

## Human Factors in Classification and Certification

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### ABSTRACT

Since the 18<sup>th</sup> century, Classification Societies have served the public interest by promoting the security of life, property, and the natural environment. This has been accomplished primarily through the development and verification of standards for the design, construction, and maintenance of marine facilities, however, new insights gained over the past decade have motivated maritime safety organizations to better address the contribution of the human element to maritime casualties and accidents.

**KEY WORDS:** accident investigation, bridge resource management, classification, fatigue, human error, human factors, shipping accidents

### INTRODUCTION

Considering the extensive presence of ships and humans at sea and the ostensible infrequency of major accidents, shipping might be said to be a rather safe industry. As shown by Fig. 1, the trend over the past 15 years is one of steady decline in serious and very serious marine accidents (International Maritime Organization, 2005), however, the magnitude of damage inflicted by a major shipping accident increases the public attention paid to those accidents, and negatively influences the perceived safety of shipping (O'Neil, 2001).



Figure 1 Losses of Ships of 100 Gross Tons and Above

Since its beginnings in 1862, the mission of the American Bureau of Shipping (ABS) has been to serve the public interest, as well as the needs of clients, by promoting the security of life, property, and the natural environment. This is accomplished primarily through the development and verification of standards for the

design, construction and operational maintenance of marine-related facilities.

Through a procedure known as classification, ABS determines the structural and mechanical fitness of ships and other marine structures to meet their intended purpose. To that end, ABS has been very successful. New insights and understanding gained over the past decade have motivated ABS and other Class societies to broaden their role in maritime safety in significant ways. One of these is to address the concerns of the contribution of the human element to maritime casualties.

It is widely held that human error contributes to 80 percent of marine casualties and accidents (O'Neil 2001). 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 accidents involving death. Fig. 2, summarizes their findings (MAIB 2003).

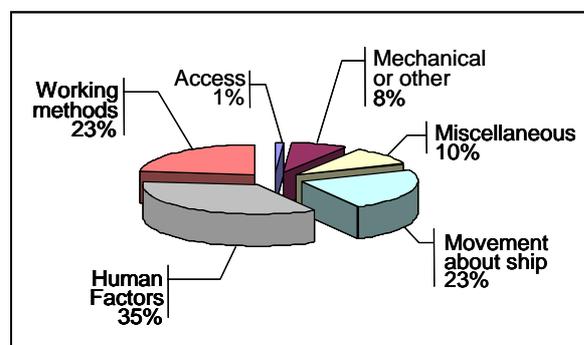


Figure 2 MAIB Allocation of Root Causes to Maritime Deaths

In Fig. 2, 35 percent of accidents leading to death are attributable to human factors. Looking deeper, 23 percent are attributable to “Working Methods” and an additional 23 percent to “Movement about Ship.” In the United States, the Human Factors and Ergonomics community considers working methods and movement about the ship 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 82 percent of these deaths, as reviewed by MAIB, were related to human factors/ergonomics concerns (Baker 2002).

While the figures discussed above may seem unduly large, they are not unsubstantiated, nor are they inconsistent with observations of other industries in terms of the contribution of human error to accidents, specifically (Baker 2002a, Baker 2002b, US Coast Guard 1995):

- Approximately 50 percent of tug and tow boat accidents (ABS)
- 90 percent of ship collisions (US National Transportation Safety Board)
- 85 percent of ship accidents (US Navy Safety Center)
- 75 percent of merchant ship accidents (Germany)
- 66 percent of marine oil spills (UK)
- 90 percent of nuclear emergencies (American Nuclear Society, 50 percent according to the US Nuclear Regulatory Commission)
- 62 percent of hazardous materials spills (US Office of Technology Assessment)
- 65 percent of all airliner accidents (Boeing)
- 90 percent of automobile accidents (US Department of Transportation).

While the raw numbers such as those above point to human error as a principal culprit in maritime casualties, catastrophic accidents such as the loss of the *Ocean Ranger* and *Piper Alpha*, and grounding of the oil tanker *Braer* demonstrate how significant human errors can be to human life and to the environment. From a risk perspective, it is evident that opportunity for failures, in the form of human error, are common and that consequences of these errors can be extreme. The clear result is that human error presents significant risk to maritime safety.

