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A GUIDE TO UNDERSTANDING HUMAN FACTORS & HUMAN BEHAVIOUR

In Safety Management & Accident Investigation







NAVYSAFE

LETHAL TO OUR ENEMIES - SAFE TO OURSELVES



FOREWORD

This guide has been prepared as part of the Navy Safety Improvement Programme “NAVYSAFE” to help develop our understanding across the Naval Service of the human factors and behaviours that contribute to accidents, incidents and near misses.

It is intended as a ready reference document for all personnel in leadership positions, from AB and Marine all the way up the management chain. First and foremost it is designed to help prevent accidents but also to assist investigators (after an event) to identify the root causes. In doing so we will be able to uncover weaknesses in our environment, organisation and equipment design; take action; learn from our experiences and ensure that we remain lethal to our enemies and safe to ourselves.

In line with the First Sea Lord’s Safety Pledge, safety is everyone’s business and we all have a role to play. So read and refer to this guide, use the examples to discuss where you may have made errors or violations in the past and ensure we are sensible about taking risk such that we remain an effective fighting force that is risk aware, not risk averse.

Vice Admiral Philip Jones CB
Fleet Commander

A GUIDE TO UNDERSTANDING HUMAN FACTORS AND HUMAN BEHAVIOUR

In Safety Management and Accident Investigation

By **R S BRIDGER, P PISULA, A BENNETT**

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This guide has been produced by the staff of the Institute of Naval Medicine and is provided to support procedures for safety management and accident investigation as described by BRd 9147.

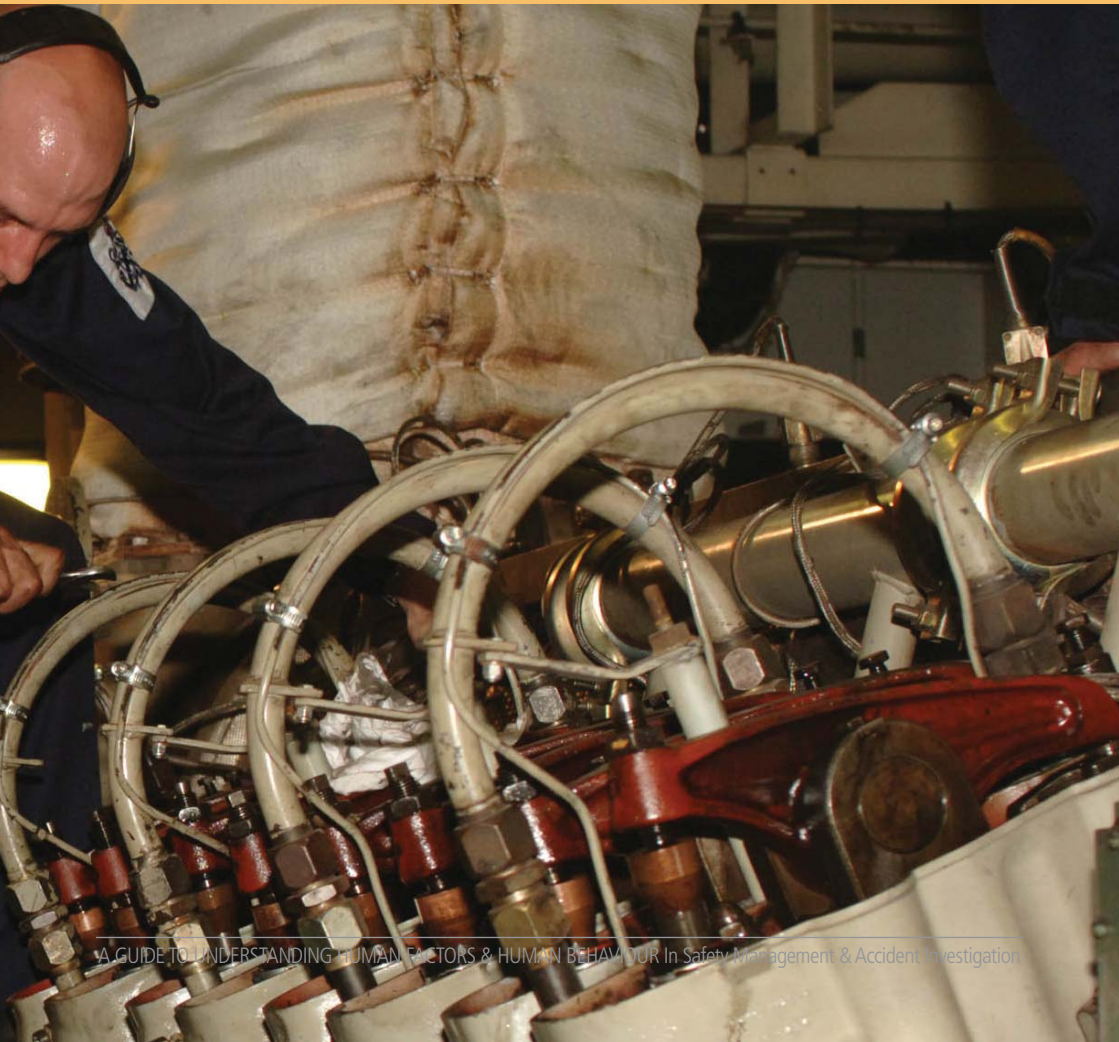


The aim of the guide is two-fold:

- to provide an understanding of Human Factors and Human Behaviour for all personnel, at all levels, to help identify risk and prevent accidents and incidents before they occur.
- to help accident investigators ask the right questions about accident causation. This will enable them to better identify performance shaping factors in the work environment and make recommendations for improvement.

“Human error is not random. It is systematically connected to features of people’s tools, tasks and operating environment... Human error is not the conclusion of an investigation. It is the starting point”

¹Dekker, S. 2006. The Field Guide To Understanding Human Error. Ashgate Publishing, pp 236.



CONTENTS

This guide is structured in three parts:

Part 1 - An Introduction to Human Factors and Human Behaviour.

Part 2 - Classification of Human Factors within accidents: Errors and Violations.

Part 3 - Identifying Human Factors and Human Behaviours after an accident.

This guide is intended to supplement the training received by personnel during Career courses and act as an 'aide-memoire' for routine planning and management of activity. To achieve this aim, real-life examples are provided which detail faults in equipment design, environmental hazards and organisational failings which have led to equipment damage and personal injury.

Note: Throughout this guide, accidents, incidents and near misses will be referred to; they are collectively known as events and are defined as follows:

Accident: An undesired event resulting in death, ill health, injury, damage or other loss.

Incident: An event that gives rise to an accident or had the potential to lead to an accident. An incident where no death, ill health, injury, damage or other loss occurs is also referred to as a "near miss". The term "incident" includes "near miss".

Near miss: An event that, while not causing harm, had the potential to cause death, ill health, injury, damage or other loss but which was avoided by circumstance or through timely intervention.

PART 1 - AN INTRODUCTION TO HUMAN FACTORS AND HUMAN BEHAVIOUR

The Scope of Human Factors

The diagram below depicts the general scope of Human Factors. It highlights that an individual's behaviour may be influenced by the environment (the physical world), the organisation of their work and the design of machines, equipment, software and workspaces.

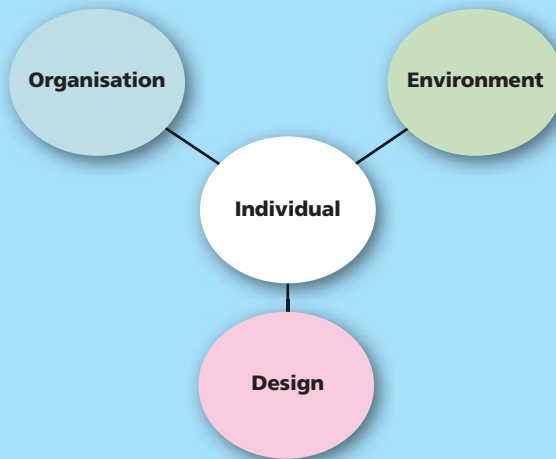


Figure 1 - Where to Look For Human Factors

Within these domains there can be a number of different areas that can affect Human Behaviour.

