The Janus Principle in Maritime Safety: Looking Backwards to Look Forward

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SUMMARY

The significance of human error in commercial shipping operations is now universally recognised. This paper opens with a summary of our current understanding of human error and accident causation. The paper provides a review of recent accident analyses and five case studies to highlight the importance of human and organisational factors in contributing to maritime casualties. The paper concludes with the results of some preliminary research, based on observations of trainees during simulator-based exercises, which explores certain social interaction behaviours in team working. Such behaviours may be responsible for the kind of poor team performance often implicated in maritime accidents.

1. INTRODUCTION

The most widely known model of accident causation, and one which is applicable across a range of safety-critical industries, is provided by Reason [1]. It is commonly referred to as the “Swiss Cheese” model.

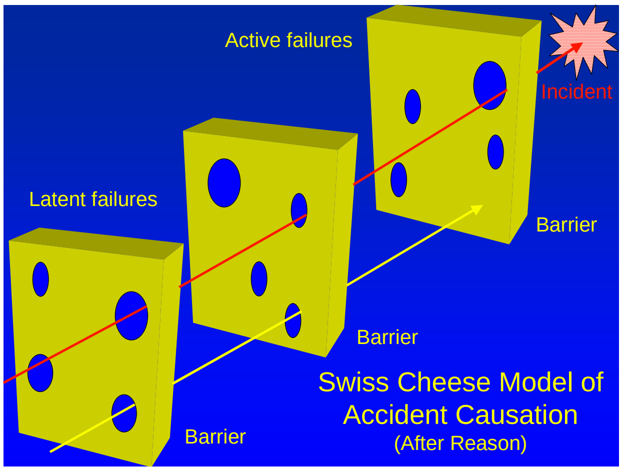

Figure 1: The Swiss Cheese Model of Accident Causation

The safety of the system, or organisation, is considered as a series of barriers or “defences in depth” against the potential for failure. These barriers may take a variety of forms, including hardware, software, and the human element (the live ware). Normally, the presence of one or more of the barriers will prevent accidents from happening, sometimes only the final barrier will hold (a “near-miss”), but very occasionally, all the “holes” in the system will align, the safety barriers are penetrated and an accident occurs.

A significant contribution of this model to our understanding of how accidents happen is that it recognises both active failures at the “sharp” end of the system, for example, human errors on board ship, but also latent failures in design, management practices, and procedures that may have lain dormant within the system for many years. Implicit in the model is the concept that most accidents have multiple antecedents that contribute to the event. Without all of them being present, the accident would not occur. This fundamental truth makes the determination of a **single** cause for any accident virtually impossible:

> *“…almost any accident…can with equal validity be traced to inadequate design, inadequate training, inadequate instructions, inadequate attention, an unfortunate coincidence of rare events or just to human error”* [2]

This axiom of accident theory is an uncomfortable truth both for lawyers attempting to apportion blame and also for statistically minded researchers who need to reduce narrative to a single cause for the categorisation and subsequent analysis of accident data. It also has implications for those professionals, from a variety of disciplines, who seek to find cost-effective measures for risk mitigation, as this classic tale suggests:

> *“A man has a protracted argument with his wife. He stamps out of the house to the nearest bar and drinks four highballs. He then decides to go for a ride. It is nighttime, there is a skim of snow on the ground, and the tyres on our victim’s car are smooth. In rounding a poorly banked curve at excessive speed, the right front tyre blows out; the car leaves the road and is demolished. What was the cause of the accident? The argument? Drinking? Speed? The weather? The smooth tyres? The blow out? The poorly designed highway? It is impossible to say, for if we had changed any of these factors, perhaps the accident would not have happened. We have no way of assigning a “cause”, even though we may have a complete description of the circumstances leading up to the accident. In fact, the chances are very good that a coroner, state policeman, minister, psychiatrist, and highway safety engineer would each find different causes in this event.”* [3]

This interpretation of cause by different professional interests is an element of one of the two main problems of hindsight. This first problem is referred to as “analytical bias”:

"There are numerous forms of bias that can affect the analysis of incidents. These include author bias……confirmation and frequency bias, recognition bias, political, sponsor and professional bias." [4]

Confirmation bias occurs when the analysis supports hypotheses that exist before the incident occurred and therefore simply confirms pre-conceptions. Frequency bias is a well-known phenomenon and refers to a tendency to ascribe certain factors from an accident narrative as causal, simply because they are observed more often than others. Recognition bias is a term used to describe the problem of having too limited a vocabulary to describe certain causal factors.