Further, looking at the types and causes of those human errors reveals that failures of situation assessment and awareness are exceedingly common. Fig. 3 presents data related to the types of human errors reported in accident reports (Baker 2002).

An ABS review of 100 accident reports from the web site of the Australian Transportation Safety Bureau (ATSB), 100 accident reports from the Web site of the

Canadian Transportation Safety Board (TSB Canada), and 100 accident reports from the United Kingdom Marine Accident Investigation Board (MAIB) was performed to identify and to codify the causal factors of each reported accident (Baker 2005). According to the analysis of MAIB data, 82 percent were deemed to be associated with the occurrence of human error, compared to 85 percent as represented by the ATSB data and 84 percent according to the TSB Canada data.

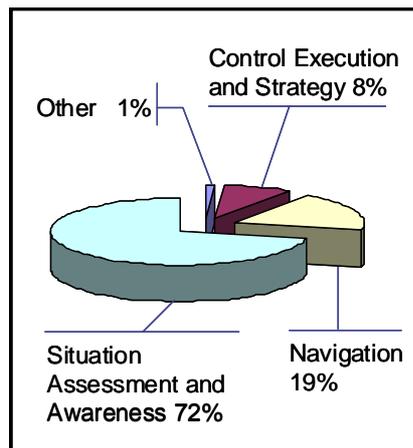


Figure 3 Types of Human Errors Reported (USCG Data)

Table 1 identifies the causal factors of ATSB accident reports, as assessed by the authors. Very similar findings were observed for the other repositories of maritime accident reports. In all, failures of situation awareness, instances of task omission (often itself due to inaccurate situation assessment), and risk taking/risk tolerance dominate (Baker 2005). Situation Awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley, 1988). It is a state of knowledge that directly relates a dynamic environment to operational goals. Situation awareness generally involves:

- Sensing and perceiving the environment
- Assessment of the environment
- Identifying and updating immediate and long term goals in relation to the assessment
- Planning, based on goals and the environment
- Predicting results of plan execution.

Situation awareness does not include deciding or implementing plans. Crew situation awareness is the collective state of knowledge related to the operational environment of the crew. Crew situation awareness is a more complex concern than for individuals, as it

involves the interaction of bridge crew members, engineering department crew, and deck crew.

Classification societies are responding to these observations with a number of human element-related initiatives. Since 1999 ABS has had an established Risk and Human Factors (RHF) Department within the Technology Group. Similar groups have been established at other societies, including Lloyds Register and Det Norsk Veritas. The RHF of ABS is charged with developing and providing effective means to design equipment for human use, and to address management, organizational, ambient environment, and personnel and social factors that are proven to contribute to human error.

Table 1 Causal Factors of Shipping Accidents (ATSB Data)

Causal Factor	Count
Task omission	16
Situation assessment and awareness	15
Knowledge, skills, and abilities	13
Mechanical / material failure	6
Risk tolerance	5
Bridge resource management	5
Procedures	5
Watch handoff	5
Lookout failures	5
Unknown cause	5
Communications	4
Weather	4
Navigation vigilance	3
Complacency	3
Fatigue	3
Maintenance related human error	3
Business management	3
Commission	2
Manning	2
Uncharted hazard to navigation	1
Substance abuse	1
Total	109

## HUMAN FACTORS INFLUENCING SAFETY

One of the more significant institutional efforts to address the human element in maritime safety is the US Coast Guard's Prevention Through People (PTP) program. According to the PTP web site (<http://www.uscg.mil>):

Prevention Through People (PTP) is a people-focused approach to marine safety and environmental protection that systematically addresses the root cause of most accidents: the human element. This approach recognizes that safe and profitable operations require the constant and balanced interaction between the management, the work environment, the behavior of people, and the appropriate technology. PTP itself promotes a cultural change within a company to improve their safety posture.

Beginning in the 1980's, PTP continues to be an energetic contributor to the cause of maritime safety strongly addressing the human element.

Safety and efficiency in job performance are affected by many factors, including those that comprise the foundations of human factors and ergonomics in maritime systems (Miller 1999). These are:

- Management and organization,
- Design and layout of equipment and spaces,
- Control of the working ambient environment,
- People/mariner readiness.

