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Searching for the Root Causes of Maritime Casualties
– Individual Competence or Organisational Culture?

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Abstract

This paper opens by placing our current understanding of human error within a model of accident causation. The philosophical problems of bias and hindsight in accident investigation are discussed and a classification of human error types is presented. Two recent surveys of accident data and three case studies are used to highlight the main concerns in the sources of failure. These concerns are onboard violations, lack of onboard situational awareness, and failures in management practice. The paper provides an overview of how these issues have led to developments in maritime training and research. The first development has been the design of more effective training courses through a better understanding of the nature of the skill requirements of situational awareness. The current training is outlined and other areas of research, which are now being undertaken, are described. The paper concludes with a summary of further research and development needs.

Key words: accident causation, human error, situational awareness, organisational culture

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 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

1 Reason, J.: *Managing the Risks of Organisational Accidents*. Aldershot: Ashgate Publishing, 1997, p. 12.

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]

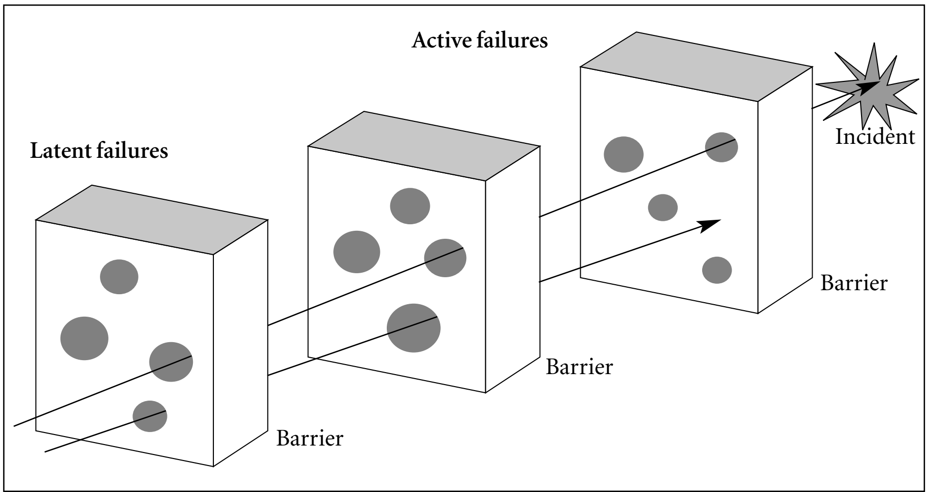

Figure 1 – The Swiss Cheese Model of Accident Causation

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

2 Singleton, W. T.: *Theoretical approaches to Human Error.* In: *Ergonomics*. Vol. 16 (1973), No. 6, p. 730.

> 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 by this author as "*the Janus principle*"[5], in homage to Koestler, who used the phrase in a different context when expounding on systems theory.[6] Following Hausman, 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

3 Chapanis, A.: *Research Techniques in Human Engineering*. Baltimore, MD: John Hopkins Press, 1959, p. 94.

4 Johnson, C. W.: *Failure in Safety-Critical Systems: A Handbook of Accident and Incident Reporting.* Glasgow: University of Glasgow Press, 2003.

5 Grey, M.: *The two faces of human error.* In: *Lloyds List Viewpoint*. January 31, 2005.

6 Koestler, A.: *Janus: A Summing up*. London: Hutchinson & Co., 1978.

7 *Op. Cit*. 4.

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]

The next section presents a model for the classification of human errors, and reviews some recent analyses of accident databases in search of root causes.

2 The Classification of Human Errors

Another major contribution made by Reason[10] is his model of human error. Building on Rasmussen's work which describes levels of human performance as either skill-based, rule-based or knowledge based, Reason uses a simple *plan-action-consequence* model to illustrate the four main types of human error: slips, lapses, mistakes and violations.

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8 Gyles, J. L., Salmon, D. R.: *Experience of Bridge Team Training using the Warsash Ship Simulator*. In: *Proceedings of 1st International Conference on Marine Simulation*. Warsash: MARSIM, 1978.

