn't say very much about CB analyses--almost only identifying the different types of costs. WG 2 does have a specific section on the subject.

This paper attempts to break new ground by incorporating the methods and principles of the discipline of human factors, as they address human performance and safety, within the elements of HSE MS. In this paper we have:

- Identified a baseline HSE MS structure and summarized its processes and phases
- Attempted to make a case for HF in the context of HSE MS
- Identified the potential interactions and contributions of HF within the HSE MS framework
- Generated a table containing detailed guidance to conduct and assess the managed integration of HF in the HSE MS framework.
- Suggested a cost-benefits analysis is useful to assess the viability, robustness, and costs associated with integrated processes

It must be noted that the integration presented in this paper is notional, and is in no way validated or proved, nor is it recommended for immediate use by HSE MS personnel that may be interested in such a union between HSE MS and HF. The objective of this paper was to initiate discussion and dialog on the potential for such integration. This we believe was accomplished during the 2002 Workshop for this topic.

We recommend that integration of these disciplines continue to be developed and analyzed, and implemented in discrete elements to help quantify and qualify any benefits and costs that may be accrued. Ultimately, this paper represents an early step on the path to an integrated HSE MS and HF process.

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WORKING GROUP 6

2ND INTERNATIONAL WORKSHOP ON HUMAN FACTORS IN OFFSHORE OPERATIONS (HFW2002)

EFFECTIVE APPLICATION OF BEHAVIORAL BASED PROCESSES IN OFFSHORE OPERATIONS

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EFFECTIVE APPLICATION OF BEHAVIOR-BASED PROCESSES IN OFFSHORE OPERATIONS

1.0 INTRODUCTION

The introduction of the behavioral-based safety process in the offshore industry over the past decade has had a significant impact on safety in general and the offshore safety culture in particular. The Behavior-Based Safety (BBS) process compliments Human Factors Engineering (HFE) efforts in the struggle to improve safety by minimizing the risk in the hazardous offshore environment. The behavioral-based safety process and HFE both focus on the workers by taking advantage of their strengths and minimizing their weaknesses.

The four key steps of the behavior based safety process are as follows:

1. Identifying behaviors – Identification of and operationally defining the behaviors that make up the pool of risk is the first step. This is most commonly accomplished by studying a statistically valid sample of past incident reports and extracting the behaviors that facilitated the injury. The objective is to validate these and then to develop an operational definition of wht it looks like when the employee is executing the behavior in a risk averse manner.
2. Gathering data – This second step is to sample the occurrence of these identified critical behaviors out in the workplace. This measure is a proactive stimulus or predictor of whether there is likely to be an injury or not.
3. Providing performance feedback – This step trains the sampler to reinforce the safe behavior the employee is doing and dig in and find out why the behaviors that are being donne in a risky manner are being done that way.
4. Removing system barriers.- Lastly this step is to take the data from sampling and feedback and to use it as the impetus to do intervention at the system level.

The primary objective of HFE is to design the workplace or system to eliminate or minimize the potential for human error. The behavioral-based safety process uses a continuous improvement process based on observations and positive feedback to pinpoint at risk behaviors and weaknesses in management systems. Thus, whereas HFE's goal is to build a work environment that is as safe as practical, the behavioral-based safety process tackles the difficult task of identifying and rectifying bad habits and gaps in management systems with the ultimate goal of creating a safety culture that supports safe behaviors. Together, the two processes complement one another in improving safety by minimizing the risk in the hazardous offshore environment.

This paper presents the overlap and interaction between HFE and Behavior-Based Safety in managing workgroups safety performance. For example, It will highlight how BBS tools can provide useful feedback to the facility designer for consideration in improving the design, and in the design of future facilities. After introducing three categories of critical safety-related behaviors: enabled, difficult, and non-enabled, the paper discusses the primary concepts of the behavior-based approach to accident prevention. It then sketches six current myths about behavior-based safety, and addresses them through a detailed presentation of the four key activities of Behavior-Based Safety at the level of the workgroup. This paper will focus on what works and does not. Frequent references will be made to BAPP®, one approach fostered by Behavioral Science Technology (BST) for illustration sake. It is one of many available approaches that operationalizes the principles of BBS. A sample listing of some other available BBS approaches and programs are identified in the reference section of this paper.

2.0 BACKGROUND

Over the past few decades the focus on safe operations has become a norm for those businesses that have the potential for large loss of human life and environmental catastrophe. The two are not much different in the minds eye of the public.

The oil industry and specifically offshore industries came aboard with this thinking in the more recent past. This need to improve safety has been reinforced by the losses that have occurred in this industry and the realization that they had to find more economical means to operate given the pressure on profits from the global competition. Safety, in short, became a two edged sword for the offshore industry.

First, it was good business not to be incurring the financial burden of mishaps. It became a way to let the employee know that even in the uncertain world of re-engineering, reorganization, cost cutting, and other tough survival activities that the organization has to undertake, that it still cares about the employee.

3.0 THE REALITY

Behavior is one of the components of almost every injury. If we took the people out of the picture there would be no real injuries to speak of. This said, there are virtually no behaviors executed by anyone in pursuit of an injury. So the question that Behavioral science gives us is why people do things that enhance the chance of an injury occurring.

Another frequent component associated with injury is the facility or task design. These are the physical constraints built into the design that form the physical working environment for accomplishing task. Design shortcomings can negatively or positively impact the performance of a desired behavior that may be recognizable to the observer with basic HFE knowledge. Also, here is where the BBS and HFE processes can work together to improve the design, provided the design flaws are recognized and communicated back to the design engineer or to the design engineering process.

The conditions that increase the likelihood of a certain outcome are called risk factors. These are design-related that increase the likelihood of developing a work-related musculoskeletal disorder, also called repetitive stress illness or cumulative trauma disorders.