Ignoring any of these elements may result in reduced safety, productivity, and efficiency.

## Management and Organization

The establishment of a safety, health, and environmental policy, which includes a human factors and ergonomics program, and management and organizational processes that implement safety and health policy, tracks performance, and assesses process and occupational safety, is essential in controlling human error. The premise is that well designed and implemented management and organizational systems will foster, control, and monitor a work environment that successfully assesses and addresses risk factors.

Establishing an effective human factors and ergonomics program requires the *visible* involvement of top management. This requires management to fully integrate operations and system design processes with safety and health. Management's commitment to enhancing human performance can be demonstrated by:

- Uniformly enforced rules for employee conduct,
- Easy to read and understand management policies,
- Work schedules to minimize employee fatigue,
- Existence of a high level management with authority to actively pursue human factors and related safety problems,

- Positive means to reinforce employees to follow company safety regulations,
- Company commitment to ship maintenance.

## Design and Layout

These factors address design integration of equipment and humans. Interfaces address both maintenance and operation of systems and components. It also includes design of components such as: controls and displays, computer screens, consoles, alarms, procedures and job performance aids, ladders and stairs, and overall workspace arrangement.

The design, arrangement, and orientation of the hardware and software should match the social, psychological, and physiological capabilities and limitations of personnel. Workplace design is concerned with the human-system interface, including the physical design and arrangement of the workplace, and its affect on safety and performance of mariners.

## Ambient Environment

This addresses the physical comfort and occupational health characteristics of workplace vibration, noise, lighting, and indoor climate. By exercising control of the physical environment, mariners are free to perform their duties without having to overcome environmental impediments (e.g., impediments to voice communications due to ambient noise characteristics or physical exhaustion from working in high ambient temperatures). Control of the environment is an important element in control of mariner fatigue and appropriate environmental design of rest and recreation spaces helps in the recovery from fatigue.

## People

Personnel readiness and fitness-for-duty represents assessments of mariner's ability to safely and reliably perform their duties. Included here are mariner:

- Knowledge, Skills, and Abilities (KSAs) that stem from an individual's basic knowledge and general training
- Task specific maritime training and abilities (certifications and licenses), and ship/offshore structure specific skills and abilities
- Physical characteristics and abilities, including resistance to, and freedom from, fatigue. Additional factors include physical qualifications (e.g., sensory function), physical fitness and endurance, physical illness, and substance dependency
- Psychological characteristics, such as individual's tendencies for risk taking and risk tolerance and resistance to psychological stress.

Placing a person in a position without the requisite skills, training, or tools will reduce safety, efficiency, and increase the potential for error.

It is well established that the presence of fatigue greatly influences human performance both ashore and asea. In fact, physiological definitions of fatigue invoke the notion of decreased capacity as a central component of the definition. Recent reports by the International Maritime Organization (IMO) have publicized the fact that crewmember fatigue is increasingly being recognized as a major factor in maritime accidents (International Maritime Organization MSC/Circ.565). Crewmember fatigue jeopardizes ship, passenger, and crew safety when it leads to human error. Evidence for the role that human error plays in maritime accidents has been provided by recent submissions to IMO (International Maritime Organization: MSC 71/INF.8; MSC 69/INF.15; MSC 68/INF.15).

In a maritime environment, the symptoms relating to crew-specific fatigue factors have long been recognized. It has also been noted that such symptoms can be a major source of impaired human performance and reliability. Specific symptoms or impairments seen in individuals that can arise due to fatigue, and that can be easily related to human error, are summarized below.

- Feeling tired, muscular weakness
- Pattern and object recognition error
- Significantly reduced short term memory
- Reduced sensory threshold and discrimination
- Reduced manual dexterity
- Inability to concentrate
- Difficulty recalling information or making decisions
- Difficulty reading displays, manuals, charts
- Increased risk taking behavior
- Task delay or complete omission
- Mood swings and changes
- Attitude changes

In extreme cases of fatigue, anxiety, perceptual narrowing, slurred speech, obsession with sleep, hallucination, and incidence of microsleep (microsleep is a period of sleep-like unconsciousness, lasting usually few seconds, without the knowledge or intent of the sufferer).