The second major problem with hindsight is a more philosophical one and is due to the nature of time and our position as an observer in relation to past and future events, a phenomenon described as *"the Janus principle"*[5], in homage to Koestler, who used the phrase in a different context when expounding on systems theory. [6]

Johnson refers to the same idea as **causal asymmetry**:

"If we know the cause then we can determine the effects. However, if we observe the effects then it can be difficult to reach firm conclusions about the ***multiple*** possible causes of those observations." [7]

The principle is that, once an incident has occurred, we tend to interpret the past, prior to the event, only in terms of its bearing on that event. The total contemporaneous context is now missing and we concentrate only on "chains" of events that we, as witnesses or analysts, believe to be significant. This lack of context partly explains why people's behaviour sometimes seems so odd in retrospect, or why normally competent and experienced individuals did not see what appears so obvious to us in hindsight. The sense of frustration felt by those responsible for ship safety is illustrated by the following extract that eloquently describes the lack of situational awareness by those onboard prior to an accident occurring:

"In every case it was easy to establish what went wrong. There was no gross negligence, no recklessness or stupidity, no drunkenness or fatigue; no question of the ship being without enough trained personnel; no lack of equipment. But there were mistakes. Mistakes of the kind that all men are liable to make on occasions. Seeing what they expect to see; not seeing what they should see, failing to recognise a mistake in a colleague, reacting too late, or not at all, in the face of the unexpected. The key point was that the initiating mistakes themselves by no means made the accidents inevitable. On the contrary, in every case, the consequences of the mistake were eminently avoidable. They were not avoided because those in charge remained quite unaware of the danger until too late to avoid it." [8]

Despite the problems of hindsight, we can learn valuable lessons from both individual casualties and from the study of accident databases, by looking for patterns, trends and root causes. Although it is now universally recognised that human error is a fundamental and significant factor in accident causation, the following advice summarises the modern approach to accident investigation:

"There is much evidence that major accidents are seldom caused by the ***single direct action (or failure to act) by an individual.*** *There may be many contributing factors that may not be geographically or managerially close to the accident or incident. There might also be environmental factors arising from or giving rise to physical or work-induced pressures. Accident and incident investigation procedures need to be sufficiently thorough and comprehensive to ensure that* ***the deep-rooted underlying causes are clearly identified*** *and that actions to rectify problems are carried through effectively."* [9]

A recent review [10] of the accident databases from the USA, UK, Canada, Australia and Norway confirms that human error continues to be the dominant factor in maritime accidents. The following conclusions were drawn:

- While the total number of accidents is declining, human error continues to be a dominant factor in 80 to 85% of maritime accidents.
- Failures of situational awareness and situation assessment overwhelmingly dominate.
- Human fatigue and task omission seem closely related to failures of situation awareness.

In their review of 150 accident reports from the website of the Australian Transportation Safety Bureau (ATSB), causal factors were classified in root cause groupings, which included a situational awareness group (27.5%), management group (24.5%), a risk group (30%) and a non-human error group (15%). Although the authors acknowledge that these root cause groupings are subject to interpretation, the results correlate well with the UK Marine Accident Investigation Branch (MAIB) database. However, the management group refers almost entirely to onboard management factors, with only 4.5% of these factors being ascribed to organisational influences, such as the level of manning or business management.

As this study illustrates, the majority of accidents and incidents are *not* caused by technical problems but by the failure of the crew to respond appropriately to the situation. Most maritime professionals would probably agree with Helmreich et al [11] that in order to ensure safe and efficient operations there is a need to understand the behaviours of effective error detection and management.

The following section reviews five case studies to illustrate how our understanding of human error allows us to gain insights into the root causes of maritime casualties. The first case illustrates both failures in system understanding by the onboard engineers and poor communications between teams. The second case provides an example of the human errors associated with automated systems. The third case illustrates issues of maintenance and poor safety management culture. The fourth case illustrates how the root cause of onboard violations may be related to organisational culture. Finally, Case Study Five combines poor bridge resource management and communications with violations and distractions. It also provides an example of where national cultural differences may play a part in accident causation. All five cases indicate that in any accident, there are likely to be multiple causes and that loss of situational awareness is implicated in most incidents.