Example risk factors, associated with the design, that can positively or negatively impact behavior are as follows:

Awkward posture - For each joint in the body, there is a range of motion which is considered neutral or non-stressful. For example, any flexing, bending or twisting of the wrist takes it out of neutral (straight) posture.

Repetitive motions - Movements that are frequently repeated will increase risk. Finger movements at keyboard and mouse are examples.

Forceful motions or exertions - Activities involving forceful motions can increase MSD risk. Examples are gripping a pen too hard or striking the keys of a keyboard too forcefully.

Contact Stress - Pressure applied to a nerve can damage it. An example is resting the wrist of the hand on the sharp edge of a table, which applies excessive pressure to the median nerve coming out of the wrist.

Sustained posture - Any posture, even neutral, can be stressful if it is sustained over long periods. This is most often noticed when the neck, back or shoulder are held in one position for an extended time.

There are three types of behaviors that make up the pool of at risky behavior in any work environment and different types of interventions to deal with these very different types of behavior. It is also the case that the same behavior can fall into any of the three categories at any time depending on the circumstances. The three types of behavior are Enabled behavior, Non-Enabled behavior and, Difficult behavior.

3.1 Enabled Behavior

This is behavior that the employee has discretionary control over. This is not to say that there are very valid and insidious reasons that the employee would not execute it properly. For example, an improperly designed task may introduce certain risk factors that may cause discomfort and possibly injury, which would likely negatively impact the desired behavior. However, it may not always be so overt a barrier to doing it the right way. In most cases the reason for the employee doing this behavior in a risky manner may seem very benign. This is due to, for the most part, to the fact that they have done it many time for long periods with no adverse consequences. In fact, when it is done in the risky manner, it produces some very powerful positive consequences. Examples of these positive consequences are speed, ease, or less work, etc. In most of these cases changing the physical system is not going to yield much change.

3.2 Non-Enabled Behavior

This is the second and polar opposite of enabled behavior. This is a behavior the employee is not in control of. The system allows for one option, in the case of safety, usually that option is not the correct or least risky one. These situations demand some type of intervention strategy. This strategy almost always requires HFE. Without some formal change in the system the behavior has little or no chance of being changed.

3.3 Difficult Behavior

This behavior is one that crosses both of the above categories and is an interesting mix of both systems issues and perceptions. In managing risk in the difficult category the issue seems to be the risk-to-effort ratio. When doing something the correct way involves a lot of effort, or a level of preciseness that is perceived unrealistic, and if the perception of danger is not acute, the employee is very likely to improvise and not take the precautions necessary to avoid exposure.

An example would be the employee that jumps up on their chair or desk to change the light bulb above the desk. We all know that using a ladder would be best. What the employee knows is that to use the ladder they have to go down stairs, find the janitor, get the key to the supply room, unlock it, get the ladder, climb to the second floor, use the ladder then reverse all of the previous steps. This behavior is difficult enough to overshadow the risk in the employee's mind.

Another example was a machine that had identically designed controls on both sides of the operator's console for different functions. The operator would frequently engage the wrong control. The operator had to be one hundred percent alert to what they were doing to prevent a mishap. They had informally developed a method for use of the controls that prevented them from being used without breaking the train of thought.

These behaviors usually require HFE. In many cases, some thought and some action by the workers or supervisors is sufficient. These behaviors do not always require a capital-intensive solution.

4.0 The Hierarchy of Safety & Health Controls

Initially most safety efforts were very traditional and focused on injury or mishap as the measurement medium and trigger for action. Human Factors Engineering and Behavior-Based Safety (BBS) were not on the radar screen. The proactive measures that the companies undertook were catastrophe prevention through engineering and design, and the approach to behavior management was training or rules and procedures. The order of the day was to utilize the Hierarchy of Safety Control. This Hierarchy consisted was a list of intervention methods that started out independent of employee behavior and as it progressed got increasingly dependent on employee behavior (See *Figure 1*).

Until fairly recently management only superficially recognized the HFE management approach in the hierarchy as a method of injury prevention. The problem was that it was seen as expensive and slowed things down. There was not a good way to determine the resultant impact of a particular design or redesign. Also, due to the limited number of HFE experts, it proved difficult for companies to hire such experts. Getting the everyday engineer to think in terms of human behavior was, and remains, difficult at best.

The prevailing thought was that you could not make it error-proof, so don't try; and there was a belief that the employee could overcome the obstacles if they wanted to. The real focus of HFE was primarily on guards and interlocks.

I am not saying that using this approach is incorrect or not something that needs to be done. But the fact remains that even though all or any of these interventions are implemented, none of them effectively assures that the employee is executing the right behaviors at the right time. Thankfully, it has grown in scope as more has been learned about HFE and HFE's potential for error reduction. It has become indisputable over the years the way things are designed and installed have a dramatic impact on error. I believe it is also the case that this methodology is in fact having an impact on the way we think about human behavior. Human behavior is for the most part shaped by the environment it functions in. The behavior you are getting in your organization is what the organization is asking for through the design of the work, facilities, equipment, and culture. If the behavior is occurring consistently it is a factor of the system.

There was another issue that was pushing companies away from taking the HFE or BBS approach. It was an acute recognition, especially in management ranks, that the employee was doing things that caused mishaps. This recognition in many instances resulted in an approach that then assigned blame to the employee. After all, if the employee did something that was obviously risky we need to do something that shows we don't condone it. The best illustration of this is looking at supervisory reports on mishaps.

In almost every instance the supervisors mitigating action of the mishap included solely, or as a major portion, the notion of re-instruction, counseling, warning, disciplining, or retraining the employee. To the naïve this looks like the employee is the problem. To the Behavior-Based Safety expert this means there were identifiable behaviors that the system was producing or reinforcing, that could be measured and could mitigated. Meaning, in essence, that the system was providing antecedents and consequences favorable to at-risk behavior, and the existing system was incapable of reliably producing the behavior that would reduce the risk and mishap rate.