Environment

The environmental domain focuses on environmental conditions such as noise, lighting, temperature and humidity. The presence of environmental hazards such as high sea states, chemicals and radiation are also included in this domain.

Organisation

The organisation domain focuses on the way operations and tasks are organised. This includes examples such as: how units are manned; what instructions are given to personnel; what levels of training are considered necessary to complete a task; the type of watch system used; the level of supervision required for a task and the creation and application of Standard Operating Procedures (SOPs).

Design

The design domain focuses on workplace ergonomics and the design of equipment, user interfaces and software such as the location of a valve operating point, the arrangement of an operating console or the layout of a computer screen (graphical user interface).

Personnel involved in Safety Management should consider the effect that environmental, organisational and design factors may have on an individual performing a task. Accident Investigators should focus not only on what personnel did, but at the situation personnel were in at the time the accident happened. Investigators should ask what environmental, organisational and design factors played a role, and how these affected the personnel involved.

Note:

Appendix A gives practical examples of environmental, design and organisational factors that can influence behaviour and lead to errors and accidents.

Appendix B gives some examples of Human Factors in real accidents.

Human Behaviour

The contemporary view of human behaviour is that human error is not the cause of failure - rather it is an effect or symptom of a deeper trouble. After an accident has occurred focus must therefore extend beyond '...what occurred?' to '...why did it occur?' This particularly applies to accident investigation where priority must be placed on understanding why errors occurred or why personnel behaved in an unexpected manner.

The Accident Chain

Accidents are usually the end point of a series of events in which the situation becomes increasingly unsafe. Organisations erect multiple barriers to prevent accidents and maximise safety, but none are perfect. By looking beyond the immediate cause, back from the time the accident occurred and outwards, to the wider context, accident investigators can often identify weaknesses at the organisational level from which useful lessons can be learned. Figure 2 illustrates how events can unfold in the form of an accident trajectory (known as the "Swiss Cheese" model).

In almost all accidents, personnel are a key part in this accident chain. Human behaviour is never constant but the actions of individuals can often be attributed to the environment in which they are placed. An understanding of these Human Factors within design and organisation and a dynamic assessment of them against the current environment can greatly assist in the prevention of accidents.

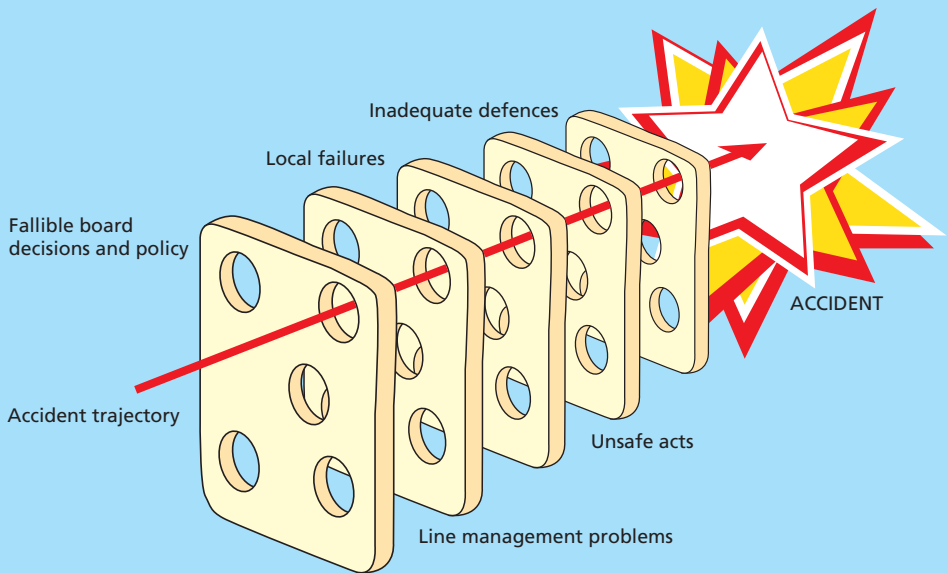


Figure 2 - 'Swiss Cheese' Model of Accidents
 (Redrawn from Reason, J. 1990. Human Error. Cambridge University Press, Cambridge, UK.)

Note:

Appendix C presents case studies to assist with the understanding of Figure 2 and its implications for accident investigation. These case studies illustrate how organisational policies and practices can make it possible for latent failures to exist in the workplace causing accidents to occur when the remaining safety systems fail.

Safety Culture

As well as explaining the behaviour of individuals in the context of Human Factors, the shaping of events should also be considered against the influence of the local and organisational Safety Culture.

Safety Culture is the term used to describe the shared attitudes and beliefs about safety and safety related activity within an organisation.

For example, whether personnel perceive that they work in a hazardous occupation; whether they feel confident to speak out when things don't seem right; whether safety is rewarded and recognised or whether the focus is just on getting the job done at any cost. Often, hazards linger in the workplace and eventually cause an accident because they were not recognised or reported at an earlier time.

To fully understand the Accident Chain, the influence of Safety Culture at all stages, before and after an event, should be carefully examined.

PART 2 - CLASSIFICATION OF HUMAN FACTORS WITHIN ACCIDENTS: ERRORS AND VIOLATIONS

Recognising the background presented by these Human Factors, the action of personnel still requires explanation. Basic behaviours in the context of accidents can be defined as **Errors** or **Violations** as described below:

ERRORS (Unintentional Action)

Errors in Action – associated with familiar tasks that may not require much attention. These skill based errors can occur if the attention is diverted from the task and are often a sign of fatigue or distraction by overload.

- **Slip (Commission)** – carrying out an incorrect action or task: for example, entering the wrong heading into the autopilot; deleting instead of saving a file; taking a reading from the wrong instrument.
- **Lapse (Omission)** – failure to carry out an action or task when action was required: for example, failing to check the condition of ropes used for towing; failure to check that all were seated safely in a RIB before moving; failure to turn-off the electrical power supply before undertaking repairs to a piece of equipment, missing a crucial step in a safety-critical procedure.
- **Psychomotor** – Accidentally operating a control or changing the state of a component through clumsiness: for example, knocking oneself unconscious while handling awkward loads in a confined space with limited headroom; man overboard due to loss of balance in high seas.

Errors in Thinking – involve mental processing linked to planning, gathering information and communication.

- **Rule-based error** - Successful task performance often requires that personnel follow simple rules of the 'If 'X', then 'Y' variety. Errors can occur when personnel either do not know the rule, when the situation changes and the usual rules do not apply or when personnel do not receive the information they need to act on the basis of the rule. For example: An individual is very familiar with filling a tank, it usually takes 30 minutes. However, the individual does not know that the size of the inlet pipe has been enlarged and the tank now fills more quickly. After 15 minutes the gauge indicates that the tank is full, but the individual ignores it, thinking it is faulty. The tank overflows. The individual is applying a rule, but the context has changed and the rule no longer applies.

- **Knowledge-based errors** - Mistakes and poor judgment are examples of knowledge-based errors. In many situations, we may have all the necessary knowledge to deal with a problem but we fail to use our knowledge correctly. Fatigue, time pressure, a lack of communication and many other human factors may cause personnel to act before they have all the facts needed to make the right decision. For example: A man is injured when removing the lid of a drum using a burning torch. He had not been told that the drum contained flammable liquid which exploded when the torch was applied.

VIOLATIONS (Intentional Action)

A violation is explained as a conscious action by an individual which did not conform to policy instructions or standard procedures. This involves a deliberate deviation from the rules, and in some cases this non-compliance with the rules can become the 'norm'. There may be several explanations for violations:

Routine violations - not following the rules/procedures in a usual operating environment.