9 Her Majesty's Rail Inspectorate (HMRI): *Assessment criteria for railway safety cases.* In: *Technical report for Health and Safety Executive (HSE)*. London: HSE, 2000. http://www.hse.gov.uk/-railway/criteria/index.htm

10 *Op. Cit.* 1, p. 72.

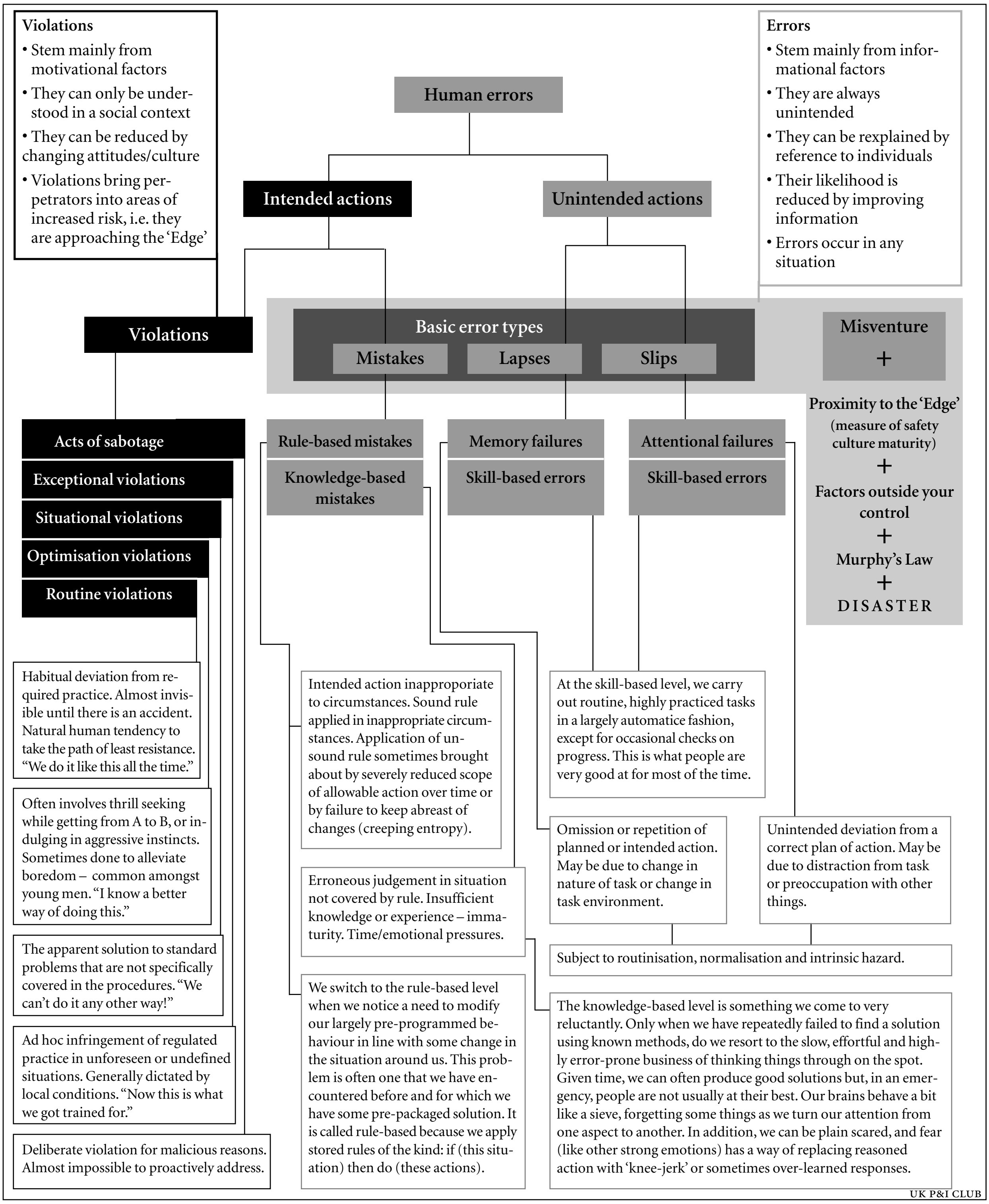

Figure 1: Summarised sources of human error

His original model has been developed to produce the very comprehensive description of the sources of human error shown in Figure 2, reproduced here by kind permission of the UK P&I Club. The chart highlights a number of important points:

- The chart makes a clear distinction between the slips and lapses associated with largely automatic tasks, and the mistakes and violations associated with intended actions.
- Rule-based mistakes can either be the application of a bad rule, or a good rule applied in the wrong situation.
- Knowledge-based mistakes may occur when we have to think our way through a novel situation for which we do not have a procedure or "rule". Lack or loss of situational awareness is an example of a knowledge-based mistake.
- Errors in themselves do not always produce disasters. It is the consequences of the error that determines whether it will or not. The column on the right hand side of the chart illustrates this concept.
- The fact that the consequences of our actions can be either good or bad, depending on other factors, leads to the concept, in Reason's words, of the "successful violation", where paradoxically, people can break all the rules and still become heroes!
- There are a number of ways in which deliberate violations can occur. Of particular significance are the habitual or routine deviations from normal practice. Individuals have learnt short cuts that may work on a number of occasions until the violation itself becomes the normal practice.
- The chart emphasises that violations raise the notion that they are attitudinal in nature and that the operational or organisational culture is often the root cause of violations.

What the chart does not reveal is which types are most likely to be present in maritime casualties. A recent study by Uchida[11], reviewing 173 Japanese accident records relating to marine engine management, suggests that onboard violations are significantly more likely to occur than other sources of error. He estimates that as many as 45% of the accidents he reviewed can be attributed to onboard violation. Knowledge-based and skill-based mistakes by crewmembers accounts for a further 13% and 9% respectively. Only 7.5% of the accidents could be attributed to organisational failures ashore.

A recent review[12] of the accident databases from the USA, UK, Canada Australia and Norway also confirms that human error continues to be the dominant factor in maritime accidents. The following conclusions were drawn:

11 Uchida, M.: *Analysis of human error in Marine Engine Management.* In: *Advances in International Maritime Research. Proceedings of Annual General Assembly No 5.* Tasmania, IAMU, 2004, pp. 85–93.

12 Baker, C.C., McCafferty, D. B.: *Accident database review of human element concerns: What do the results mean for classification?* In: *Proceedings of the International Conference on Human Factors in Ship Design and Operation*. London: RINA, 2005.

1. While the total number of accidents is declining, human error continues to be a dominant factor in 80 to 85% of maritime accidents.
2. Failures of situational awareness and situation assessment overwhelmingly dominate.
3. 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.

These studies suggest that both onboard violations and the knowledge-based mistakes associated with lack of situational awareness are the predominant human error types. However, although both studies have categories associated with organisational factors, neither category is apparently significant.

In our search for root causes, the question is: are accidents predominantly the result of "active" failures by individual or teams on board ships, as both these studies suggest, or are the root causes to be found elsewhere, in the "latent" failures in the organisational environment or culture? The following extract suggests we may need to cast our search wider for the underlying root causes of accidents:

> In these criteria the term ***'root causes'*** includes consideration of ***management' s real and perceived messages to workers***, environmental and human factors, as well as plant failures and inadequate procedures. Human errors arising from poor operating conditions, procedures, management expectations or plant design ***are not root causes; the predisposing factors are.***[13]

The following section reviews three case studies to illustrate how our better understanding of accident causation and human error allows us to interpret the root causes of maritime casualties. The first case illustrates both onboard violation as well as failures in management practice. The second case is a classic example of loss of situational awareness by both the onboard deck and engineering teams. The third case illustrates how the root cause of onboard violations may be related to organisational culture. It also indicates the sharp distinction between potential remedies for future prevention depending on whether one interprets this type of accident as a failure in

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13 *Op. Cit.* 9.

individual competence or the results of predisposing factors within the organisational culture. All three cases indicate that in any accident, there are likely to be multiple root causes.