5.0 *BEHAVIOR- BASED SAFETY GOALS*

Behavior-Based Safety is principally a method for focusing the organization on behavior as the improvement target. Behavior is the most accurate and proactive indicator of not only how safe the organization is working, but also how capable the environment is of producing the type of behavior that reduces the risk or exposure to the employee. By focusing on behavior a person is able to overcome several obstacles that are present when using injury/illness or incident rates as the sole performance measure.

First, you are able to get a more statistically valid sample of workplace safety. Having a hundred observations of workplace behavior in a three month period is a much more valid measure of safety performance to a workgroup than one injury in the same quarter. Second, the measure is active not passive and sets up the opportunity to do real value added activities such as feedback, and problem identification around the observations. Third, if you collect the data and analyze it, a firm has the basis for very focused system barrier identification and HFE can be applied in a more focused manner for system change.

The real goal of Behavior Based Safety is to reduce the variation in the safety related behavior through feedback and system change.

6.0 *PRIMARY IMPLEMENTATION PHASE CONCEPTS*

In applying BBS methods there are some principles that are utilized for insuring success. Some of these principles followed in the implementation methodology are:

- Build a process, do not implement a program
- Adapt to the culture of the organization versus adopt a canned program
- Engage employees in the adaptation and implementation
- Focus on the system versus blaming the employees
- Develop internal resources for leadership of the effort
- Management and the workforce need to understand and buy-in

6.1 Process Not Program

Many traditional approaches to safety have developed reputation for just a “program of the month.” The BAPP® approach is not just another program. It is *process* with the potential for continuous safety improvement. BAPP® technology allows for flexibility and focus within the process, eliminating the need to constantly change programs to match an evolving culture.

An ongoing process builds more credibility than a series of programs. The process becomes part of the culture, “the way we do things around here.” As the process produces results, it gains a larger following and moves into an upward spiral of credibility among the facility population.

The BAPP® approach is more effective than programs, but it means more work, especially at first. Establishing a new process in an existing culture requires an ongoing, focused, concerted effort. More training time and start-up time are required for a BAPP® implementation than for a program designed to last only a month or two. Facilities that are unable or unwilling to expend such time and effort are not ready for BAPP® technology.

While some safety programs provide quick wins, few produce long-term results. When the program ends, so does the impact. The BAPP® approach, on the other hand, has the potential to establish an ongoing cycle of improvement. While early efforts may produce some results through the Hawthorne effect, the real results come as the process matures and begins to change behavior and the cultural elements that reinforce behavior. While these changes tend to take longer than program changes, they also last longer.

These long-term results come from improving the system that sustains behavior. An approach that ignores the factors that reinforce behavior cannot accomplish lasting change. Instead, BAPP® technology looks through the lens of behavior at the issues of culture, attitude, and environment that shape behavior. It supplies the data that organizations need to identify areas where focus can launch permanent change. Identifying such areas is critical to accomplishing continuous long-term safety improvement.

This approach is what makes BAPP® technology a process, rather than just another safety program.

6.2 Adaptation vs. Adoption

Off-the-shelf products have little chance of becoming part of a company's culture. Every culture is different, and the differences must be addressed. For behavior-based safety to be effective, its principles must be adapted in every instance to fit the people and the environment involved in the process. BAPP® implementations may be similar across companies, but they will always contain critical differences. Adaptation often makes the difference between success and failure.

Adapting the process means involving people in meaningful ways to make the adaptations. Adaptation leads to another important principle of BAPP® technology.

6.3 Employee Involvement

Without involvement, there is no commitment. BAPP® safety initiatives provide opportunities for participation by people at all levels in the organization. People tend to support what they help to create. Adaptation allows many to help create the particulars of a process.

From the onset, each level in the organization has specific roles and responsibilities that are critical to the success of the BAPP® initiative. Continuous improvement in the maturing process provides many more opportunities for involvement, which can eventually reach every person in the facility.

The ownership of the nuts-and-bolts workings of the process is entrusted to the Hourly workforce. Since it is often the most stable group in a facility, involving the Hourly workforce actually becomes a mechanism to sustain the process over periods of change in various levels of Management, or even change of company ownership.

Once the expertise needed to run the process is taught to a group of workers and Supervisors, those workers, in turn, train Observers, and the rest of the workforce. This group of Hourly and Management are also the decision makers in the day-to-day administration of the process. They design the process around the basic principles of BAPP® technology and adapt it to their specific work environment.

6.4 Don’t Blame Employees

Focusing on behavior does not imply fault-finding with individuals. Behavior is not a simple matter of personal choices. Behavior is affected by many factors, most of which are ultimately controlled by Management. Accurately placing blame for At-risk behaviors would be embarrassing and counterproductive. Fixing the problem, not fixing the blame, is the principle that truly prevents accidents.

Analyzing how systems affect behavior is a starting point for designing systems that stimulate and reinforce safe behaviors. Designing systems in this way is an ongoing process, adapted to the organization in which the system operates. The design of such system requires a high level of involvement and participation from all levels of an organization.

6.5 Parallels with Quality, Involvement

Quality is inextricably linked to the involvement of the people who perform the process. In the same way that Quality improvement relies on the people who manufacture a product, safety improvement depends on the people who are At-risk for injury: the Hourly workers. They have the most to gain from effective safety measures and the most to lose from ineffective ones. They have the most influence over each other and know the most about the details of the daily routines that shape behavior on the floor. Their support can ensure success; their opposition can make progress difficult, if not impossible.

6.5.1 Feedback

As Deming, Juran, and others began to explore the real questions of Quality improvement, they made an interesting discovery: most people in the plants of the 1940s were isolated from the results of their efforts. They made a product, or part of a product, and seldom knew if the product received praise or complaints from the customer. If they did get such information, it was much later. The net result was that the average worker got no meaningful feedback on the quality of his or her work. Likewise, the average worker today gets little or no feedback on safety behavior.