- **Situational Violation:** rules could not be followed due to situation-specific factors e.g. excessive time pressure, unsuitable tools to complete the task, SOPs do not relate to the task at hand.
- **Violation for Organisational Gain:** deliberately ignoring the rules while trying to support the organisational objectives, e.g. ignoring safety procedures in order to sail on time.
- **Violation for Personal Gain:** deliberately ignoring the rules to save personal effort, e.g. finish early or 'show-off'.
- **Recklessness:** ignoring risks and the potential consequences for themselves and others, e.g. a RIB being driven unsafely in a high sea state for enjoyment.
- **Sabotage:** occurs when there is the intent for both action and consequence, e.g. malicious damage.

Situational Violation: rules could not be followed due to situation-specific factors e.g. excessive time pressure, unsuitable tools to complete the task, SOPs do not relate to the task at hand.

Exceptional violations - not following the rules in unforeseen or highly unusual circumstances. Often this occurs when something has gone wrong. To solve a new problem you break a rule, even though you know you are taking a risk.

The procedure for how to identify each of these errors or violations when investigating accidents can be found in Part 3 of this guide.

PART 3 - IDENTIFYING HUMAN FACTORS AND HUMAN BEHAVIOURS AFTER AN ACCIDENT

BRd 9147 and BRd 172 (the Yellow guide) provide guidance for conducting safety, health and environment accident/incident investigations.

When seeking to understand the contribution of Human Factors to an accident this guide proposes a two stage approach:

- **Stage 1** - Identification and Classification of Human Behaviour
 1. Did an error or violation contribute to the accident?
 2. Did Human Factors increase the risk of the error/violation occurring?
 3. Why did these Human Factors exist in the first place?
- **Stage 2** - Consideration of how to prevent recurrence.
 1. If Human Factors contributed to the accident, what can we do to remove them to prevent recurrence?
 2. How can we shape future Human Behaviour to prevent recurrence?



STAGE ONE: IDENTIFICATION AND CLASSIFICATION OF HUMAN ERROR AND HUMAN BEHAVIOUR

Stage one aims to identify and classify errors/violations, human factors and root causes. This involves answering three questions using Figures 4 to 6 as a guide and should be done in the steps shown below:

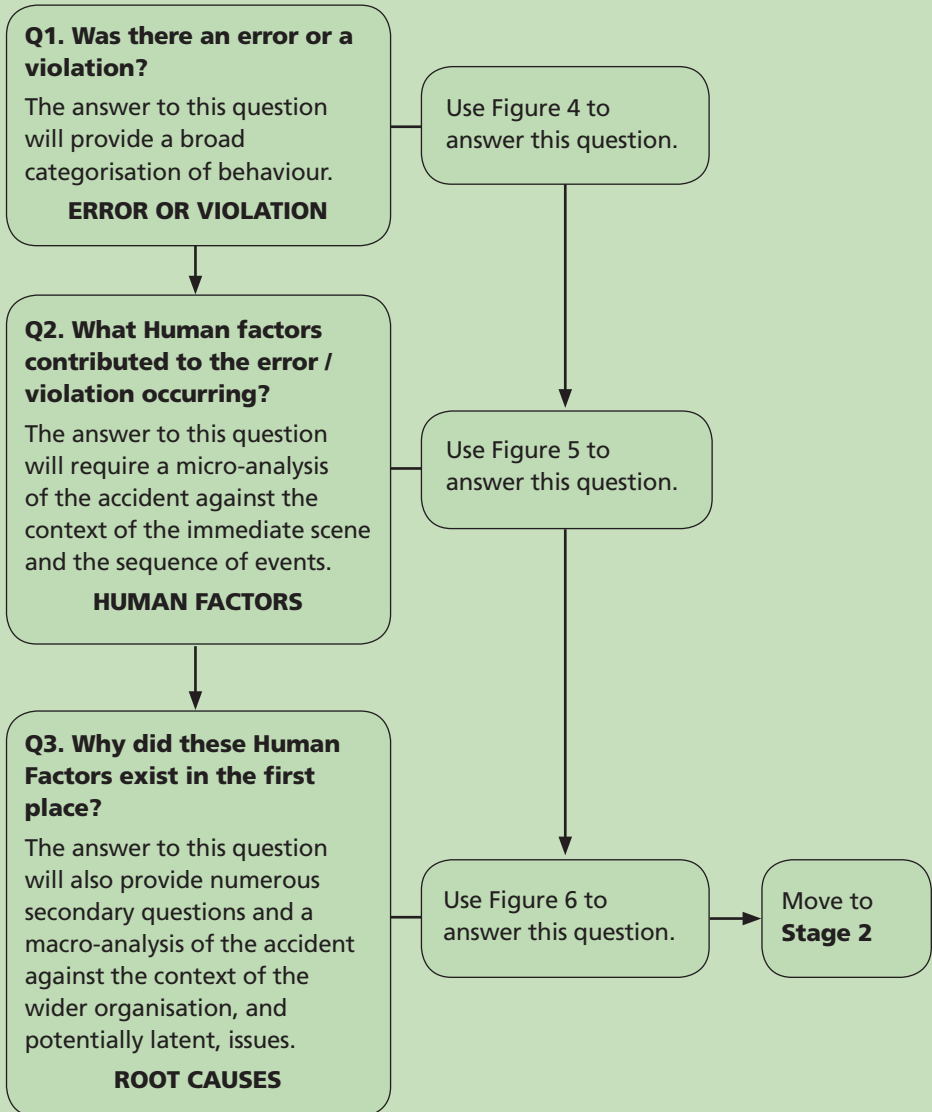


Figure 3 - Identification and Classification of Human Error and Behaviour.

Q1. WAS THERE AN ERROR OR A VIOLATION?

To answer this question the following flow chart should be considered (definitions for these can be found in Part 2 of this guide):

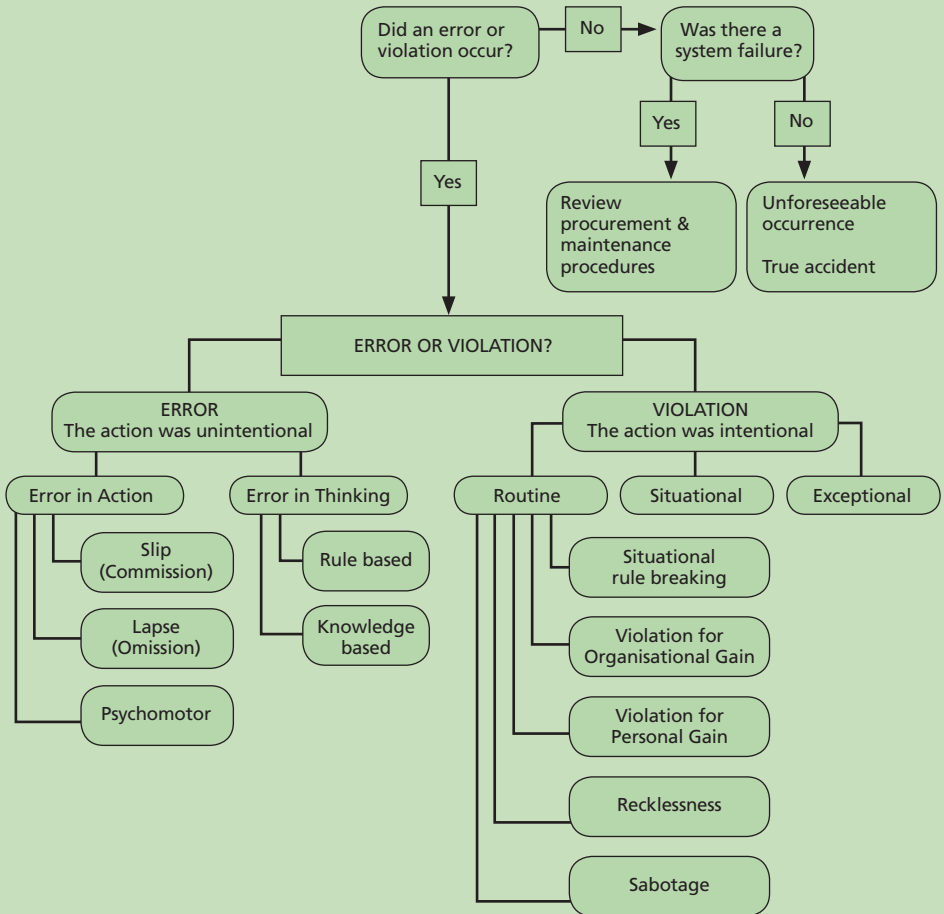


Figure 4 - Classification of errors and violations

Typical questions for this process are (not exhaustive):

- What tasks were taking place at the time of the accident/incident?
- What information did the person have at the point of occurrence of the accident/incident?
- Could personnel adhere to procedures?
- Were the conditions outside normal practice, i.e. did the personnel find themselves in an environment that differed from the normal operating environment?
- Was there anything different from normal that day?