2. LOOKING BACKWARDS - FIVE CASE STUDIES IN HUMAN ERROR.

2.1 CASE STUDY 1: THE GROUNDING OF THE HANJIN DAMPIER [12]

2.1 (a) The circumstances

At 1032 on 25 August 2002, the Korean flag bulk carrier *Hanjin Dampier* departed from the port of Dampier, Western Australia. A pilot was conducting the navigation of the ship, which was loaded with iron ore and had a displacement of 233 158 tonnes with draughts of 17.94 m forward and 18.10 m aft. At 1127, two of the ship's three main generators stopped, leaving only one generator running and connected to the main switchboard. At 1152, the third generator's circuit breaker tripped open. With the total loss of power to the main switchboard the main engine stopped and the ship lost steering. The rudder had stopped at 10° to starboard. As the ship slowed, it started to turn to starboard towards shallow water. The emergency generator failed to start automatically and, as a result, steering was not restored for some four minutes. At 1202, *Hanjin Dampier* touched bottom. The ship suffered only minor damage to the bottom shell plating, but the consequences of this incident could have been a lot worse.

2.1 (b) The analysis

There would have been no incident if there had been no loss of electrical power on the vessel. Water had entered the port diesel oil storage tank through a broken manhole gasket. This water was then transferred, during a normal fuel transfer operation, to the diesel oil settling tank.

However, due to the engineers' use of an incorrect sized gravity disc in the diesel oil purifier, and their incorrect setting of the purifier's fuel outlet line back pressure, the water in the diesel fuel in the diesel oil settling tank was passed to the diesel oil service tank. From here the water reached the three diesel generator engines, leading the to the loss of electrical power on the vessel. The emergency generator then failed to start automatically upon the loss of the main source of electrical power, due to a faulty starting battery. Had the emergency generator restored power automatically to the emergency switchboard within the 45 seconds required by the SOLAS regulations, the ATSB concluded that it was likely that the grounding would have been avoided.

The report states that numbers one and two generators tripped off the main switchboard, and stopped, at about 1128. At this time the ship was still in the buoyed channel, and being fully laden she had little room for manoeuvre, the open sea still being more than an hour and a quarter away. Given his uncertainty regarding what had caused the first two generator shut downs, and his awareness of the ship's critical navigation situation, the Chief Engineer should have discussed the situation more fully with the Master. This would have given the Master the opportunity to form a contingency plan, in consultation with the pilot, to mitigate the risk to the ship. With number three generator continuing to supply power for a further 24 minutes, there was adequate time at this point in the passage to stop the ship either in the channel, or after it had cleared the channel in deeper water, and to call for tug assistance. In the event, the Chief Engineer did not communicate the gravity of the generator problem to the Master and this failure of communication directly contributed to the grounding.

The lack of effective communication between the Chief Engineer and Master meant that the bridge team were unaware of the risk to the vessel after the first two generators had stopped and thus precluded the possibility that they could take pre-emptive action to reduce the level of risk to the vessel. The ATSB report makes the following statement:

> *"Had there been more effective communication between the Chief Engineer and Master at the critical time after the first two generators had shut down, it is likely that the grounding of Hanjin Dampier could have been averted."*

2.2 CASE STUDY TWO: POLLUTION FROM THE "RANDGRID". [13]

2.2 (a) The circumstances

Randgrid arrived in the area of the Tetney monobuoy at 0055 on 20 December 2000, where she was met by the service boat *Spurn Haven,* and the tug *Lady Debbie*. Berthing was carried out safely, and *Randgrid* was secured at 0135. Both berthing masters confirmed that the chain stopper was fully closed on to the chain before arranging for the messenger rope to be slacked back as usual. The chief officer discussed the discharge with the cargo surveyors and went to supervise the pump and line set-up. The first discharge hose was connected at 0210, and discharge started at 0245 with a line pressure of 11 bar. A small leak caused a delay, but by 0350 the discharge pressure was back to 11 bar. At that time the bridge berthing master became concerned about the vessel's movements under wind and tide, so arranged for the steering control to be changed from DP to manual. The chain stopper was also checked. Between about 0415 and 0430, the chief officer went to the bridge and shut down the hydraulic pumps controlling the power systems forward.