The feedback they get on At-risk behavior is often sporadic and usually comes in the form of criticism or discipline. The lack of feedback makes it difficult for workers to improve their safety performance. The BAPP® approach provides such feedback and provides it in an effective and usable form.

6.5.2 Measurement

Quality experts will tell you that "what can be measured can be managed." However, this axiom is correct only if the measured signs truly point to the subject. The same principle applies to safety. Companies that learn to measure the real indicators of safety, develop tools to interpret this data, and use the data to design appropriate interventions into the process have an opportunity to effectively manage safety performance.

6.5.3 Upstream vs. Downstream

Just as inspecting the only finished product is an inefficient way to manage quality, reacting to accident data is an inefficient way to manage safety. The first step upstream from accidents is Behavior. Measuring behavior provides an invaluable tool for managing accident prevention. Shifting the focus from reaction to prevention, it works on the final common pathway of most accidents: At-risk behavior. As the number of At-risk behaviors occurring in the workplace declines, the number of accidents follows suit.

6.5.4 Problem Solving

Quality training provides problem-solving tools that equip employees to develop, test, and implement solutions to the problems they identify. BAPP® technology provides such tools also. Employees are trained to use behavioral analysis and Cause-Tree Analysis to identify root causes and multiple causes of At-risk behavior. They are also taught intervention methods to assure the process accomplish real results and measures success. Systematic approaches tend to produce better results both in quality (defect prevention) and in safety (accident prevention).

6.5.5 Statistical Methods

An important part of measurement and problem-solving requires a working knowledge of statistical methods. Quality teaches Statistical Process Control (SPC) in which workers mathematically determine whether a change is the result of some special causes or just normal flux. Safety also involves managing a process of behaviors that can have either normal or special flux. Many safety efforts panic or relax due to changes in incident rates that are statistically insignificant. The BAPP® approach teaches those involved how to interpret data according to sound statistical methods so that the action they take is based on significant information.

6.6 Develop Internal Resources For Implementation

Outside expertise is typically used to train those who initiate the process, but the ultimate goal is to bring the process in-house. This involves selecting the right individuals and exposing them to the right training and involvement experiences to build sufficient levels of commitment and confidence. This approach affords the maximum opportunities for involvement. Maximum involvement means maximum commitment. Maximum commitment means maximum change for long-term success.

BAPP® safety efforts are directed by *Steering Committees,* composed of Hourly employees and sometimes one or two First-line Supervisors. Once the Steering Committee members are trained and functioning, they have gained valuable experience in team building, problem solving, process analysis, and the basics of Total Quality Management, and the facility has gained a valuable resource for accident prevention. The Steering Committee members often amaze their Managers with what they learn and accomplish. They set the tone for future generations of participants in the BAPP® safety initiative.

6.7 Objective

It is important to always remember the goal of BAPP® safety efforts. Many safety efforts are satisfied with immediate reduction in recordables or other signs that the efforts are producing results. Such results could be nothing more than the normal variation in downstream safety statistics. The goal of BAPP® safety efforts is continuous, statistically significant improvement.

7.0 MANAGEMENT AND THE WORKFORCE MUST UNDERSTAND AND BUY-IN

In order to develop a process built on these primary concepts, it is imperative for both Management and the workforce to understand and buy into the effort. The first step towards buy-in is to have the key players in the organization develop a thorough understanding of what the process entails. This includes the theory of Behavior Management and the elements of a successful implementation. The next step is to develop a clear path forward including the distinct roles, responsibilities, and resources needed for a successful implementation, and a plan to acquire those resources.

Without taking these steps, the likelihood of a successful implementation is much lower. All of these principles help assure the process is effective and following them reduces the amount of organizational resistance that a change effort such as this normally encounters.

8.0 *Six Myths about Behavior-Based Safety*

Before getting to a detailed description of Behavior-Based Safety it is important to understand that BBS has some myths that have grown up with it. These myths are pervasive and have effected some organizations in their ability to understand and use the technology successfully. These myths have muddied the water in general about the technology. The most common myths are:

1. Behavior-Based Safety replaces or subverts HFE or the hierarchy of safety controls.
2. Just doing observations constitutes Behavior-Based Safety.
3. Behavior-Based Safety is for the hourly workforce only.
4. Behavior-Based Safety pushes blame onto the workers.
5. Behavior-Based Safety is just from the realm of psychology.
6. All this Behavior-Based Safety stuff is the same.

9.0 *Four Key STEPS of a Behavior-Based Safety Process and what the Behavioral Science specialist does to implement them*

The four key steps of the implementation process are as follows:

5. Identifying behaviors
6. Gathering data
7. Providing performance feedback
8. Removing system barriers

The first really critical step in utilizing the concepts and principles discussed above is to understand the context of the situation in which you are about to try to apply them or what is the organizational functioning level of the organization that you are going to work in. Understanding this is probably the single most important factor that the consultant or specialist must know and consider before proceeding. Every project should begin by conducting an assessment of the organization where the implementation is going to happen. The objectives of this assessment are to ascertain organizational characteristics that will influence implementation details.

The first stage of the assessment phase will be information gathering, which can be done through a series of interviews of personnel by consultant or specialist and through administration of a validated Organizational Functioning Survey.

Interviews should be conducted with a cross-section of personnel cutting across levels and functions. One-on-one interviews are conducted with senior leadership, small group interviews with supervisors, and larger group interviews with front-line workers. The objectives of these interviews are to help surface issues important to designing the implementation, and to collect information to support the 4 steps of the implementation.

The Organizational Functioning Survey needs to be a unique instrument that measures a series of variables indicative of the underlying organizational effectiveness factors that shape what we see as organizational culture. For example, where the quality of communications is often cited as a component of culture, the instrument should look “below the surface” at factors such as “organizational justice” and “leader-member exchange,” which are root causes of the more readily apparent aspects of organizational culture. By understanding these culture factors, improvement strategies can be designed to strengthen culture and enhance organizational functioning.