Q2. WHAT HUMAN FACTORS CONTRIBUTED TO THE ERROR / VIOLATION OCCURRING?

To answer this question the following flow chart should be considered:

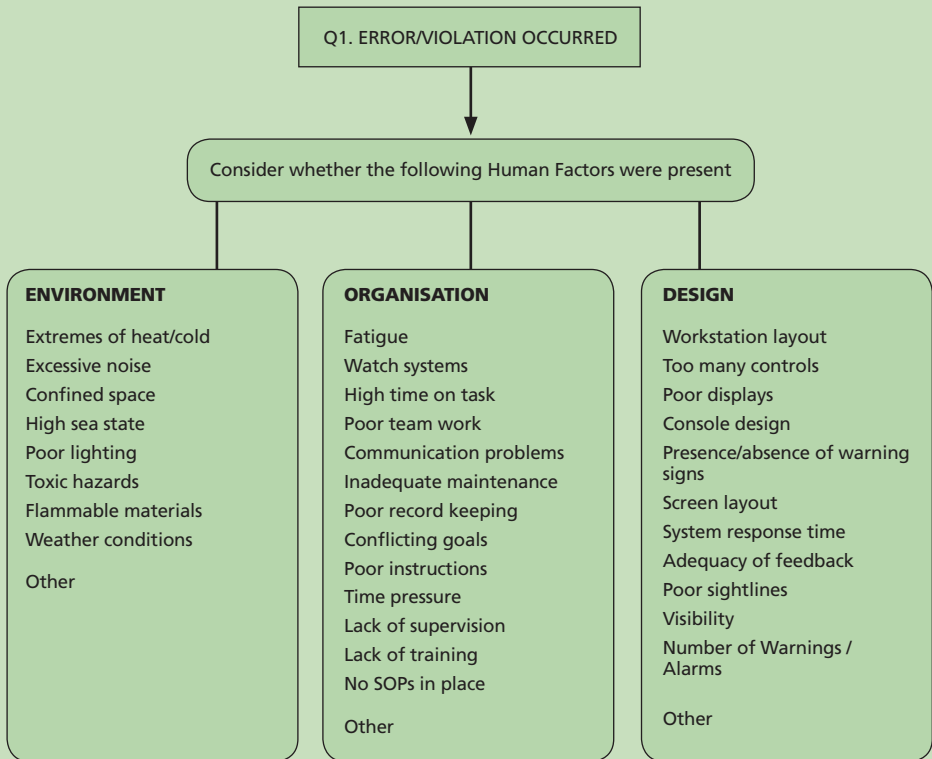


Figure 5 - Flowchart to identify what risk factors were present

Typical questions for this process might be (not exhaustive):

- What were the environmental conditions?
 - Were the levels of lighting and noise appropriate for the task?
 - Was the environmental temperature appropriate?
 - Did the weather conditions create a different environment from normal?
- Is there evidence of sleep deprivation or fatigue?
 - Time of day – was the operator starting or finishing a watch?
 - How many watches did the operator do previously?
 - When was the operator's last rest day?
 - Had those involved had adequate food and hydration in the time prior to the accident/incident?

- Is there evidence of poor teamwork or communication?
 - Were clear instructions given?
 - Was the goal of the task clearly explained?
 - Was there adequate support or supervision present?
- Was adequate time available or was there conflict with other tasks?
- Was the workspace configured appropriately / normally at the time of the accident?
 - If hazards were present, were they properly identified and understood?
- Could the operator see all the necessary controls and displays while carrying out the task?
 - Were the controls designed to support ease of use and transparency of operation?
 - Was the operator able to reach and operate all the necessary controls?
 - Could they be operated comfortably for the duration of the task?
 - Was communications equipment adequate?
- Were any warning lights/audible warnings present at the time?
- Had anything changed in the workplace recently? E.g. layout of workspace, introduction of new equipment?

Q3. WHY DID THESE HUMAN FACTORS EXIST IN THE FIRST PLACE?

Many of the Human Factors identified in Figure 5 may have root causes – it is important to consider why these Human Factors existed. Figure 6 (opposite) gives examples of some Human Factors shown in Figure 5 and the root causes that may explain their presence in the workplace at the time the accident took place. In some cases more than one Human Factor may have a single root cause (for example, poor safety culture).

If Human Factors (in Environment, Organisation or Design) were present, consider the following root cause analysis (not exhaustive):



Figure 6 - Analysis of Human Factors and their root causes

Typical questions for this process might be (not exhaustive):

- Was the accident connected to a wider sequence of events?
- Was this a secondary effect of another change?
 - A change in policy, manning, resource?
- Was this an extraordinary or new evolution?
- Were management objectives clear or did this create conflicting demands?
- Had similar circumstances occurred previously?
- Were standards and practises adequate?
- Were there high levels of work stress?
 - Was morale good at the time the accident took place?

STAGE TWO: CONSIDERATION OF HOW TO PREVENT RECURRENCE

Stage 2 seeks to identify what needs to be done to prevent recurrence of the accident. The primary questions which must be asked in Stage 2 are:

Q1. If Human Factors contributed to the accident, what can we do to remove them to prevent recurrence?

Environment

- Can the environment be changed to reduce hazards? For example:

The lighting levels in the room where the equipment was located were low and encouraged users to touch type rather than look at the keyboard. This made keying errors more likely due to slips of attention and lapses of memory. For poorly lit spaces, design equipment that does not place high demands on vision OR improve the lighting.

Organisation

- Can organisational factors be changed to reduce hazards? For example:

Despite numerous complaints from operators about the unfamiliar keyboard, it was assumed that users would 'soon get used to it' and it was 'their job to enter the correct codes anyway'. At the organisational level, improve the feedback from users to designers and procurement specialists at DE&S, including contractors. Ensure that end-user feedback is exploited in a continuous improvement process over the equipment life cycle.

Design

- Can the equipment/workplace be made safer by changing the design? For example:

An accident occurs because personnel entered the wrong codes into an automated system. The keyboard had an alphabetic layout instead of a QWERTY layout. Replace the keyboard with a QWERTY keyboard that personnel are familiar with.

Q2. How can we shape future Human Behaviour to prevent accidents and incidents?

Better Safety Culture: Encourage personnel to follow safety rules within a just and fair culture where all feel able to raise concerns about equipment design, operating procedures, training etc.

Better Supervision: Focus on getting the job done safely and not just on getting the job done. Supervisors should ensure that all are aware, not only of the accidents that might happen, but also, the likely consequences of those accidents.

Better perception of risk: Consider how human fallibility can interact with poor working conditions to cause accidents. Learn how to recognise these factors and take action before an accident or incident occurs.

Better leadership: Consider how leadership can be used to encourage safety awareness, behaviour and culture.

Better communication and feedback: Focus on communicating risks and accident feedback to inform behaviour if a similar situation arises. An accident may be prevented by early identification of hazards. Report all accidents, incidents and near misses.

Error is common, accidents are rare. People make errors all the time, but in well-designed systems, nothing usually happens.