Before going to his cabin, he told the duty AB to check the mooring at regular intervals. This was carried out between 0500 and 0730; the mooring being confirmed secure. By 0715, with the flood tide due, the berthing master arranged for the tug astern to maintain a slow astern speed.

At 0753, the aft discharge hose pulled away. The duty cargo officer stopped the pumps and started to close the valves. Shortly afterwards, the forward hoses broke away. On the bridge, the berthing master became aware that something was wrong with the mooring, looked up, and saw the first of the hoses pulling free. Tetney Terminal was informed, and the standard terminal emergency arrangements were implemented. The astern tug was brought into play while *Randgrid*'s main engines were started, and by 0812 the vessel was able to manoeuvre under her own power. *Randgrid* then went to an anchorage, while terminal vessels contained and dealt with the oil spillage.

An investigation revealed that both spool pieces and flanges were damaged on the hoses, with slight deformation and cracking in weld flanges. The chain stopper was found in the closed position, but the chafing chain was missing. Subsequently, it was established that the chafing chain had been released from the chain stopper because the chain stopper controls had been operated accidentally. The pickup rope held the vessel until the lashing, securing the chafing chain to the pickup rope, failed at about 0750.

No staff were injured, but an estimated oil spill of about 12 tonnes occurred.

When connecting or disconnecting the monobuoy mooring, the bridge screen showed an appropriate message with the screen background varying in colour to emphasise the condition:

GREEN chain stopper closed
YELLOW chain stopper operating
WHITE chain stopper open

Like many other computer systems, the bridge monitor had been installed with a multi-functional screen system, i.e. No 1 screen would show a number of differing controls and systems, some of which could be operated using the function keys, F1, F2, etc. When switched to No 2 screen, a different set of systems and controls would be displayed, but using the **same** set of function keys: F1, F2, etc.

SCREEN 1
chain stopper open/closed
chain stopper operating
coupler valve open/closed
crude line valve open/closed
loading on/off
buzzer off

SCREEN 2
hydraulic pump No 1 on/off
hydraulic pump No 2 on/off
hydraulic pump No 3 on/off
dog clutch engaged
pressure selection for pump station
buzzer off

An example of the dual operation of the function keys is as follows:

SCREEN 1	chain stopper open	F9
SCREEN 2	hydraulic pump No 1 off	F9

Using this installation it is important, therefore, that the operator is aware at all times through which screen interface he/she is currently operating.

2.2 (b) The analysis

This incident was the direct result of human error in opening of the chain stopper, which was activated from the bridge. This human error was the primary factor in the release of the vessel from its mooring. The operator most likely meant to turn off a hydraulic pump, but had the wrong screen for this task displayed. Without looking at the screen for verification that it was the correct screen, the operator depressed the function key and the chain stopper "open" command was sent. Alternative, but similar causes of the release of the chain stopper proposed in the incident report are that the operator could activate the chain stopper release in error while trying to silence one of several routine engine room alarms sounding on the bridge, or by accidentally depressing the emergency mooring release button, as this button was not covered.

The chain stopper claw would have opened sufficiently to allow movement of the chafing chain within 2 to 3 seconds of the start. Allowing for a system change delay of about 1 to 2 seconds, any immediate error correction is unlikely to prevent the claw opening enough to allow chain slippage. Allowing for the slackness in the pickup rope, there would be a forward movement of about 2 to 3 metres. This would be sufficient for the chafing chain to pull clear of chain stopper.

The MAIB report stated that one of the key requirements of a control station is that it, together with the equipment within it, is ergonomically designed to minimise the risk of error during operation. The design of the control system onboard the Randgrid, whereby the same function key controls two different but interrelated systems, depending on what screen level is selected, did not meet this key requirement.

Anecdotal evidence from many shipboard users of screen based distributed control systems (DCS) indicates that many of these systems have confusing graphical user interfaces (GUI).

2.3 CASE STUDY 3: COLLISION OF THE "BRIGHT FIELD". [14]

2.3 (a) The circumstances

On December 14, 1996, the fully loaded Liberian bulk carrier *Bright Field* temporarily lost propulsion power as the vessel was navigating outbound in the Lower Mississippi River at New Orleans, Louisiana. The vessel struck a wharf adjacent to a populated commercial area that included a shopping mall, a condominium parking garage, and a hotel. No fatalities resulted from the accident, and no one aboard the *Bright Field* was injured; however, 4 serious injuries and 58 minor injuries were sustained during evacuations of shore facilities, a gaming vessel, and an excursion vessel located near the impact area. Total property damages to the *Bright Field* and to shore side facilities were estimated at about $20 million. This incident raises the issue of the adequacy of the ship's main engine and automation systems.