The specialist should use these results, along with the information gathered in the interviews, to refine the strategy for the implementation. For example, survey results may inform the identification of critical behaviors for supervisors and managers, and/or may indicate areas where some focused skills training is needed.

During this assessment phase, you need to identify success metrics for the performance improvement initiative. These metrics are important for both the specialist and the organization to be able to assess the effectiveness of the implementation effort. The metrics should relate closely to your corporate objectives for this initiative, and should be measurable through reliable objective data.

In addition the composition of an Implementation Team – a cross functional, cross level group who will play the primary role in undertaking implementation activities should be chosen carefully to work with the specialist or consultant. It is also recommended from experience that a full-time facilitator be appointed for the initiative. This team and this individual must be selected carefully. Their skills and influence bear heavily on the likelihood and level of success.

Following the assessment, the implementation begins in earnest. The implementation will consist of a series of activities designed to build support for the behavior-based process and transfer the competencies needed to make the process successful. The specialist needs to periodically to work with your Implementation Team and management, and define work to be performed between visits by the Team.

It is important to understand that reducing the description of Behavior-Based Safety to these key activities does not in any way imply that it is easy to implement. In fact the one of biggest mistakes that some companies make is to underestimate the organizational resistance to this process or to not balance resources with objectives.

9.1 Identifying Critical Behaviors

The first step for the implementation team will be to figure out and validate which behaviors make up the pool of exposure for an organization. Operationally, this means which behaviors appear consistently before injuries. Once this list of critical behaviors has been determined then operationally defining those behaviors. In other words what would each of these behaviors look like if they were being done in a way that it reduced exposure, communicated to everyone what acceptable risk looks like. Or from the other perspective when you are not doing it as described you are at risk. This list and definitions should become the yardstick for measuring the safety performance of the organization especially at the workgroup level on a day-to-day basis.

The specialist needs to work with the Implementation Team to refine and validate the critical behaviors, gaining buy-in from the team at the same time, until a final instrument is complete.

During this step of the implementation, it is also critical to conduct introduction/buy-in meetings for all employees within the affected organization. These meetings usually take approximately an hour each and are designed to explain the process and build enthusiasm and support among the workforce. The number of meetings should be determined with the principle of interaction and the feasibility of freeing people up for these sessions. Past experience has shown that these meetings are most effective if limited in size to about 20 people.

Another task early in the implementation will be to develop critical behaviors for the management group. The behaviors for these individuals will be those things critical to supporting the implementation and supporting the organization's objectives. It is easier to identify critical behaviors for management group members in small meetings involving two or three management group members.

When critical behaviors have been identified and introductory meetings held it is then time to begin training the Implementation Team to be able to conduct observation and feedback.

9.2 Gathering Data

The next activity is to formally begin to measure or sample the behavior being executed by workforce in a systematic and standardized way. This usually requires formal observation. The objective is to discover where the critical behaviors are occurring in way that exposes the worker and at what frequency they are occurring. This measure is a much more proactive measure than using injury numbers after they occur. This measure is also more statistically valid than the injury numbers due to the fact that whether an injury occurs or not is to some degree a factor of luck or randomness. The same behavior can be done literally thousands of time with no injury associated with it the next two times it happens and injury results. No one can predict when it will occur or how serious it will be. Having this data allows us to begin to truly see where the exposure or risk is.

This data gathering or observation also sets us up for a couple of other high leverage activities. First it allows us to provide the employee feedback on what we see them doing that we want to reinforce and continue to generalize. It also sets us up to discover why the behavior is being done in lieu of the safest behavior and whether the behavior falls into the enabled, Non-enabled or difficult category. In other words it is easy for the observer to discover from the worker, in the feedback, the reason the behavior is being done in the manner it is. This data is very critical to the organization. It is now the case that the human factors group has literally engaged every set of eyes and ears in the field. They are collecting data that clearly pinpoints where the exposure is and why the exposure is occurring.

Key principles that are embedded into this training are to avoid blame, to recognize systems causes of undesired behavior, and to produce quality documentation that can be used to make the HFE group more effective and to be able to change the employees ability to recognize hazards.

9.3 Providing Performance Feedback

Providing ongoing, two-way feedback is the third key activity in Behavior-Based Safety is the mechanism for dealing with the discretionary behavior that is occurring that puts the employee at risk. Feedback in this application is defined as information about performance in relation to a goal. This feedback is intended to be a two-way exchange between the observer and the observed. The purpose is to reinforce and get a generalization of the behaviors that the employee is able to change and to discover which behaviors the employee has incentive to do in a risky manner. This incentive is a naturally occurring factor of the system. Also, the purpose is to determine which behaviors the employees really have no control over, due to the system.

9.4 Removing Barriers to Continuous Improvement

Lastly but most important for lasting and reliable change in the behaviors that are producing the most exposure are identified from the observation data and dealt with in the manner most effective. If the behaviors identified as producing the most exposure turn out to be not a result of the equipment or engineering then other systems are examined such as training, feedback, or design of the work. If the behaviors identified are driven by culture the feedback and other methods are utilized. If the behaviors are due to engineering or equipment then those are dealt with through engineering or new and better equipment. In other words the barriers to the best behavior for the situation are identified and systematically removed.

10.0 Eight Critical Success Factors

In implementing Behavior-Based Safety it is the case that there are many opportunities for error and missteps. It is critical that the factors leading to success in implementing behavior-based technology are known and attention is paid to them. As with HFE, the more we know about what works and why it works the more effectively the technology can be utilized. We have studied the factors present in about 800 implementations of Behavior-Based Safety and there were eight that seemed to make the real difference in whether a company was successful in its use of Behavior-Based Safety.