3 Three Case Studies in Human Error

3.1 Case Study 1: The Grounding of the "Royal Majesty"

3.1.1 The circumstances

In June 1995 the passenger vessel "Royal Majesty", with 1509 passengers aboard, went aground near Nantucket Island on a voyage from Bermuda to Boston. The vessel was fitted with an integrated bridge system including an autopilot which, when engaged, was capable of steering the vessel along a pre-programmed route using the vessel's GPS system as a primary source of positional information. In the case of insufficient satellite data, the GPS was designed to default to a Dead Reckoning (DR) mode. The autopilot, however, was not capable of recognising any change in GPS status and thus, with the GPS in DR mode, was only able to continue navigation without correction for wind or current.

The autopilot was set on departure from Bermuda, but after about an hour the GPS defaulted to DR mode (probably as a result of a loose connection on the receiver cable), and for the next 34 hours, the vessel was navigating on DR through the autopilot. At no time during this period was this situation detected by the bridge team, so that when the vessel eventually grounded, she was 17 miles off course.

The official National Transportation Safety Board report gave as the probable cause of the grounding:

> The watch officers' over reliance on the automated features of the integrated bridge system, Majesty Cruise Line's failure to ensure that its officers were adequately trained in the automated features of the integrated bridge system and in the implications of this automation for bridge resource management, the deficiencies in the design and implementation of the integrated bridge system and in the procedures for its operation, and the second officer's failure to take corrective action after several cues indicated the vessel was off course.[14]

3.1.2 The analysis

- This case illustrates the problems of over reliance on the available technology by the bridge team. All the officers have been lulled into a false sense of security by a modern system that appears to be protecting the vessel but is vulnerable. Their understanding of the system and its weaknesses is incomplete and their reliance on technology has led the team to use only a limited number of sources of information to determine the vessel's position. Other sources are ignored and not used

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[14] National Transportation Safety Board (NTSB): *Grounding of the Panamanian Passenger Ship Royal Majesty on Rose and Crown Shoal near Nantucket, Massachusetts, June 10, 1995.* In: *Marine Accident Report*. Washington, DC: NTSB, 1997.

for crosschecking. This deviance from normal watch keeping practice has gradually become the accepted norm by all members of the team.

- There were several opportunities when both the chief officer and the second officer on their respective watches could have avoided the grounding through the observation of buoys visually and by use of the radar. However, because of their over confidence in the GPS, the team is in a "mind set" where conflicting evidence is not analysed critically and assumptions are not questioned. The result is that the individuals remain confirmed in their bias towards the information from one source and remain in blissful ignorance of the real situation.

3.2 Case Study 2: The Grounding of the "Green Lily"

3.2.1 The circumstances

On 18th November 1997, the 3,624 grt Bahamian registered vessel "Green Lily" sailed from Lerwick in the Shetland Islands with a cargo of frozen fish for the Ivory Coast. The weather on departure was bad with wind speeds increasing to severe gale force 9. The following morning, while hove to about 15 miles south-east of the island of Bressay in the Shetland Isles in storm force 10 winds, a sea water supply line fractured in the engine room. The engineers controlled the flooding and pumping out had begun when the main engine stopped. Unsuccessful attempts were made to restart the engine while the vessel drifted northwards towards Bressay. Shetland Coastguard was advised and three tugs, the Lerwick RNLI lifeboat and a coastguard helicopter prepared to proceed to the casualty.