The *Bright Field* owners' oversight of testing and maintenance of the vessel's engineering control systems was inadequate and led to unreliable performance of the engineering plant and contributed to the shutdown of the main propulsion engine on the day of the accident.

According to statements from the Chief Engineer and other engineering crewmembers, the normal practice for the *Bright Field* while operating in restricted waters was to have the No. 1 lubricating oil pump running and the No. 2 pump on automatic standby and that the vessel was operating in this configuration on the day of the accident. On January 4, 1997, Safety Board investigators tested the oil pump automatic changeover feature by reducing the lubricating oil pressure sensed by the device. During these tests, the pressure switch failed to activate the standby pump. The original pressure switch was removed from the vessel for laboratory testing. Test conclusions were that, "the contact resistance is abnormally high," and could, under certain conditions, "cause a problem; i.e., giving erroneous …or faulty readings." The probable cause of the main engine trip that led to the incident was the failure of the standby main engine lubricating oil pump to automatically start following a partial loss of lubricating oil pressure from the running main engine lubricating oil pump. When this standby pump failed to start, because of the faulty pressure switch, the loss in main engine lubricating oil pressure was sufficient to initiate the automatic main engine low lubricating oil pressure trip.

2.3 (b) The analysis

The poor maintenance of the automatic control equipment onboard the Bright Field was one of the root causes of this incident. Maintenance and calibration errors when setting up control systems can lead to catastrophic consequences.

It was a poor risk management culture within the shipping company led to the errors in maintenance and calibration of essential automated systems.

2.4 CASE STUDY 4: THE COLLISION OF THE "DIAMANT" AND THE "NORTHERN MERCHANT". [15]

2.4 (a) The circumstances

On the morning of 6th January 2002, two ferries were crossing the Dover Strait in reduced visibility of less than 200 metres. The "Diamant" had sailed from Oostende and was heading for Dover. The "Northern Merchant" was heading to Dunkerque from Dover. Both vessels were travelling at close to normal cruising speed: "Diamant" a high-speed craft was travelling at 29 knots, and the "Northern Merchant", a Ro-Ro ferry, was travelling at 21 knots. If both vessels had continued their course and speed, their paths would have taken them to within half a mile of one another. However, at just over a mile apart, the bridge teams started to question the assumptions they had made about each other's probable course of action and started to implement course changes, but not speed changes, that would, they believed, put a greater distance between themselves. At 0952 they collided.

The MAIB report lists 18 possible causes and contributing factors in this accident, including the unsafe speed of both vessels, bridge team failures in risk assessment, violation of collision regulations and adherence to an "unwritten rule" that high speed craft will keep clear of all other craft.

2.4 (b) The analysis

This case is similar to previous collisions in reduced visibility in which the participants have violated regulations and operational practices. Both teams are making assumptions about the intentions and actions of others and, at the speeds involved, have little time to rectify the developing crisis situation when they realise what is actually happening.

However, this case also raises questions about the solution to such problems, specifically, the ability of operator training to provide solutions to this type of problem. The actors in this case were all experienced and professional officers who knew the collision regulations perfectly well but, for one reason or another, violate them, probably as a matter of routine. The root causes of these violations may not be resolved simply by sending "offenders" on remedial training in the interpretation of radar interpretation or the collision regulations.

Organisational culture plays an important part in reinforcing the appropriate behaviours required on board. If an organisation's shore-based management team pays "lip service" to its own operating policies and procedures by failing to implement them on the vessels and, at the same time, tacitly accepts or rewards deviant behaviour, then the individual officers on board will adopt a similar cultural attitude.

2.5 CASE STUDY 5: GROUNDING OF THE "ATTILIO IEVOLI". [16]

2.5 (a) The circumstances

On 3 June 2004, the Italian registered, double hulled chemical tanker *Attilio Ievoli* ran aground on Lymington Banks in the west Solent. The vessel suffered bottom plate indentation forward but no hull penetration. Nobody on board was injured and there was no pollution. The Master had decided to proceed to the English Channel via the west Solent and Needles Channel, as he had done on a previous occasion 6 weeks before. This decision was contrary to his company's standing instructions that required its vessels to use the east Solent route when arriving or sailing from Southampton.