Policy-Related Documents

BRd 2 Queen's Regulations for the Royal Navy

JSP 375 MOD Health and Safety Handbook

JSP 418 MOD Sustainable Development and Environment Manual

JSP 832 Service Inquiries

BRd 9147 Navy Command Safety and Environment Management System

BRd 172 Guide to Ship's Investigations and Royal Marine Unit Inquiries (The Yellow Guide)

BRd 167 SHE Manual for HM Ships and Submarines

APPENDIX A

EXAMPLES OF HUMAN FACTORS THAT COULD CONTRIBUTE TO AN ACCIDENT

ENVIRONMENT

Poor visibility. Risk of injury due to slips, trips and falls, anxiety and stress reactions, damage to equipment. Consider how well personnel were briefed, whether their training was in date and whether there were a sufficient number of trained personnel in the team.





Working in the heat. If not managed correctly, may result in dehydration and fatigue which can affect cognitive processes, increase the likelihood of error and the risk of dizziness and fainting. Why are personnel carrying out this task at the hottest time of day? Is there a supply of drinking water nearby? Is the work being carried out in accordance with official guidance (JSP 539 'Climatic Injuries in the Armed Forces').



WORK ORGANISATION

Time pressure. Were personnel under time pressure when the accident happened? Was this a result of poor planning, equipment failure or unanticipated events?

Unsafe Sea Boat driving. Consider the factors that led the coxswain to drive the boat in this fashion: time pressure; training, lack of awareness of hazard.



DESIGN

Badly designed workspaces.

Accidents and injuries can happen when there is a mismatch between the physical dimensions of the work environment and personnel. Slips, trips and falls and head injuries are examples. The mismatch between personnel and their work environment and time pressure can interact such that personnel take unsafe measures to complete a task.



Console layout. Dials and gauges should be easy to read to the required level of accuracy. Vigilance task overload can occur when having to maintain continuous heads-up stance; forward visual displays containing machinery and navigation data may be an appropriate design solution.

APPENDIX B

EXAMPLES OF REAL ACCIDENTS

There is a great deal of evidence from a variety of fields that basic workplace ergonomic failings can increase the risk of human error and the likelihood of accidents in settings as diverse as health care and nuclear power. In the Royal Norwegian Navy, Gould et al. investigated 35 accidents involving fast patrol boats. Some examples of accidents are given and the reader is advised to relate the contents of the narratives to the different components of Figure 3 in order to understand how the model can be used as an aide-memoire to support a human factors focus in accident investigation in the field.

Lack of training/lack of supervision: An inexperienced navigator lost control over his exact position. Failing to observe a waypoint, he was late turning. The vessel hit a submerged rock. This is a knowledge-based error caused by a lack of proper training and supervision.

Work Organisation/ineffective teamwork: Two boats in an exercise were unaware of each other's position due to lack of radar/lantern use. The CO of one boat failed to inform the navigator of their relative positions. The lookout on one boat was visually impaired and unaware that he was supposed to be on duty, believing his main task was to man the gun. The boats collided. This is an error of omission caused by a failure to follow correct procedures.

Quality of Bridge Design: A coast guard vessel grounded when the retractable sonar dome was left out by mistake following a crew change. The sonar indicator was only visible from one side of the bridge, leaving the navigator unaware if the ship had increased depth. The dome was damaged entering shallow waters. This is an error of omission (failure to monitor) caused by poor design of the workplace.

Fatigue/Work Organisation/Environment: A single patrol boat crew was ordered to sail during a rest period in foreign waters. The crew had been awake for 48 hours and the previous rest period had been disturbed by high seas. The navigator misjudged two lights and consequently ordered a wrong turn. This is an error of commission caused by fatigue and environmental factors (high seas).

Displays/Bridge layout: The cruise liner ROYAL MAJESTY is grounded off Nantucket Island in 1996. After the ship set sail from Bermuda bound for New York, it dropped the harbour pilot off and the Navigator compared their position on the GPS (Global Positioning System) against the Loran-C (a radio based navigation system designed to provide data along the coast of the United States) and found

it to be well within tolerable limits. Shortly before reaching New York the ship ran aground on Nantucket Island, having drifted 15 miles off-course. The grounding occurred because, shortly after leaving Bermuda, the GPS connector cable from the antenna had come loose and the autopilot had defaulted to dead-reckoning mode. There was nothing on the main bridge display to indicate that this had happened. A small maintenance console in a corner of the bridge did have a display to indicate the state of the system but, because the main display indicated that all was well, there was no obvious reason to check the maintenance console while underway. This is an error of omission (failing to check the GPS connection) caused by bad design and by bad drafting of SOPs.

Gould KS, Knappen Røed B, Koefoed VF, Bridger RS PhD, Moen BE. 2006. Performance-shaping factors associated with navigation accidents in the Royal Norwegian Navy, Military Psychology (Suppl), S111-S129.



APPENDIX C

TAKING A WIDER VIEW: LOOK BACKWARDS AND OUTWARDS TO IDENTIFY LATENT FAILURES THAT MADE IT POSSIBLE FOR THE ACCIDENT TO HAPPEN

Flooding in HMS ENDURANCE² 16 December 2008

HMS ENDURANCE was operating in the South Atlantic when she suffered severe flooding in the Engine Room, prompting damage control efforts by the Ship's company and resulting in near loss of the ship.

The Service Enquiry concluded that the flooding was due to an inadvertent opening of a hull valve during the cleaning of an inlet strainer. There was no necessity to clean the strainers at sea, this operation could have been performed before sailing or on arrival at the next port. Incorrect reconnection of control airlines is likely to have caused the inadvertent opening of the valve. The first time it was disconnected and reconnected this was undertaken correctly by two different persons, on the second occasion it was undertaken incorrectly by a third person.

Key contributory factors identified included: the absence of a responsible trained maintainer, the inability to maintain engineering standards, poor procedures, inadequate risk assessment and inadequate risk mitigation. Additionally, long deployments in isolated locations had not factored into manning organisation, with the result being up to 33% gapping. Design problems and lack of communication of these problems were also cited as contributory factors.

Following Human Factors principles and the structure provided in the Guide, you can work backwards from the event to identify the behaviour behind the accident, contributing Human Factors and root causes. Figures 7 and 8 illustrate Stage 1 of the Guide for the example of HMS ENDURANCE with an explanation of these shown below.

Q1. Was there an error or a violation?

The person who reconnected the valves was unaware that his reinstallation was incorrect. His action was unintentional and he carried out an incorrect action, therefore this would be classified as a slip, an error in action.

²Service Enquiry into the Flooding of HMS Endurance 16 December 2008 (Restricted)

Q2. What Human Factors contributed to the error/violation occurring?

Six Human Factors were identified as contributing to the error, all within the Organisational and Design domains. These were:

- Insufficient skill/experience (ORGANISATION)
- Time pressure to re-install lines (ORGANISATION)
- Unnecessary decision to clean filters at sea (ORGANISATION)
- Lack of communication (ORGANISATION)
- Design flaw (DESIGN)
- Insufficient assessment of risks (ORGANISATION)

Q3. Why did these Human Factors exist in the first place?

Once the 6 factors were identified, you can work backwards and outwards to determine WHY these existed.

For example:

The Human Factor contributor of Insufficient skill/experience (within the Organisational Domain) existed because there was a poor level of supervision of an unqualified operator.

Why?

There was insufficient manning resource to support adequate supervision.

Why?

There was hybrid manning procedures in place (flexible managed gapping routine).

Why?

A decision to increase deployment length was made. To allow for mandated harmony requirements the 'managed gapping' routine was adopted but this was not identified as a risk.

Why?

The cumulative risk within the Manpower, Equipment, Training and Sustainability pillars was not identified and, outside of the ship, there was no clear owner of this cumulative risk (ROOT CAUSE).

Once this process is complete, this can be mapped onto Figure 8 to provide a summary of the classification, contributory Human Factors and their root causes.