## HUMAN FACTORS ACTIVITIES

As stated above, a human factors approach for reduction of human error is multifaceted, and all RHF activities are directed towards exercising reduction of error through management processes, equipment design, design of the environment for habitability, and

mariner readiness. ABS activities related to these areas are discussed below.

## Human Factors Design Guidance

There are numerous documents addressing application of human factors data for the maritime industry, including those by standards institutions (British Standard EN ISO 8468, 1995; American Society for Testing and Materials F-1166, 1995), international bodies (International Association of Classification Societies 1992, International Maritime Organization 2000 and 1995), and classifications societies, including the International Association of Classifications Societies (IACS), (International Maritime Organization 2000 and 1995; International Association of Classification Societies Unified Interpretation of ISC 181, 2005). These documents have been well received by the maritime industry, and many shipping and offshore organizations have adopted the *ABS Guidance Notes on the Application of Ergonomics to Marine System* as a design reference (American Bureau of Shipping 2003). The acceptance of this document is because the Guidance Notes provide an industry specific source of human factors criteria that can be applied internationally. When used in concert with human factors engineering design processes, the Guidance Notes provide the full range of information and data needed to integrate humans and machines at sea. This document was initially published in 1998, and was significantly revised and republished in 2004. It presents a broad coverage of human factors and ergonomic guidance specifically related to seagoing equipment design. The *ABS Guidance Notes on Ergonomics Design of Navigation Bridges* (American Bureau of Shipping, 2002a) extends the guidance provided to more specifically address the design of navigating bridges. When used in conjunction with more general ergonomic design guidance, complete coverage of human factors concerns related to bridge design is provided.

## Habitability and Comfort Guidance

ABS has generated a series of crew habitability and passenger comfort guides. The Guides for *Crew Habitability on Ships* (American Bureau of Shipping 2002b) and *Crew Habitability on Offshore Installations* (American Bureau of Shipping 2001) represent a significant step in the development of classification rules that will improve maritime safety by limiting or avoiding crew fatigue.

Appropriate comfort criteria and design practices significantly influence passenger comfort, safety, and overall well being. The *ABS Guide for Passenger Comfort on Ships* (2001) has been developed with the objective of providing criteria that will assist in improving the comfort of the passengers aboard

passenger vessels. These criteria have been chosen to provide a means to increase the comfort, enjoyment, and passenger satisfaction.

Habitability design guidance is complementary to existing human factors design guidance as all address the importance of human factors and ergonomics in the safe operation of ships and offshore installations. The new ABS Guides have been developed to provide a comprehensive set of criteria aimed at improving human performance, reducing fatigue and enhancing quality of life at sea by improving living and working conditions. The focus of these documents is on five habitability areas that have been identified as being critical in their capacity to influence habitability and performance. These areas are: accommodations design, human whole-body vibration, noise, lighting, and indoor climate (to download Guides, see [www.eagle.org/rules/downloads.html](http://www.eagle.org/rules/downloads.html)).

## Review of Accident and Near Miss Databases

The objective of this activity was to find, assess, and review existing maritime incident/accident databases to identify causal factors associated with maritime incidents, accidents, and near misses. Analysis of these data can be used to identify clusters of factors associated with human error and maritime incidents/accidents. The major product of the effort will be a listing of human factors that have, in recent history, been closely related to incidents and accidents. Another objective of this activity is to develop human factors / ergonomics methods to collect and analyze human error-related root-causes for near misses and marine accidents, and to formulate methods where these can be stored in databases to be used in the identification and analysis of trends.

## Leading Indicators of Maritime Safety

In the aftermath of catastrophes, it is common to find prior indicators, missed signals, and dismissed alerts, that, had they been recognized and appropriately managed before the event, might have averted the undesired event. Indeed, the accident literature is replete with examples, including the space shuttle Columbia, the space shuttle Challenger, Three Mile Island, the Concorde crash, the London Paddington train crash and American Airlines flight 587 to Santo Domingo, among many others (Grabowski 2004).

Recognizing signals before an accident occurs offers the potential for improving safety, and many organizations have sought to develop programs to identify and benefit from alerts, signals and prior indicators. A recent study by the U.S. National Academy of Sciences focused on these signals, the

conditions, events and sequences that precede and lead up to accidents, or the "building blocks" of accidents.