The pilot disembarked at the East Lepe Buoy, automatic steering was engaged and the vessel continued her passage through the west Solent with the master conning from his forward console chair at the starboard radar. It was a clear day, with little traffic in the west Solent. Neither the second officer nor the cadet were sure of who was responsible for plotting positions on the chart, although both did some rudimentary checking off of buoys passed. The Master was not paying attention to the navigation of the vessel, and was distracted, using the ship's mobile telephone.

The MAIB report concluded that:

"Poor bridge team management on the vessel resulted in a lack of accurate vessel positional awareness and an inappropriate division of tasks. The use of the mobile telephone distracted the master from his primary responsibilities".

2.5 (b) The analysis

Human factors issues relating to this accident include the Master's violation of company instructions, no briefing of the bridge team relating to their roles and responsibilities, ineffective use of the available bridge equipment and the distraction of the Master through his use of the mobile phone.

Also of particular interest in this case is the analysis of the cultural difference between the Italian Master and the Ukrainian second officer. It is believed that the second officer may have been reluctant to question the authority of the Master, although he had realised that the vessel was not on track. This reluctance may be explained by the cultural dimension of "power distance" whereby the Eastern European second officer would show more deference to authority than his Western European counterpart.

The human factors analysis conducted by Qinetiq concluded that:

"The 2/O knew that the vessel was not following an appropriate course but failed to communicate this to the master. The poor standard of teamwork accepted by the master probably contributed to this failure. Language difficulties probably did not play a part, but cultural differences and communications practice may well have made a contribution".

3. LOOKING FORWARD

In summary, both reviews of the patterns and trends of accident databases and the study of individual case studies suggest that poor team performance leading to loss of situational awareness and poor decision making is the cause of many accidents. Cultural issues (national, organisational and professional), are often the root causes of poor team performance through violation of procedures, lack of communication and system understanding between team members.

In terms of developing the situational awarenss and decision making skills of teams, there are at least two specific training requirements:

- To provide exercise scenarios in which the individual's mental models of systems, situations and the cues by which they recognise them, may be enriched;
- To develop a general critical thinking skill which resolves conflicting information and tests the assumptions on which decisions are based.

Based on these principles, an innovative crew resource management (CRM) training course is currently being developed at Warsash. The course uses a number of forms of simulation, including role playing exercises and full mission simulator exercises, which combine both bridge and engine room teams. In addition to the specific development of critical thinking skills and the enhancement of situational awareness, the objectives of the course also include the development of the other non-technical skills of CRM, for example, communication, team co-ordination and leadership development.

The course builds the learning experience from classroom lectures on theoretical aspects, followed by brief exercises to practice specific techniques, culminating in simulator-based scenarios in which the various elements can be brought together. The final exercises bring both bridge and engine room teams together, through linked simulators, where complex evolving situations have to be managed by both teams.

The development of the course is leading to further research. A major issue is to what extent will the CRM skills, learned in a simulated environment, *transfer* to the real world? Questionnaires are being used to follow up course participants to assess what has been retained from their training after a defined period.

Three other research issues are of particular interest in the maritime context. The first is related not only to the sharing of situational awareness between members in a team but also between distributed teams. Video observations from our own simulator exercises suggest that team leaders can find it difficult to articulate their understanding of the situation to other team members. This difficulty is not limited to intra-team communication, but can work at an inter-team level too. It is apparent from observation of our exercise scenarios that one team can easily become oblivious to the information needs of a separate team when under stress, and, as illustrated by the *Hanjin Dampier* case, bridge and engine room teams can habitually fail to update each other as a situation unfolds. Measuring the effectiveness of synchronous training and the characterisation of behavioural markers for distributed teams represent interesting challenges to the maritime training and research community.

The international shipping industry shares with the offshore industry a similar working environment in that multi-national, multi-cultural crews work and socialise together in an isolated environment for months on end. The effect of national culture on team working is a particularly challenging area of research. Our experience from simulator training suggests that different national cultures do work together in noticeably different ways. For example, a UK/US team does display a more individualistic way of sharing situational awareness than those from a more “collective” culture [17]. Questions that have yet to be addressed include: what effects are produced by cultural factors and how may they be characterised? What is the impact on the overall safety performance of a team, especially in stressful situations, by placing individuals from one culture into a different culturally based team?

