Chapter 12

Recommendations

Chapter 5.4 described how operators must often make immediate recommendations in the aftermath of an incident. These are intended to preserve the short-term safety of application processes. These immediate actions often exacerbate the consequences that they are intended to mitigate. numerous potential problems can prevent an effective response to an incident. Inadequate training, poor situation awareness, time pressure, the lack of necessary information, inadequate system support, pressure to preserve levels of service all impair operators' attempts to rectify an adverse situation. Chapter 5.4 also described a number of incident and emergency management techniques that are intended to reduce the impact of these factors. This chapter looks beyond the short-term recommendations that are made in the aftermath of an incident. In contrast, the intention is to examine the range of techniques that have been developed to identify potential remedies for the various causes that can be extracted from the approaches that have been introduced in Chapters 9.3 and 10.4.

12.1 From Causal Findings to Recommendations

A number of problems make it difficult to identify recommendations that reduce the likelihood or mitigate the consequences of future failure. The following paragraphs briefly summarises these problems. For example, there is a danger that investigators will continue to rely upon previous recommendations even though they have not proved to be effective in the past. Many authors have identified a form of 'conservatism' that affects large and complex organisations. It can take significant periods of time for new solutions to be adopted even when there is a considerable body of evidence that indicates the efficacy of alternative remedies.

There are several variations on the previous requirement. Many accidents occur because previous incidents have resulted in recommendations that do not adequately address the causes of previous incidents. Previous incidents provoke a range of different recommendations that reduce particular types of failure but which do not target underlying safety problems. Often these piecemeal recommendations avoid the expense or political involvement that are eventually committed in response to a subsequent accident. This can be illustrated by the US Central Command's investigation into a 'friendly fire' accident at Udairi Range in Kuwait. Previous incidents had resulted in procedures that were intended to ensure that crews were prevented from deploying their weapons if there was any danger of them mistaking observation posts for potential targets. Four previous incidents involving similar close-support operations had led to a number of local remedies being taken to minimise any potential confusion. Range procedures for fixed-wing aircraft to ground operations were changed to restrict delivery of ordnance to within two kilometers of Bedouin camps. The target was also altered to decrease the chances of any confusion. A tower was also constructed to help distinguish an observation post. The rooftop of the tower was painted white with a red cross. All of these physical changes failed, however, to address the overall problems of ensuring that crew did not inadvertently deploy their weapons at an observation post. The report concluded that 'despite four documented incidents in the past eight months, and attempts to improve conditions, observation posts and targets remain hard for pilots to see day or night' [825].

It is important that investigators should avoid arbitrary or inconsistent recommendations. Similar causal factors should be addressed by similar remedies. Of course, this creates tensions with the previous guidelines. The introduction of innovative solutions inevitably creates inconsistencies. The key point is, however, that there should be some justification for treating apparently similar incidents in a different manner. These justifications should be documented together with any recommendations so that other investigators, line managers and regulators can follow the reasons why a particular remedy was proposed.

Different organisations have proposed radically different approaches to the influence of financial or budgetary constraints on the identification of particular recommendations. Some organisations, such as the US Army have argued that 'the board should not allow the recommendation to be overly influenced by existing budgetary, material, or personnel restrictions' [807]. Other incident reporting systems, such as the local hospital systems that have been mentioned in previous chapters, accept a more limited horizon in which any recommendations must 'target the doable' [119]. The key point here is that investigators must ensure that their recommendations are consistent with the scope of the system. In the Army system, incident reporting is more open-ended with the implicit acknowledgement that significant resources may be allocated if investment is warranted by a particular incident. In the local system, incident reporting is constrained to maximise the finite resources of the volunteer staff who have run these systems. It is easy to criticise this constrained approach by recommending a more ambitious scope for the recommendations of a reporting system. It should be noted, however, that these systems have continued to introduce safety innovations for over a decade and without the national resources that are now being devoted to clinical incident reporting.

It is clearly important that any potential remedies must not introduce the possibility of new forms of failure into a system. Of course, it is easier to state such a requirement than to achieve it. The implementation of particular recommendations can introduce new forms of working that may have subtle effects. Given the relatively low frequency of many adverse occurrences it may only be possible to witness the safety-related consequences of those effects many months after particular recommendations have been introduced. The debate surrounding the concept of risk homeostasis provides numerous examples of such recommendations. Users may offset the perceived safety benefits of new regulations and devices against particular performance improvements. Cyclists who are compelled to wear safety-helmets may cycle faster than those who are not. Motorists who are provided with advanced braking systems may delay deceleration maneuvers [373, 372]. Others have conducted studies that reject the existence or the magnitude of such effects [533, 866]. The controversial nature of such studies not only indicates the difficulty of validating such effects, it also indicates the difficulty of ensuring that particular recommendations do not have any undesirable side-effects.