Leading indicators are conditions, events or measures that precede an undesirable event, and that have some value in predicting the arrival of the event, whether it is an accident, incident, near miss, or undesirable safety state. Leading indicators are associated with proactive activities that identify hazards and assess, eliminate, minimize and control risk. Lagging indicators, in contrast, are measures of a system that are taken after events, which measure outcomes and occurrences. Examples of leading indicators include near hit reporting in anesthesia management, accident precursor assessment programs in nuclear safety, and hazard identification and analyses for offshore oil and gas in the United Kingdom. Examples of lagging indicators include recordable injury frequencies, lost time frequencies, total injury frequencies, lost time severity, vehicle accident frequencies, worker compensation loss, property damage costs, and numbers of accident investigations (McCafferty 2005).

## Fatigue Countermeasures

With the recognition by the international maritime community that crewmember fatigue can greatly affect ship safety at sea and in port, numerous studies and initiatives have been undertaken to better define the causes and effects of fatigue. In a recent submission to the IMO (MSC 74/15, 2001), Guidelines on Fatigue provided practical information to assist the marine industry in understanding and managing fatigue. Within these guidelines, the potential causes of fatigue were categorized as follows:

- Crew-specific
- Ship-specific
- Physical Environment
- Management

Recognition of categories of causes of fatigue is important because too often it is supposed that individual crewmembers are responsible for their fatigue through poor lifestyle management or personnel habits. Contributing to this limited view was the belief that strong will and stronger coffee would prevail over fatigue. Through the work of many different segments of the maritime industry, the variety of factors which impact crewmember fatigue and its effects on human performance are becoming better recognized.

**Crew-Specific Fatigue Factors.** In a maritime environment, the symptoms relating to crew-specific fatigue factors have long been recognized. It has also been noted that such symptoms can be a major source of impaired human performance and reliability. Specific symptoms or impairments seen in individuals that can arise due to fatigue, and that can be easily related to human error, are summarized below. The

conditions and environment of the sea, in concert with the requirements of the mariner's job, can lead to debilitating fatigue. It is therefore imperative that control be exercised over the accrual of fatigue. Causes of fatigue are many and varied, but generally include combinations of the following.

**Conditions of Sleep.** Of importance here are the following three conditions: ability to amass sleep; sleep comfort, and; amount of daily sleep.

**Biological Clocks/Circadian Rhythms.** Related to conditions of sleep is the timing of sleep according to endogenous (internal) biological "clocks."

**Workload and Work Duration.** These factors concern the physical requirements of the job, in terms of:

- Cognitive and physical energy expended during task performance and over time
- Provision of rest periods during the work day
- Length of the workday.

**Crewmember-specific factors.** In addition to the factors mentioned above, individual variables affect the susceptibility to the incidence of, and recovery from, fatigue. Among these are personal health status, age, fitness, diet, and chemical use, including beverage/drug consumption, and over the counter medicines.

**Ship-Specific Human Fatigue Factors.** Another set of factors which can affect human performance and fatigue is the design of the ship itself. Two of the more influential ship design factors for enhancing human performance and reducing human errors are (1) usable human-machine interfaces and (2) the provision of accommodations that promote reliable human performance and combat human fatigue.

**Human Fatigue Factors in Design.** "Ergonomics produces and integrates knowledge from the human sciences to match jobs, systems, products, and environments to the physical and mental abilities and limitations of people. In doing so, it seeks to improve health, safety, well-being, and performance."(SO/TC 159/SC 1/WG 1, 1997). From this definition, it is clear that human factors principles when applied to ships can result in equipment, systems, and overall designs that will support reliable human performance. Human factors in the design of ships, marine structures, and equipment is addressed in numerous handbooks, textbooks, guides, and standards. Such documents include military standards and guidelines, industry documents, national and international standards, and general texts. These specify the design processes and criteria for achieving at-sea control space designs that are compatible with humans. The bulk of these present a full array of design guidance for designers of maritime vessels, including design related to:

- Ambient environment (vibration, noise, etc.)
- Console profiles, dimensions, and orientations
- Computer software interfaces
- Maintenance interfaces
- Equipment design
- Habitability spaces
- Written procedures and operations documents
- Job performance aids (e.g., labels and markings)
- Safety
- Space layout
- Training systems
- Hardware interfaces.