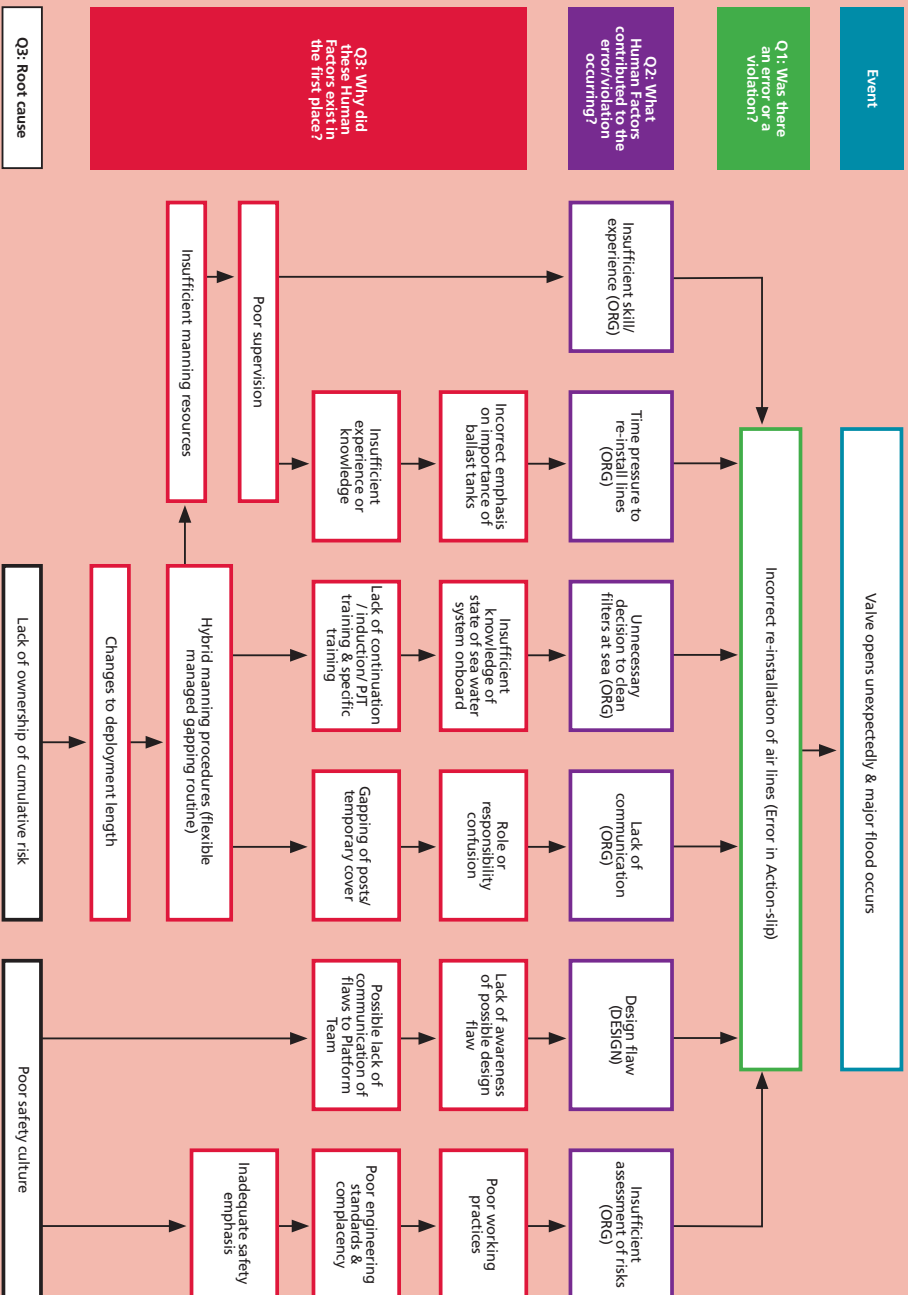


Figure 7 - Looking backward and outward from the event, classification, identifying contributory factors and root causes

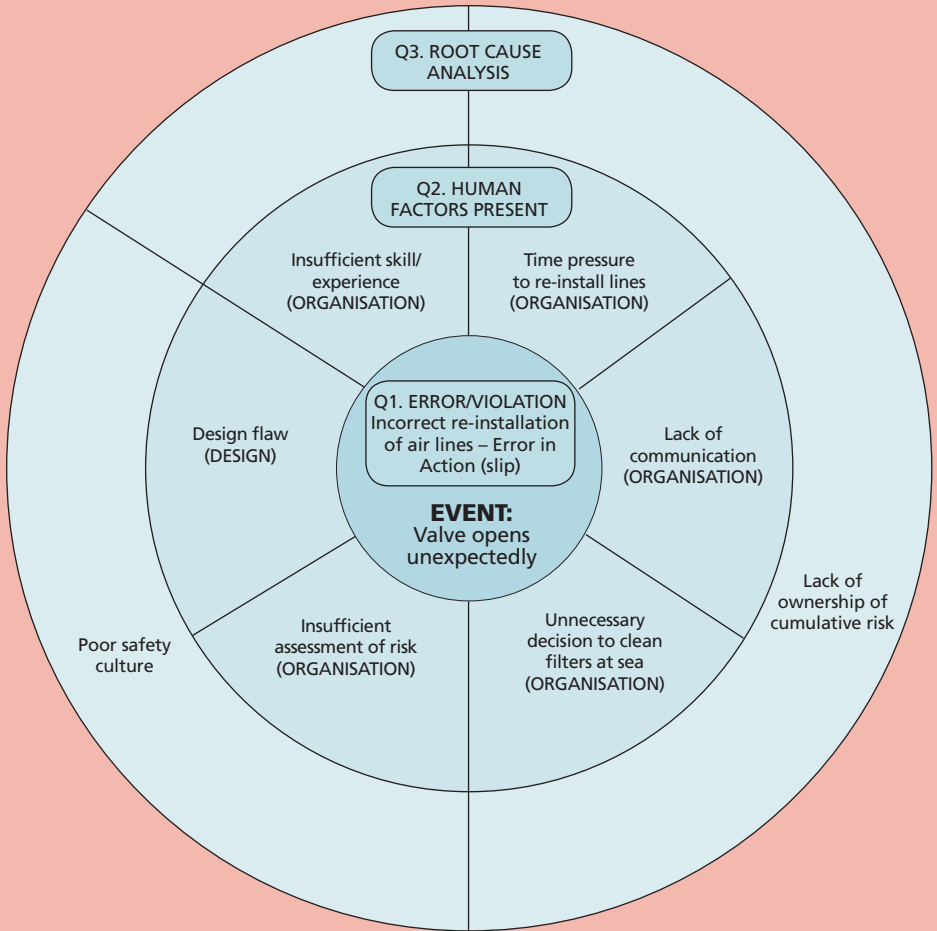


Figure 8 - Classification, identification of human factors and root causes (summary of Figure 7).



Grounding of HMS NOTTINGHAM³

7 July 2002

HMS NOTTINGHAM was en route to Wellington, New Zealand after weighing anchor at 20:57hrs from Lord Howe Island. She ran aground on Wolf Rock at 22:02hrs after changing course to stow a Lynx helicopter that had landed the Commanding Officer (CO) returning from the Island.

The Board of Inquiry (BOI) concluded, inter alia, that:

HMS NOTTINGHAM grounded on Wolf Rock because insufficient attention was paid by the Officer of the Watch (OOW) to the navigation of the ship and, in particular, the navigation of the ship in relation to navigational hazards.

³Board of Inquiry Report into the Grounding of HMS Nottingham at Wolf Rock, Lord Howe Island, Australia on 7 July 2002.



The Executive Officer (XO) and Navigating Officer (NO) had not ensured that a safe navigational plan was constructed which ensured a safe departure from the island and catered for the changes required for the recovery of the helicopter.

Working backwards from the immediate accident:

22:02:38. HMS NOTTINGHAM grounds on the western side of Wolf Rock.

22:02. The OOW was distracted by calls from the flight deck and engine room and at 22:02 saw a 'pale white glow' when he looked out of the window. The NO also saw this and went to check the chart. Realising the ship was in immediate danger, he called to the OOW to change course but 5 seconds later, the ship grounded.

Immediately before the accident the OOW and the NO had a lengthy discussion about the correct procedure to shut down an engine. This, according to the BOI, distracted him from his 'primary duty' of navigation and maintaining a



proper lookout. With the OOW fully engaged dealing with the helicopter, whose responsibility was the navigation?