As mentioned above, the relatively low frequency of many adverse occurrences makes it difficult to determine whether or not recommendations have any palliative effect upon the safety of a complex application. In consequence, the impact of many recommendations must be measured through indirect means. For instance, it can be difficult to determine whether training operators in the potential causes and consequences of poor situation awareness can reduce the number of incidents that stem from this particular human factors problem. Simulator studies can, however, be used under restricted experimental conditions to show the short-term benefits of this training [865]. If such results cannot be obtained then there is a danger that the justification for any recommendation will be challenged. The support for particular remedies can be eroded as the salience of an incident fades over time. Further support for a recommendation can be elicited by repeating measurements that demonstrate the benefits of a particular approach. Unfortunately, these indirect measures can also be used to justify particular recommendations even when there is more direct evidence that casts doubt on the usefulness of a particular approach [412].

Previous sections have argued that incidents seldom recur in exactly the same manner. Future failures are often characterised by subtle variations in the causal factors that have been identified in previous failures. It is, therefore, important that recommendations are proof against these small differences. Similarly, recommendations must be applicable within a range of local working environments. They must protect against similar failure modes even though individual facilities may exploit different technical systems and working practices. These problems are, typically, addressed by drafting guidelines at a relatively high-level of abstraction. Safety managers must then interpret these recommendations in order to identify the particular remedies that might prevent future failures. If guidelines are too context specific then it can be difficult for safety managers to identify those lessons that might be usefully transferred to their own working environment.

There is, of course, a tension between identifying recommendations that protect a diverse range of systems and drafting recommendations that provide safety managers with the level of detail that is necessary to guide subsequent intervention. If recommendations are drafted at a high level of abstraction then there is a danger that different managers will choose to interpret those recommendations in ways that reflect arbitrary preferences rather than the local operating conditions, mentioned above. This is illustrated by a recent US Army safety alert. Previous incidents had led to ground precautionary messages that recommended military personnel not to use commercial heaters in unventilated areas 'use of unflued or unvented heaters is inherently dangerous because they vent exhaust containing carbon monoxide into living spaces' [816]. However, many soldiers chose to disregard this generic warning and continued to use heaters inside tents. These were not well ventilated The fabric was not intended to 'breathe' and several soldiers died as a result.

Recommendations are, typically, made by an investigator to the statutory body that commissions their work. These statutory organisations must then either accepting the recommendations or explain the reasons why they choose to reject them. If a recommendation is accepted then the statutory or regulatory body must ensure that it is implemented. This division of responsibilities is apparent in the aviation [423], maritime [834] and nuclear industries [205]. There are, however, occasions when investigators must identify who will be expected to satisfy a requirement. For instance, the US army requires that 'each recommendation will be directed at the level of command / leadership having proponency for and is best capable of implementing the actions contained in the recommendation' [807]. Such recommendations encapsulate good practice. If investigators do not identify suitable proponents for a recommendation then there is a danger that it may eventually be passed back and forth between a number of different organisations [444].

These potential difficulties make it important that any recommendations are well supported by the products of causal analysis. If this is not the case then it can be difficult for investigators to justify why particular remedies were, or were not, advocated in the aftermath of an incident. The following section, therefore, identifies a number of requirements that are intended to ensure that the results of a causal analysis can be used to support subsequent interventions.

A number of factors complicate the task of extracting appropriate recommendations from the findings of a causal analysis. For example, it can be difficult for investigators to assess the relative priorities of particular causal factors so that resources can be targeted towards effective forms of intervention. This task is further complicated because regional factors can reduce the impact of particular recommendations or, in extreme cases, can even mitigate any beneficial effects. Similarly, it can be difficult to identify recommendations that offer long term benefits rather than immediate or short-term palliatives. Finally, all of these problems are compounded by the difficulty of ensuring agreement amongst the diverse and multi-disciplinary groups that must concur with the recommendations that are produced by an investigation.