There is extensive general-purpose guidance on human factors in equipment design. These present the philosophies and underpinnings of human factors, as well as the science behind it, and generalized approaches and processes used to infuse human factors data and principles into system design. Some of the recent and more salient documents to maritime control space design are:

- IMO's Guidelines on Ergonomic Criteria for Bridge Equipment and Layout (MSC 73/Circ 982)
- IMO's Navigational Bridge Visibility and Functions (IMO Res.A.708-(17))
- Ship's Bridge Layout and Associated Equipment – Requirements and Guidelines (BS EN ISO 8468)
- IMO's Role of the Human Element in Maritime Casualties - Engine Room Design and Arrangements. (IMO DE 38/20/1)
- IMO's Guidelines for Engine Room Layout, Design and Arrangement (MSC 68/Circ 834)
- IMO's Role of the Human Element in Maritime Casualties - Guidelines for the On Board Application of Computers (IMO DE 38/20/2)
- ABS Guide for Crew Habitability on Ships (2001)
- ABS Guidance Notes on the Application of Ergonomics to Marine Systems
- ASTM's Standard Practice for Human Engineering Program Requirements for Ships and Maritime Systems, Equipment, and Facilities (F-1337, 1991).
- IMO and SOLAS Chapter V, Regulation 15 on the Safety of Navigation.
- IACS Unified Interpretation of ISC 181 Bridge Design, Equipment Arrangement and Procedures in response to SOLAS Chapter V, Regulation 15.
- ASTM's Standard Practice for Human Engineering Requirements for Ships and Maritime Systems, Equipment, and Facilities. (F-1166, 2000).

## Human Fatigue and Habitability

Habitability is another ship-specific factor that affects the mariner. Habitability can be defined as the acceptability of a ship as determined by its physical accommodations (design and provision of rest facilities, food services, etc.), as well as by the conditions of the ambient environment (e.g., vibration, noise, thermal, and lighting levels). As stated earlier, the inherent habitability (or "comfort") of a vessel can have direct and significant effects on crew in terms of quality of sleep, speed of onset, and severity of fatigue, and human performance and error. The importance of providing acceptable accommodations was recognized as long ago as the 1940's when the International Labor Organization published both the *Food and Catering (Ships Crews) Convention*, the revised version of *Accommodation of Crews Convention*, and *Crew Accommodations*, also known as Convention 68, Convention 92, and convention 133 crew accommodations 133, respectively.

## PHYSICAL ENVIRONMENT HUMAN FATIGUE FACTORS

As mentioned previously, the term "habitability" includes factors related to the ambient environment. The conditions of the ambient environment influence human fatigue in several important ways. *First*, working in unfavorable environments facilitates the onset and magnitude of fatigue. Factors such as high or low temperature and high noise and vibration require the human body to use resources to counter those conditions, and resources used to counter the environment are not available to perform the productive work required of the human (until after a rest period). *Second*, slow oscillations of the human body and workspace (for example, ship motions) consume energy resources. These motions present complex, multidirectional g-forces that the human must constantly overcome, and that therefore consume muscular resources. A *third* manner in which the environment influences fatigue is to influence quality of sleep. Extreme conditions can result in lowering of depth and length of sleep, thus inhibiting recovery from fatigue.

## Management Human Fatigue Factors

The last category of factors discussed in this paper that are recognized to influence mariner fatigue are management policy and practice. These factors range from top-level organizational goals to management decisions relating to vessel operations, schedules, and voyages. The IMO recognized that the way a ship is managed not only affects mariners on board, but also affects the health, safety, and environment of people outside the ship. In order to ensure that shipping owners and operators examine the potential impact of

their corporate actions, the IMO passed the International Safety Management Code.

#### ***IMO and the International Safety Management Code.***

International Maritime Organization's International Code, International Management for Safe Operation of Ships and for Pollution Prevention (the "ISM Code") was adopted in November 1993. The ISM Code initially required (Phase I) most ship operators to have a certified safety management system in place by July 1, 1998. The purpose of the Code was to ensure safety-at-sea, prevent human injury or loss of life, and avoid damage to the environment and to property. It also requires companies to establish specific safety objectives, based on their sphere of operations, and this includes objectives related to crew fitness-for-duty (which incorporated fatigue factors) and control of human error. Phase II of the ISM Code became mandatory on the first of July 2002 and is to be applicable to all vessels above 500 gross tons that were not covered under Phase I.