They are:

1. Having a blueprint for implementation
2. Demonstrated leadership
3. Highly competent implementation team
4. Communication
5. Buy-in and understanding
6. Skills training
7. Use of data for process improvement
8. Ongoing technical support

Interestingly, a parallel study of TQM implementations turned up the same factors as critical to success.

11.0 CONCLUSION

In conclusion, Behavior-Based Safety is a natural extension of a compliment to HFE. The technologies are not in conflict at all. It is the case that HFE could benefit from the data generated from a Behavior-Based Safety process and a Behavior Based Safety process could benefit from the gains and learning's of HFE. It has been my experience that in almost every accident the employee did something that was the final pathway to the event. I am not attaching blame. I am saying that the system that that employee functioned in made the "at risk" behavior more attractive than the "safe" behavior. Until the organization recognizes that and aggressively attacks the system, the behaviors and resulting events will continue.

It also seems the use of behavior-based systems suffers from the same hardships as HFE. It requires integration of all systems in the organization, behavior-based methods are not widely understood, it is seen as a cost to be added rather than a way to be world class and successful, a good measurement system is not readily available to measure its true impact. The catastrophe that is prevented is never recognized. The result of these hardships is when implemented the first question seems to be how can we cut corners. In today's environment of cost pressure, doing the same or more with less, and pushing responsibility to the lowest possible level, doing it right the first time seems of more importance than ever before. Spending resources on new and better ways to achieve reliability and error reduction seems to make as much sense as investing in new technology for drilling or exploration. Integrating the two technologies seems to be the next natural evolution.

Attached is a longitudinal study conducted by BST on over 100 sites that implemented BBS over a 15-year period.

11.1 BAPP® System Longevity

Behavior-based technology is highly sustainable. This chart shows the percentage of all BST-led implementations across the globe started in a given year and still functioning today. The majority of these sites have experienced major reorganizations, changes in site leadership, changes in ownership, downsizing, or other disruptive events. Even with these changes their Behavior-based initiatives survive and their organizations continue to reap the benefits.

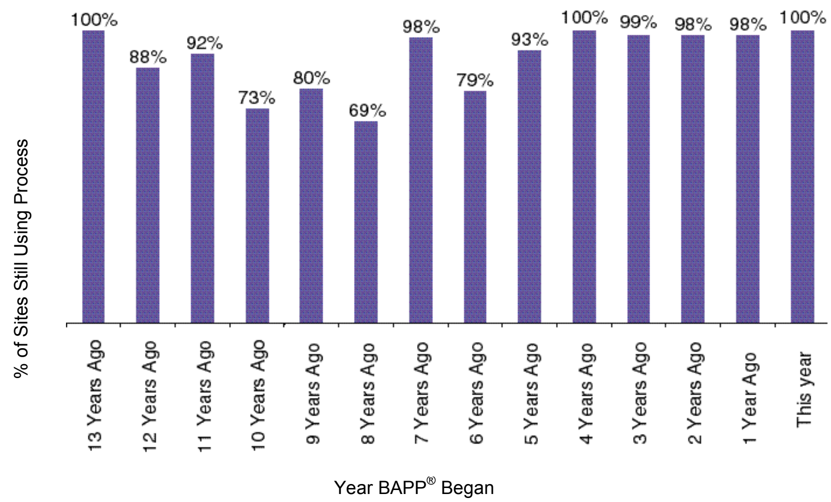


Figure 1. BAPP® System Longevity

11.2 What the Data Show

This chart summarizes at-risk behavior over a two-year period from five sites. A total of 13,264 risks were logged and categorized by the primary factor preventing safe behavior. Arguably, only one category represents enabled behavior: Personal Choice. All other barrier categories contain elements of being non-enabled. Personal choice was the primary barrier in only 17% of the risks, which means the majority of at-risk behaviors are not enabled. *These findings support the conclusion that reinforcement alone won't work in many situations.*

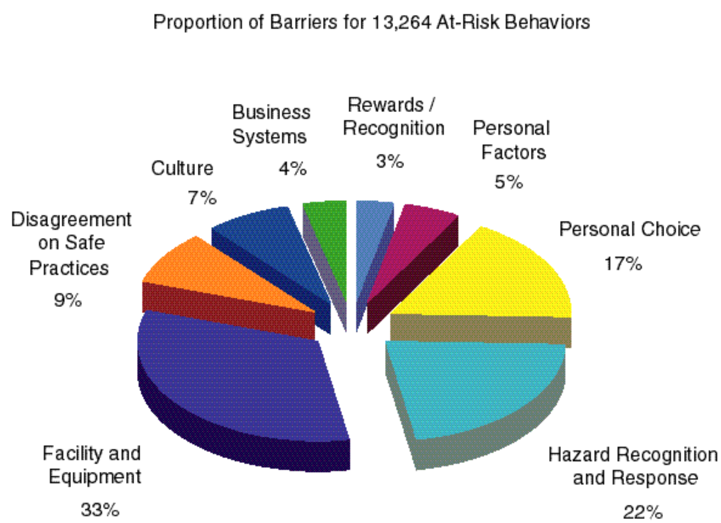


Figure 2. Proportion of Barriers for 13,264 At-Risk behaviors

11.3 The Limitations of Behavioral Observation and Reinforcement

Many simple "behavioral" safety approaches are based on the concept that reinforcement shapes behavior, and therefore reinforcing safe behavior is all one needs to do to improve safety. As the above study shows, this approach is flawed; there are many situations in which no amount of reinforcement, however skillfully delivered, can make a difference. Why? Because the root cause of the problem is not the person, but rather the *interaction* between the person and his/her environment. This is what BST has called the *working interface*.

BST has studied how skillful reinforcement interacts with the working interface. The charts seen here contrast two items observed over a period of three years in which employees received specific, credible, and collaborative reinforcement.