Attempts were made by two of the tugs to secure a line and tow the "Green Lily" away from land but although initially successful, each line parted. The starboard anchor was released and the third tug attempted to snag the cable and pull her head to wind, but the cable parted. At this time, the lifeboat rescued five crewmen, including two injured, from the ship's deck. The Coastguard helicopter rescued the ten remaining crewmembers but the winch man, who had remained on the deck of the ship, was swept into the sea and lost. The "Green Lily" went aground and started to break up. The investigation by the Marine Accident Investigation Branch (MAIB), published in June 1999, advised the cause of the grounding was:

> The lack of propulsion and failure to restart the main engine to arrest the drift of the vessel towards the shore in the prevailing environmental conditions. Contributory causes included flooding of the engine room, failure to reset the mechanical over-speed trip, inadequate knowledge of the cooling water system, failure of the towage attempts and inadequate teamwork[15]

3.2.2 The analysis

- An initial technical failure precipitated events and was compounded by a hostile environment and further technical problems and failures. The situation was escalating

15 Marine Accident Investigation Branch (MAIB): *Report of the Inspector's Inquiry into the loss of MV Green Lily.* In: *Marine Accident Report*. No. 5, 1999, p. 9.

in severity. The available emergency plans, which tended to be procedures based on single failures, were not applicable. The individuals involved were forced to fall back on their experience to cope with an increasingly complex and unpredictable set of circumstances.
- Initial diagnosis of the technical failure was incorrect and led to a faulty but persistent mental model of the situation. In this case, the chief and second engineers, together with the electrical engineer, failed to understand why the main engine stopped and were consequently unable to restart it. They believed that the main engine failure was due to the effect of the flooding, previously caused by the fracture of the sea suction pipe. The probable reason for the main engine stoppage was actually due to the mechanical over-speed trip either not being reset or reset incorrectly.
- Awareness of the overall situation by individuals was based on incomplete or inaccurate information. In this case, both the Master, based on his calculation of drift, and the engineers, were over optimistic in their belief that a tow would be available before the ship ran aground. Meanwhile, the skippers of the rescue craft had unexpressed reservations about various aspects of the operation including the appropriateness of some of the towing gear, the weather conditions and sea room, and the ability of the ship's crew to handle the towlines.

3.3 Case Study 3: The "Diamant" and "Northern Merchant" Collision

3.3.1 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[16] 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.

3.3.2 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

16 Marine Accident Investigation Branch (MAIB): *Report on the Investigation of the collision between Diamant/Northern Merchant.* In: *Marine Accident Report*. No. 10, 2003.

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.

4 Recent Initiatives in Maritime Safety Research

The following sections describe three research-led initiatives in the field of maritime safety currently being undertaken at Warsash:

1. To develop more effective training courses through a better theoretical understanding of the nature of situational awareness in "real world" maritime operations.
2. To identify a set of behavioural markers for assessing the non-technical skills of resource management.
3. To explore the role of organisational factors in safe operation, in recognition of the limitations of operator training to prevent the reoccurrence of accidents.

4.1 The Development of Training in Situational Awareness and Resource Management

Situational awareness is one of the skills that make up a set generally referred to as crew resource management (CRM). Table 1 indicates the skills required for effective resource management and that these may be seen as being both social and cognitive in nature.

Previous research suggests[17] that there are at least two specific training requirements for the development of situational awareness skills:

1. 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;
2. To develop a general critical thinking skill which resolves conflicting information and tests the assumptions on which decisions are based.

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17 Barnett, M. L., Pekcan, C. H., Gatfield D.: *Recent Developments in Crew Resource Management (CRM) and Crisis Management Training*. In: *Proceedings of the International Conference on Manning and Training*. Shanghai: Lloyd's Ship Manager (LSM), 2004.

Social	Cognitive
Co-Operation and communication • Team building and maintaining • Consideration of others • Support of others • Conflict resolving	**Co-operation and communication** • Team building and maintaining • Consideration of others • Support of others • Conflict resolving
Leadership and managerial skills • Use of authority and assertiveness • Planning and co-ordinating • Workload management	**Decision making** • Problem diagnosis • Option generation • Risk assessment • Option selection

Table 1: The Skills of Resource Management

Based on this research and pedagogical theory, an innovative CRM training course is currently being developed at Warsash[18]. 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 at different stages of the learning process to follow up course participants to assess what has been retained from their training after a defined period.