***IMO and STCW.*** Another area that relates to ship management concerns mariner issues is the updated IMO international Standards for Training, Certification, and Watchstanding (STCW) Convention (1995). These agreements (quickly incorporated into many individual Port State systems of law) have been put forth establishing requirements for mariner readiness. Some of the more important provisions of the 1995 amendment include:

- Requires certification of masters, officers, and ratings only when they meet the requirements for service, age, medical fitness, training, qualification, and passing examinations.
- Requires special training for certain types of ships (tankers, Ro-Ro, and passenger ships).
- Requires Flag States establish and enforce rest periods for watchkeeping mariners. Watchstanders must be provided a minimum of ten hours of rest for every 24-hour period (the ten hours may be divided into two periods, but one must be of at least six uninterrupted hours).
- Requires that watch systems be arranged so that watchstanders are not impaired by fatigue
- Requires instructors and assessors be qualified for the types of training or assessment of competence of seafarers. Those involved in training and/or assessment must be qualified in the task for which the training/assessment is being conducted.

Other management practices and policies beyond ISM, STCW, and ILO can affect the potential for crewmember fatigue. The IMO's Guidelines on Fatigue (2001) suggests that ship owners and operators develop fatigue management policies and systems. It is also suggested that practices such as the following be examined as means to counter fatigue:

- Scheduling of voyages
- Staffing policies
- Paperwork requirements
- Schedules
- Provisions for leave
- Communications with families during voyages
- On-board recreation.

These factors, together with those specified in the international regulations, will positively or negatively influence crewmember fatigue and marine safety.

## **ON GOING AND FUTURE ACTIVITIES**

ABS is actively engaged in identifying new tasks and products that are fully expected to increase safety at sea. Some of the future activities discussed below are in an evaluation and planning stage, while others are being evaluated for their potential contribution to maritime safety. Some potential future activities are introduced below.

### **Permanent Means of Access**

This ongoing project's focus is on the IACS Unified Interpretations (UI) SC (191) for the application of amended SOLAS regulation II-1/3-6 (resolution MSC.151 (78)) and revised Technical provisions for means of access for inspections (resolution MSC.158 (78)). This project will review the existing IACS UI SC191 and SOLAS regulation II – 1/3-6 and determine if there are opportunities to improve the Permanent Means of Access (PMA) requirement's clarity and interpretability.

This project will develop an illustrated guidance document to improve the comprehension and interpretation as well as promote more consistent application of the PMA requirements. Where possible, the document will provide enhanced PMA guidance through the application of human factors principles to PMA requirements. Additionally, based on the enhanced PMA guidance, the possibility exists for the development of a PMA notation (e.g., PMA or PMA+).

### **Bridge Workload and Situation Awareness Assessment**

Pressures to reduce work force aboard ships, generally in the name of competitiveness, often result in increased automation of function. In many cases the role of the human becomes to monitor those automated functions and, where necessary, intervene. In many of these cases, the responsibility for this monitoring becomes that of the bridge watchstander (often as directed by IMO or Flag State mandate). Examples of this includes unmanned engine room surveillance (generally at

night), overall ship surveillance (fire monitoring, etc.), and security monitoring. While automation has relieved the work burden of some, shunting additional surveillance and monitoring responsibility to the bridge has unknown, or at least unsure, consequences. Bridge workload and watchstander situation awareness are concerns of increasing interest to ABS, and means to address these are being devised.

### Accident Investigation Techniques

The marine industry experiences incidents that range from major accidents to near misses. Such incidents need to be investigated since many flag administration regulations require it; international agreements mandate it (such as the IMO "International Safety Management Code") and industry initiatives encourage it. Incident investigation is a process that is designed to help organizations learn from past performance and develop strategies to improve safety. The objective of any marine incident (and near miss) investigation methodology is to provide processes to identify and categorize their underlying causes. Knowing the underlying causal factors for accidents provides management direction and means to obviate or control those factors and reduce risk or reoccurrence.