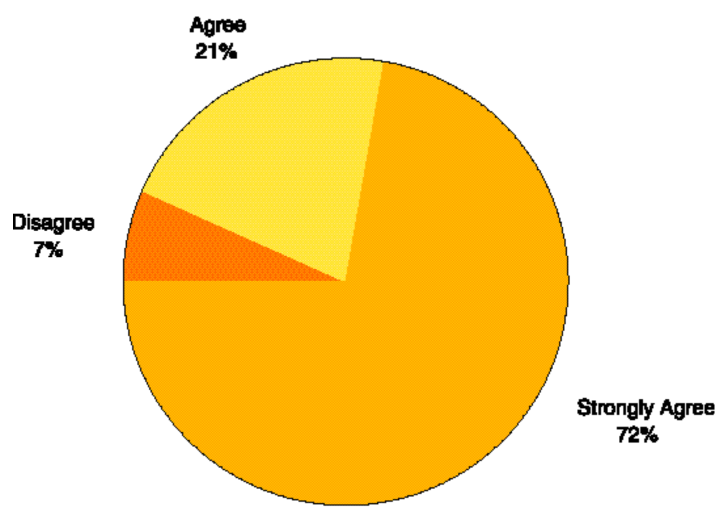
The housekeeping chart shows an enabled item that responded to skillful reinforcement. The percent score for this item consistently increased over the three-year period in which the reinforcement was provided.

The pinchpoints chart at right shows a non-enabled item that responded to reinforcement only after barriers were removed. Initially, observation and feedback did not change this exposure. However, the BAPP observers captured useful information and system barriers to safe behavior were removed. Initially, the item improved by about 25%, but because it was now possible for employees to avoid pinchpoints and still get their jobs done, skillful reinforcement helped improve the item further.

11.4 Perceptions of Success

Organizations use Behavior-based technology for a variety of reasons, not just to reduce workplace injuries or illnesses. Roughly one third of BST clients already have exemplary safety performance when they come to us; these sites implement Behavior-based technology to build on their existing success. Some see the use of Behavior-based technology as a way to improve communications, teamwork, morale, and even operations efficiency. This study asked a representative sample of facilitators from BST consultant-led projects in the United States to answer the question, ***"To what extent do you agree that your process is a success?"***

The respondents had been using Behavior-based technology from anywhere between 1 to 15 years. Responses did not vary by the age of the process. *The overwhelming majority (93%) of facilitators either agreed or strongly agreed their process was a success.* Even those who rated it a moderate success wrote very positive comments, such as, "Our department has gone four years without a [disabling injury] case," and "Behavior-based technology is definitely working." Reasons for disagreement included, "We're in the midst of labor contract negotiations," and "The process really never got started."



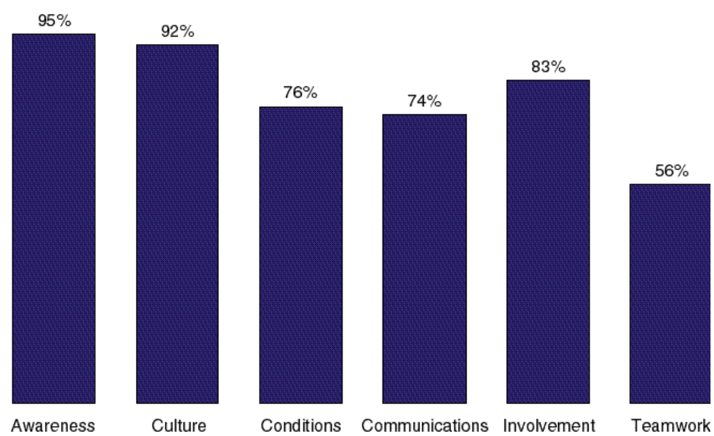
Perceptions of Success

Figure 3. Perceptions of Success

11.5 Positive Organizational Change

When an effective performance improvement process is implemented in a way that builds ownership, skills, and involvement among site personnel, positive cultural change easily follows. Behavior-based technology is exceptionally strong in the areas of employee buy-in, building feedback and coaching skills, and systematic problem solving — all of which support culture change.

This chart is derived from a study that evaluated managers' perceptions of the impact of the Behavior-based technology in a variety of areas. We asked a representative sample of managers how strongly they agreed that their Behavior-based implementation had contributed significantly to improvements in each of the areas charted. Nearly all managers agreed that the technology had significantly helped improve awareness, culture, and employee involvement. A majority of managers also agreed that it significantly helped improve conditions, communications, and teamwork.



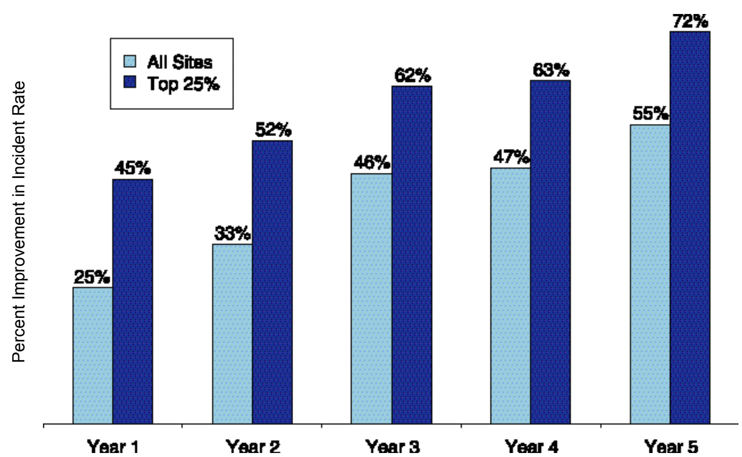
Positive Organizational Change

Managers response to how strongly they agreed or disagreed that their BAPP implementation had significantly contributed to improvements in each of the areas charted.