Two other research issues are of particular interest in the maritime context. The first is related to the sharing of situational awareness between members in a team and also between distributed teams. Both the "Diamant" and the "Green Lily" cases demonstrate difficulties in communicating mental models between teams on the same vessel and/or between separate agencies involved in a crisis situation. Video observations

18 Pekcan, C. H., Barnett, M. L., Gatfield D.: *Content And Context: Understanding The Complexities Of Human Behaviour In Ship Operation*. In: *Seaways, The Journal of the Nautical Institute.* July, 2005.

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 as the "Green Lily" case shows, can work at an inter-team level too. In addition, it is apparent that one team can easily become oblivious to the information needs of a separate team when under stress, for example, bridge and engine room teams habitually fail to update each other as a training scenario unfolds. Measuring the effectiveness of synchronous training and the characterisation of behavioural markers for distributed teams represent interesting challenges to the maritime training 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. Cultural and linguistic effects on team working are 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[19]. 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?

4.2 Towards the Development of a Maritime Assessment Framework

A PhD research programme is also currently being undertaken at Warsash that is intended to provide an understanding of how a behavioural marker system could be used to assess the competence in crisis management of merchant marine engineering officers[20].

Behavioural markers that could be used to assess competence in crisis management within the context of a simulated merchant vessel's engine room control room are being determined. Experiments are being undertaken to investigate the efficacy of these behavioural markers to assess competence in crisis management, and it is intended that this research will then go on to show if these behavioural markers can be used as the basis for an objective competence assessment framework.

The aims of this research programme are:

1. To understand how behavioural markers can be used to objectively assess competence in crisis management of merchant marine engineering officers.

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19 Hofstede, G.: *Cultures and organisations: Software of the Mind*. London: McGraw-Hill, 1991.

20 Gatfield, D.: *Using simulation to determine a framework for the objective assessment of competence in maritime crisis management*. In: *Proceedings of the SAGSET 2005 Conference*. Portsmouth: University of Portsmouth (In Press).

2. To develop and validate an assessment framework that utilises specific overt behavioural markers to facilitate the objective assessment of competence in crisis management of merchant marine engineering officers.

4.3 Organisational Factors

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, insufficient 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. In much the same way as we are striving to identify a set of behavioural markers to assess the competence of individuals, so there is a need to establish a set of organisational metrics to determine the competence of shipping companies to perform safely.

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.

5 Summary and 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, slips and lapses. Recent accident studies suggest that onboard violations and lack of situational awareness are the predominant sources of operator error. However, a review of three case studies suggest that there is also a need to conduct more research into the root causes associated with organisational pre-disposing factors.

An innovative training course is currently being developed at Warsash to develop the skills of situational awareness and the other non-technical skills of resource management. 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 to develop the skills of communication, team co-ordination and management and leadership development.

In setting an agenda for future maritime research in this area, the following issues are suggested for consideration:

- If the direct training of resource management skills is pursued, to what extent will such skills, learned in a simulated environment, transfer to the real world?
- What are the optimum training environments to ensure effective transfer?
- How can these non-technical skills be assessed most effectively, both at the level of the individual and at the level of the team?
- What behavioural markers, both at individual and team level, predict safe performance?
- In multi-national environments, how may cultural factors be characterised and what is the impact on overall safety performance of cultural differences?
- We know that organisational factors also play a significant part in accident causation but how can their significance, frequency and impact be established?
- How does organisational culture impact on accident causation?
- Finally, what are the metrics that enable the status of an organisation's safety management system to be determined?

6 Acknowledgements

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I would also like to dedicate this paper to the memory of Major Don Browne (1925–2005) with whom I had the privilege of delivering training courses from 1987 to 1998.