One technique under development is the Marine Root Cause Analysis Technique (MaRCAT). MaRCAT provides an effective approach for investigating marine incidents of any magnitude (McCafferty 2005). The objectives of the approach are to provide a tool that will guide incident investigators in the conduct of root cause analyses and in consistently identifying, documenting, and trending the causes of accidents and near misses.

MaRCAT provides instructions for the performance of incident investigation activities, including:

- *Incident Investigation Initiation* – How to determine if an incident has occurred, then how to classify and categorize the incident, and how to decide whether to conduct an in-depth investigation.
- *Data Gathering* –How to collect data related to people, processes, procedures, documents, position of the vessel, and physical evidence associated with an incident.
- *Data Analysis* –How to analyze incidents to determine causal factors using tools such as causal factor charts, fault trees, and the 5-Whys technique. Guidance is also provided regarding the identification of root causes, using the *ABS Marine Root Cause Analysis Map*.
- *Generating Recommendations* – How to document causal factors and root causes identified during an analysis, including how to identify what changes may be needed to enhance management systems and reduce risks.

- *Reporting & Trending* – How to archive findings and recommendations to allow review and trending of incident patterns after some period of MaRCAT use.

### Ship-to-ship, Ship-to-shore, and Internal Ship Communications Guide

Many human errors that occur at sea are traced to inadequate communications, whether within ship, ship-to-ship, or ship-to-shore. ABS is considering development of guidance material for the design of effective communications systems, including aided and unaided voice, digital text and graphics, and signals. The requirement to transmit and receive information without equivocation or uncertainty is considered of paramount importance to ABS.

### DISCUSSION AND CONCLUSION

The ongoing and future ABS activities discussed in this paper are targeted directly at factors that are associated with the occurrence of human error, and that influence the quality of life at sea. Recall that the principle findings of the review of accident reports and databases included:

- Inadequate situation assessment and awareness
- Task omissions
- Risk taking / risk tolerance / risk perception.

These three human performance and safety issues are interrelated, and are intimately related to a further concern: mariner fatigue. They are related in that they occur together. For example, human fatigue is known to lead to errors in estimating risk, and it is also implicated in task omissions – in particular tasks of verification and validation (for example using “all available means” to fix a ships position, rather than one). Accuracy of risk perception (or the instances of outright risk taking) is integral to situation assessment and awareness. If an authentic threat is not perceived as such, then the perception of the situation will be flawed, and subsequent plans to address that situation will likely not address that threat.

Having established many of the human performance characteristics directly associated with approximately 80 percent of marine accidents, it is evident that these need to be addressed if the objective of safety at sea is to be served. As discussed above, ABS and other maritime organizations are becoming increasingly involved in these issues. At ABS, recently authored are Guides for the habitability of ships and sea based structures. These Guides are in part an assault on mariner fatigue by providing environmental (temperature, noise, vibration, etc.) guidance that will reduce the onset and magnitude of human fatigue, and aid in fatigue recovery by potentially increasing the

depth and quality of sleep. ABS has also authored Guidance Notes addressing the ergonomic design of ships in general, and navigation bridges in particular. This guidance should, if applied, facilitate situation assessment and awareness of both a ship's bridge and a total ship's crew, and also positively influence levels of observed physical fatigue. The impending Guidance Notes on *Bridge/Crew Resource Management* squarely addresses issues associated with fatigue management and situation awareness. Fatigue management guidance is presented based on guidance offered by the US Coast Guard, the International Maritime Organization, and the Crew Endurance Management System of the American Waterways Operators, among others. Guidance on *Bridge/Crew Resource Management* is thoroughly infused with information management techniques directed at facilitating situation assessment and awareness. Finally, the review of accident reports revealed numerous potential predictors of future safety. These *leading indicators* are being examined and analyzed in the hope that a set of highly predictive indicators can be used to identify specific risks to safety – before the instance of an accident or casualty – allowing for the possibility of preventive intervention.

The approach presented is considered to be pragmatic and thorough, addressing the principal and conspicuous issues related to the human performance and safety afloat. As these factors are defined and appropriate information provided to mariners, ship designers, owners/operators, and management organizations, maritime safety will be greatly enhanced.

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