Figure 4. Positive Organizational Change

11.6 How Well Does BAPP Technology Work?

The chart at left shows the results of the largest study ever published demonstrating the effectiveness of any behavior-based approach; however, the results are specific to BAPP technology and do not generalize to all behavior-based safety approaches. Based on a representative sample of 153 BAPP user sites, it shows that the average BAPP user site achieves a 25% improvement over baseline in the first year of its process, increasing to 55% improvement over baseline in the fifth year. The top 25% of users achieve better than 45% improvement over baseline in the first year, increasing to 72% in the fifth. An early edition of this study has been reviewed by independent experts and published in a peer-reviewed journal *(Safety Science,* 1999, Vol 32, pp 1- 18).

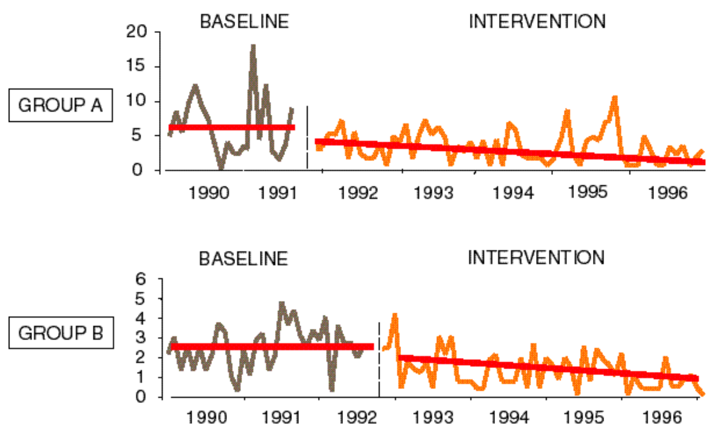


Overall Effectiveness of BAPP Technology

Figure 5. Overall effectiveness of BAPP Technology

11.7 Multiple Baseline Study

Establishing cause and effect relationships in applied research is nearly impossible to do. Demonstrating improvements in safety performance coinciding with hundreds of Behavior-based implementations across various times, companies, industries, etc. goes a long way toward establishing Behavior-based technology as the causal influence, but it is not conclusive. Multiple baseline studies like the one shown here help rule out alternative explanations for the improvement. Combined results from two groups of organizations starting Behavior-based observations at different times show that improvement did not occur until after Behavior-based observations began in either case. This type of research design is widely accepted as providing relatively strong evidence of a cause-and-effect relationship, in this case between Behavior-based technology and the improvement seen.



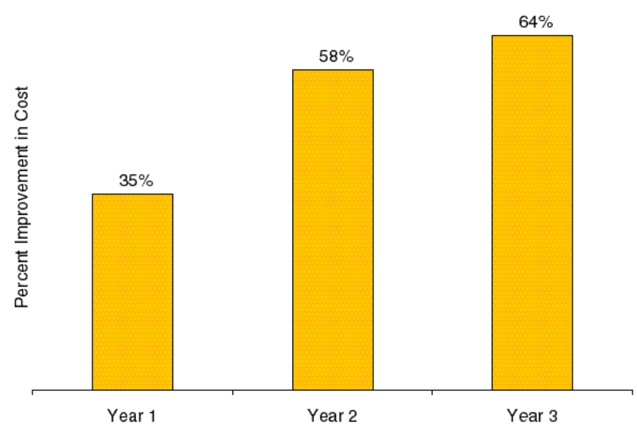
Multiple Baseline Study of BAPP results

Figure 6. Multiple Baseline Study of BAPP Results

11.8 Workers' Compensation Costs Reduction

Evaluating the impact of safety initiatives on workers' compensation costs is a slippery business. Claims history and reporting are so highly variable that they seldom provide a reliable measure of the financial benefits of any initiative. Nevertheless, we would be very concerned if, on average, organizations did not experience a reduction in workers' compensation claims coinciding with their Behavior-based technology implementations.

This chart shows the average percent reduction in workers' compensation costs across 21 sites. Comparing each year of implementation to baseline, these organizations reduced workers' compensation costs by 35% within 1 year of observations, 58% within 2 years, and 64% within 3 years.

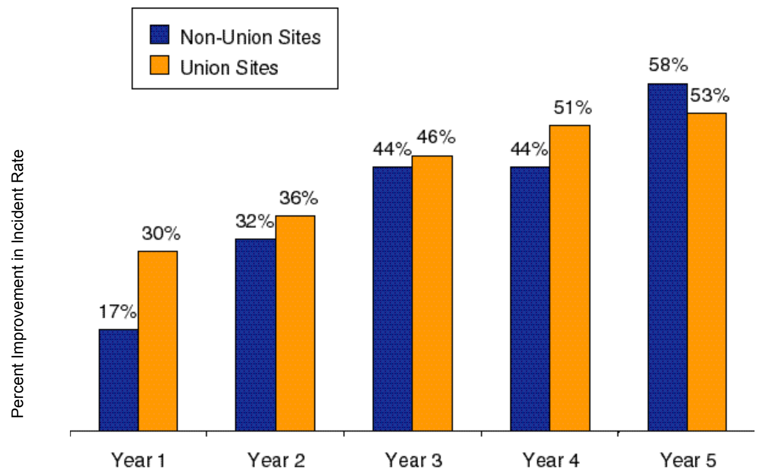


Workers' Compensation Cost Reduction (21 Sites)

Figure 7. Workers' Compensation Cost Reduction (21 Sites)

11.9 Union and Non-Union Sites

We are often asked how effective Behavior-based technology is in union environments compared to non-union environments. This study compared the results of 75 union sites to 77 non-union sites in the United States. Contrary to many expectations, union sites see greater improvement in incident rate in their first year, although non-union sites catch up by the second year. Differences after Year 1 are not statistically significant.



Union and Non-Union Sites (152 sites)

Figure 8. Union and Non-Union Sites (152 Sites)