In recent high fidelity simulator based studies two types of behaviour, which provide examples of both communication and cultural problems, have been noted that have had particularly adverse affects upon the team’s performance. These behaviours have been categorised as “verbal disruption” and “cultural isolation”.

3.1 VERBAL DISRUPTION

This behaviour has been noted where one team member has been so vocal during the simulation exercise that they have disrupted the team task. In an effort to be helpful to the team, these team members will continually verbalise the situational assessment, as they perceive it. They will offer many varied hypotheses for any perceived problem, they will continually offer advice to the other team members and they have also been observed thinking aloud. By continuously talking, they make it very difficult for other members of the team to communicate, and consequently the performance of the team suffers. When the team member who was causing the verbal disruption is given a non-participative role of observer within a simulator exercise, the performance of the remainder of the team is seen to improve dramatically.

Once the team members have been made aware of their verbal disruption behaviour, during subsequent simulator exercises, it has been observed that they make a conscious effort to limit their utterances to the minimum required to maintain effective communications with the other team members.

3.2 CULTURAL ISOLATION.

In teams of three members or more, where one of the team members is the only one from a particular culture, and the rest of the team members are from a different culture, cultural isolation has been observed. The team member who is of a different culture to the rest of the team has been observed to be isolated within the team and ignored by the remaining team members. This behaviour has been observed even when this team member is known by the other team members to have expertise relevant to the team task. The behaviour then has serious consequences for the effectiveness of the team to successfully complete the team task.

From anecdotal evidence when debriefing the team, it appears that the isolation is not carried out at any conscious level. When the cultural isolation behaviour has been discussed with those simulation exercise participants who were exhibiting it, they were unaware that they had been behaving in that way. It appears that the natural cohesion of the team members’ culture was overriding the team working principle.

Again, once team members had been made aware of their cultural isolation behaviour, during subsequent simulator exercises they made a conscious effort to ensure that all team members were fully integrated into the team task.

Finally, the argument has been made earlier in this paper that the training and assessment of operators can only ever be part of the solution to reducing accidents. Organisational factors also play a significant part in accident causation. So what are the research issues in maritime operations, at an organisational level, which need addressing?

The analysis of human factors in accident causation is still relatively immature in the maritime world. Although databases held by the MAIB and other parties interested in the causal factors of accidents – e.g. insurers and classification societies – do include human error taxonomies, little analysis is undertaken to identify trends or patterns. Even less analysis has been attempted in assessing the significance or frequency of organisational factors such as the incidence of commercial pressure or the effects of organisational culture on accident causation.

The differences in organisational culture between shipping companies is a well known phenomenon, but there has been little work on understanding the effects of organisational culture on safe and efficient performance.

Not enough is known about the parameters governing functioning and performance of management systems. There is little research evidence to indicate what makes a management system work or indeed what prevents it from working. Equally, not enough is known about the metrics that enable the status of a management system to be determined. Ideally, what is required is a set of "leading" indicators that will predict future performance so that interventions can be made before accidents occur.

The research conundrum is, first, to agree what constitutes organisational behaviour; second, in deciding which "behaviours" are leading indicators of proficiency; and third, in designing methods that can measure these indicators accurately.

4. CONCLUSIONS

Theoretical models of accident causation and human error suggest that maritime casualties are caused by a combination of factors, which may include "active" failures by onboard personnel and also "latent" conditions in the organisational system. There are a number of sources of human error, which include violations, mistakes, and distractions. Recent accident studies suggest that onboard violations and lack of situational awareness are the predominant sources of operator error. A review of five case studies tends to confirm that poor team performance leading to loss of situational awareness and poor decision making is the cause of many accidents. Cultural issues (national, organisational and professional) are often the root causes of poor team performance through violation of procedures, lack of communication and system understanding between team members.

These findings also suggest that there is a need to conduct more research into the root causes associated with organisational pre-disposing factors.

Observations during crew resource management training courses using full mission simulators, show that it is possible to detect behaviours that are detrimental to the team's overall performance. These observations also show that with debriefs, these detrimental behaviours can be changed, in the short term, for more beneficial behaviours. Further research would be required to ascertain how long these beneficial changes in behaviour would last.

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