In the minutes leading up to the grounding, the OOW was pre-occupied with stowing the Lynx and the pitch and roll of the ship. In the later interview he said he was “petrified of losing or damaging the Lynx”. While distracted with the helicopter, the OOW assumed the NO would take care of the navigation, but this was not verbally communicated.

22:00. Neither the OOW nor the NO noticed that the 2OOW had fixed the ship 4 cables South East of Wolf Rock and that it was heading directly towards it at 12 knots. The 2OOW had drawn part of the fix over Wolf Rock on the map, completely obscuring it from view. He did not communicate this fix to the OOW or NO and was not supervised by either.

21:55. The XO asked the NO his intentions for getting back on track (to Wellington). The NO stated he wished to get to the lee side of the island to stow the helicopter. NOTTINGHAM changed course to North West 350 degrees, then 320 degrees. The NO did not check this new course by any means.

21:53. Lynx lands safely with CO.

21:49. Ship alters course again to 235 degrees.

21:44. The ship alters course to 230 degrees as the XO thought this would be a good course for rendezvous with the Lynx, leaving Lord Howe Island safely on the starboard bow. This course was checked on the 1:150000 scale chart by the OOW, NOTTINGHAM was now 2nm away from Wolf Rock, with no significant safety considerations in place.

21:25. NOTTINGHAM changes course from east-west to 140 degrees en route for Wellington. The new course was not checked for hazards visually, by radar or by chart. The NO returned to the Bridge at 21:37.

At no time between getting under way at 20:57 to the grounding at 22:02 did the OOW or the NO refer to the chart or track, take a fix or ask for a fix to be reported to them. Prior to weighing anchor at Lord Howe Island, Wolf Rock had not been identified as a significant danger or ‘hatched-off’ on the chart.

Despite being 300 yards from the limiting danger line, neither Special Sea Dutymen, Tiller Flat personnel nor Blind Pilotage Safety Officer were closed up, nor was the echo sounder switched on.



The CO made a last visit to the island at 20:05 having approved the Navigator's plan for the passage to Wellington. He instructed the NO to 'stay out to the East' and the XO to 'carry on down the navtrack' and pick up the Lynx which were conflicting instructions. After some discussion, the XO and NO agreed to weigh anchor and head East. The position of Wolf Rock had not been entered into the electronic navigation aids, command system or command support system.

Looking Backwards and Outwards

The report states that Wolf Rock had not been identified as a significant danger when the ship was at anchor at Lord Howe Island. It had not been 'hatched-off' on the chart. The report indicates that this does not reflect a failure of RN navigational training but rather that the correct standards of bridgework, navigation planning and execution were not maintained. Why, with 4 officers on the Bridge at the time of the grounding, was this allowed to happen? There are a number of questions that are not fully answered through the report – some possible reasons for the behaviour on the bridge are offered overleaf.

The echo sounder was not switched on when the ship weighed anchor, nor were additional safety procedures put in place, why? Decisions made on that day, reflected a team willing to take unnecessary risks with the ship, against common practice. The behaviour on the bridge suggests that **routine violations** (not complying with standard practice) were commonplace.

The OOW had assumed that the NO was overseeing navigation on the ship whilst the OOW was concerned with the Lynx stowage in the minutes leading up to the accident. This was not communicated between the OOW and the NO. Why did the OOW assume that the NO would take charge, and why was this not communicated? A few minutes prior to the grounding the NO advised a change of heading to the OOW (without checking). This may have led to the OOW assuming that the NO was monitoring the navigation. This **role confusion** could have been avoided; it is possible that the NO had taken over navigating from the OOW in previous instances, and so he assumed this would be the case. It is also possible that the discussion regarding engine shut down left the OOW not wanting to communicate with the NO for some reason. During his interview the NO stated that he had been annoyed earlier by a change of heading that occurred without his consultation. It is possible that this made him less likely to assist the OOW later on. The question as to why this confusion occurred was not fully answered.

The 2OOW was not supervised, despite being 'unqualified'. Being the only officer to take a fix, would supervision of this task enabled Wolf Rock to have been seen on the charts? It is possible that proper supervision may have enabled the OOW to realise that there was a hazard that had not been identified. Why did the 2OOW not report the fix to the OOW and the NO? It may have been a case of a **routine violation** (it became normal for the 2OOW not to report fixes), a **knowledge based error** (he didn't know he had to report it) or an **error of omission** (he forgot to report it). Why was the 2OOW seemingly unaware of the immediate danger when he was looking at the chart? There is evidence of a **lack of correct supervision** and **leadership** (Organisational failure).

The CO approved the Navigator's plan despite serious omissions in the final plan, did not follow correct procedures in the Sea Order Book or check the navigation plan on the chart-why? He assumed the XO would undertake responsibility of executing the plan to weigh anchor and recover the Lynx en route, but this was not explicitly stated to the XO. Could these be examples **routine violations** (he'd done the same previously and no problems occurred) or a lack of appreciation of the risks (**lack of safety culture**)?

Lack of safety culture, poor communication of safety management and poor leadership are suggested as the root causes, based on the evidence of the report.

Additional Discussion Points

Passing mention is made of the rear layout of the chart table as not 'conducive' to the monitoring of the ship's progress. Could this have played a role in none of the qualified bridge team paying attention to it for over an hour prior to the accident? Although procedures should have been followed, they were not. The chart table could not be used easily while monitoring the progress of the ship, which could be addressed through a **redesign**.

Although the report states that a qualified OOW is reasonably expected to be able to simultaneously recover the aircraft, navigate the ship and maintain a lookout, the distraction by the Navigator at a crucial time and the apprehension at damaging the aircraft may have proved too much for the OOW to cope with and **lapses in attention** or **errors of omission** more likely.

Why was the Lynx continually used prior to weighing anchor, knowing that there would be difficulties landing it on the return due to the swell? Did personal priorities (getting time ashore) outweigh the risks associated with recovering the Lynx in relatively unknown waters?

Why did the NO and the XO not check the charts before weighing anchor? This is against standard practice, in **violation of the procedures** set in place to keep the ship safe.

Why was there an apparent lack of Safety Culture and risk awareness on the Bridge? The report details that previous OOW manoeuvres were conducted with few additional precautions on 1 July and the report suggests that the conduct was indicative of a team that was willing to take 'unnecessary risks' with the ship's safety. Lack of adherence to safety routines and safety practice are likely to indicate **routine violations** throughout the chain of command.

Why was everyone, from the CO downwards, seemingly unaware of the existence of Wolf Rock (lacking in **knowledge**)? Wolf Rock is named after 'Wolf' - an ex Royal Navy gun brig, which was being used as a whaler and ran aground on the rock in 1837.

Capsize of the Herald of Free Enterprise 6 March 1987

Organisations normally erect multiple barriers to stop accidents from happening. Reason (Figure 2) reminds us that none of these barriers is perfect and that an accident is often the end point of a process in which successive barriers are defeated as events unfold. The focus on organisational factors requires the accident investigator to look beyond the immediate work environment at the time the accident took place and examine how the accident might have 'escaped' through the web of barriers put in place to prevent it from happening. Some key areas of focus include: training and team composition/selection; supervisory style and safety culture; organisational policies and processes, including the composition and function of safety committees and supervisors; risk reporting and reduction and record keeping. Perceptions of safety at work, the extent to which operators perceive the workspace as hazardous and the presence of perverse incentives for unsafe behaviour are also important.

Applying Reason's Swiss Cheese model to the ROYAL MAJESTY grounding we can work backwards from the error (failure to check that the GPS was working properly) to long before the ship was built. Clearly, the decision to locate the GPS antenna connector display in a maintenance console, rather than the main console on the bridge, reflects a perception on the part of the designers that this was a maintenance issue and not an operational issue. At no stage during the construction and testing of the vessel does this appear to have been questioned. It is noteworthy that the officers on the bridge undertook all the standard checks that were required of them before leaving Bermuda, checking the GPS connector was not one of them. Therefore, a questionable design decision was compounded by inadequate drafting of procedures, leaving a 'latent failure' that resulted in the accident happening when conditions were right. The official report, however, focuses on what the bridge should have done as the ship approached Nantucket Island - easy to say with the benefit of hindsight. A human factors approach would focus on what designers should have done and what the management should have done when drafting the operating procedures for the vessel. At the time, ECDIS was a newer piece of equipment than the land based radio system (LORAN-C) and the bridge crews tended to regard it as the main source of navigational information and the ground-based radar only as a back-up. Thus, they never thought to consult the LORAN-C system before reaching New York and there was insufficient automation and integration of equipment on the bridge to compare the positional information available - technically this would have been easy to achieve.

The investigation into the ferry 'HERALD OF FREE ENTERPRISE' which capsized outside the port of Zeebrugge on 6 March 1987 provides a good case study of the way in which the Swiss Cheese model can be applied.



The HERALD OF FREE ENTERPRISE was a roll-on/roll-off ferry designed for the Dover-Calais route with double linkspans at both ports. Vehicles could be loaded simultaneously onto G and E/F vehicle decks through vertically hinged watertight bow doors. The bow doors could not be seen from the Bridge.

On the day of the accident, HERALD OF FREE ENTERPRISE was at Zeebrugge in Belgium. She had not been designed for this port and there was only one deck for loading vehicles. To load the higher decks, the bow ballast tanks were filled because the ramp was not high enough to reach E deck. After all the vehicles had been loaded, the tanks were NOT emptied, meaning the bow was lower in the sea than normal.

The assistant boatswain was supposed to close the G deck bow doors BEFORE the ship slipped her moorings. He had, however, gone for a nap after cleaning the deck.

The first officer was supposed to remain on G deck until after the doors had closed but is believed to have been under pressure to get to his station on the Bridge, believing that the assistant boatswain was on his way. The boatswain – the last person on G Deck said that he did not close the doors because it was not his duty.

At 18:05hrs, believing that the bow doors had been closed and unable to see them from the bridge, the Captain gave the order to depart. The ship had 80 crew, 459 passengers, 80 cars, 3 buses and 47 trucks.

At 18:24hrs, the ship entered the open sea. When the ferry reached 18.9 knots (21.7 mph), water began to enter through the G deck doors. The ship capsized in 90 seconds. The electrical and power systems failed immediately, leaving the ship in darkness. The ship floundered in shallow water onto a sandbar that prevented her from sinking completely.

Despite immediate attempts at rescue, 189 people died. The water temperature was 3 degrees Celsius – most drowned when they became disabled as a result of their cold immersion.

Conclusions of the main report. There were three main causes:

- Failure to close the bow doors
- Failure to check that they were closed
- Leaving port with the doors open

The following performance shaping factors should also be considered:

- Poor communication at all levels in the hierarchy
- Failure to empty the ballast tanks prior to departure
- Rejection at board level of the proposal to install a warning light on the bridge
- Hydrodynamic factors
- Bow wave above 18 knots
- 'Squat effect' in shallow water

EXTRACTS FROM THE OFFICIAL REPORT INTO THE HERALD OF FREE ENTERPRISE SINKING

The following extracts from the official report into the accident should be studied in relation to this case study, emphasising the need to consider the organisational factors that cause risk factors for human error to be present in the work environment.

No Standard Routine for Loading the Ferries

Extract from the official report:

First, Captain Lewry merely followed a system which was operated by all the masters of the HERALD and approved by the Senior Master, Captain Kirby. Second, the court was reminded that the orders entitled "Ship's standing orders" issued by the Company make no reference, as they should have done, to opening and closing the bow and stern doors. Third, before this disaster there had been no less than five occasions when one of the Company's ships had proceeded to sea with bow or stern doors open. Some of those incidents were known to the management, who had not drawn them to the attention of the other Masters.

Pressure to Leave Harbour Early

Personnel in the loading bay were under pressure to leave the bay as early as possible and return to their harbour stations (the bridge, in the case of the 1st officer). Extract from an internal memo dated 18 August 1986:

"There seems to be a general tendency of satisfaction if the ship has sailed two or three minutes early. Where, a full load is present, then every effort has to be made to sail the ship 15 minutes earlierI expect to read from now onwards, especially where FE8 is concerned, that the ship left 15 minutes early put pressure on the first officer if you don't think he is moving fast enough. Have your load ready when the vessel is in and marshal your staff and machines to work efficiently. Let's put the record straight, sailing late out of Zeebrugge isn't on. It's 15 minutes early for us."

Inadequate Information on the Bridge: no indicator lights

On the 28th June 1985 Captain Blowers of the PRIDE OF FREE ENTERPRISE wrote a memorandum to Mr. Develin. The relevant parts of the memorandum are these:

"In the hope that there might be one or two ideas worthy of consideration I am forwarding some points that have been suggested on this ship and with reference to any future newbuilding programme. Many of the items are mentioned because of the excessive amounts of maintenance, time and money spent on them."

"4. Mimic Panel - There is no indication on the: bridge as to whether the most important watertight doors are closed or not. That is the bow or stern doors. With the very short distance between the berth and the open sea on both sides of the channel this can be a problem if the operator is delayed or having problems in closing the doors. Indicator lights on the very excellent mimic panel could enable the bridge team to monitor the situation in such circumstances."

Mr Develin circulated that memorandum amongst managers for comment. It was a serious memorandum which merited serious thought and attention, and called for a considered reply. The answers which Mr. Develin received are set out verbatim:

From Mr. J.F. Alcindor, a deputy chief superintendent: *“Do they need an indicator to tell them whether the deck storekeeper is awake and sober? My goodness!!”*

From Mr. A.C. Reynolds: *“Nice but don’t we already pay someone!”*

From Mr. R. Ellison: *“Assume the guy who shuts the doors tells the bridge if there is a problem.”*

From Mr. D.R. Hamilton: *“Nice!”*

The official report concluded that:

“It is hardly necessary for the Court to comment that these replies display an absence of any proper sense of responsibility. Moreover, the comment of Mr. Alcindor on the deck storekeeper was either ominously prescient or showed an awareness of this type of incident in the past. If the sensible suggestion that indicator lights be installed had received, in 1985, the serious consideration which it deserved, it is at least possible that they would have been fitted in the early months of 1986 and this disaster might well have been prevented.”

From the above, it is clear that the immediate causes of the accident were easily identified: there were risk factors for human error in work environment at and around the time the accident took place. Fatigue, pressure to leave early, poor interpersonal communication and inadequate information on the bridge displays are examples. However, the presence of these risk factors is evidence of a far deeper malaise that permeated the entire company up to senior management level - a lack of shared responsibility for safety, poor perceptions of risk and a failure to report and circulate information about ‘near misses’ (previous incidents where ferries had left with the doors open). Using the terminology of the Swiss Cheese model, it is clear that very few barriers were put in place by the company to stop the ferry from sinking after loading, probably due to excessive focus on turnaround times and a lack of awareness of the nature of the risks.

Rescue

Operations to rescue trapped passengers and crew, and recover the dead, involved the Royal Navy; extracts from the Marine Accident Investigation Branch report⁴ state:

About 2000 HMS HURWORTH in Ostende sent her divers by road to Zeebrugge and at 2020 BNS EKSTER sailed from Zeebrugge with more divers. The RN Clearance Diving Centre at Portsmouth were alerted at this time.

By 2330 it was apparent that most of the survivors above water level had been rescued and divers were organised to begin recovering bodies while still searching for survivors.

At 0030 divers were despatched in an inflatable craft to hammer on the bottom of the wreck because there was no obvious access to the engine room.

At 0115 three survivors were found in the forward drivers' accommodation. It must be assumed that these were the last to be found alive. Shortly after this plans of the vessel arrived. Sub-Lieutenant Cox (HMS HURWORTH) organized a search with the UK and Belgian clearance diving teams. At 0145 diving was again suspended until more lights became available at 0215. Thereafter systematic searching of the vessel continued. Helicopter movements were suspended to make it possible to communicate and to listen for hammering.

⁴Report Of Court No. 8074 Formal Investigation



NOTES