12.1.1 Requirements for Causal Findings

Many organisations deliberately 'target the doable' by restricting the focus of their recommendations to changes that affect the teams which support and implement a reporting system. In general, however, recommendations affect many different groups within complex organisations. One consequence of this is that representatives of these diverse interests must participate in the identification of remedial actions. At the very least, they must consent to their implementation. This can create a number of pragmatic concerns. For instance, recommendations may be drafted to address causal findings that were identified using one of the analysis techniques introduced in previous chapters. The products of some of these techniques, including Why-Because Analysis (WBA) and non-deterministic models of causation, cannot easily be understood by non-mathematicians. It is, therefore, important that the findings of any causal analysis are translated into a form that is readily accessible to those who must participate in and consent to the identification of recommendations in the aftermath of an incident. The following paragraphs summarise a number of further requirements that help in the use of causal analysis techniques to guide remedial actions.

Summarise the nature of the incident

In order to understand the significance of the causal findings that guide particular recommendations, investigators must summarise the course of a safety-critical incident. The US Army's Accident Investigation and Reporting Procedures Handbook requires an explanation of 'when and where the error, material failure, or environmental factor occurred in the context of the accident sequence of events; e.g., during preflight, while driving, etc' [807]. Information is also required to identify the individuals who are involved in an incident by their duty position or name. Components must be unambiguously denoted by a part or national stock number. Any contributory environmental factors must also be described. These requirements are often codified in the fields of an incident reporting forms. Operators are required to state the 'national stock number' of a failed component. They may also be asked to provide information about potential environmental factors and so on. As we have seen, however, the information that is provided by an initial report can also be supplemented by subsequent reconstructions. Chapters 7.3 and 8.3 introduced a number of techniques, including computer-based simulation, that can be used to model the course of an incident. These techniques underpin the causal analyses that were described in Chapters 9.3 and 10.4.

Summarise the causal findings

It is important that the products of any causal analysis are accessible to those without any formal training in the techniques that were used to identify them in the first place. This may seem like an unrealistic requirement given the underlying and inherent complexity of some causal models. It is, however, a prerequisite for ensuring a broad participation in the identification and implementation of any subsequent recommendations. If this requirement is not satisfied then there is a danger that other investigators, safety managers, regulators or line managers will mis-interpret the findings of any STEP analysis, PRISMA categorisation or Tripod modelling. It is for this reason that WBA employs a graphical form that can include natural language annotations in addition to the clausal forms of the more formal analysis. The US Army summarises the requirement to provide the following details:

> "For human error, identify the task or function the individual was performing and an explanation of how it was performed improperly. The error could be one of commission or omission; e.g. individual performed the wrong task or individual incorrectly performed the right task. In the case of material failure, identify the mode of failure; e.g. corroded, burst, twisted, decayed, etc. Identification of the directive (i.e. Maintenance / technical manual, SOP, etc.) or common practice governing the performance of the task or function. e. An explanation of the consequences of the error, material failure, or environmental effect. An error may directly result in damage to equipment or injury to personnel, or it may indirectly lead to the same end result. A material failure may have an immediate effect on equipment or its performance, or it may create circumstances that cause errors resulting in further damage / injury inevitable. Identification of the reasons (failed control mechanisms) the human, material, environmental conditions caused or contributed to the incident. A brief explanation of how each reason contributed to the error, material failure, or environmental factor." [807]

This quotation is interesting for a number of reasons. In particular, it provides an abbreviated checklist for the causal factors that must be considered when analysing particular types of failure. For instance, any analysis must consider the particular mode that characterised a materials failure. Such high-level guidance provides a lightweight means of combining the benefits of checklist approaches, such as MORT, with the more open form of causal analysis, encouraged by STEP and MES. The previous quotation urges investigators to consider the control mechanisms that caused or contributed to an incident. This is interesting because it acts as a reminder to consider critical aspects of an analysis even if investigators choose not to exploit barrier analysis or the related concepts in Tripod.

Explain the significance of causal findings

Chapter 6.4 introduced contextual details, contributory factors and root causes. Subsequent chapters have described a range of further distinctions that have been introduced by both researchers and by practitioners. These include concepts such as proximal and distal causes [702], particular and general causes [508], deterministic and stochastic causes [315] and so on. Irrespective of the precise causal model that is adopted, it is important that investigators provide some indication of the perceived importance of any particular causal finding. For instance, the US Army recommends that findings are categorised as 'Found; Primary Cause, Found; Contributing, Found; Increasing Severity of Damage/Injuries, or Found; Not Contributing' [807]. As before, this recommendation acts as an important reminder to incident investigators. For example, the previous chapter briefly summarised the potential impact of weapon bias. Investigators can become fixated on the primary cause of an incident at the expense of secondary failures that increased the severity of any outcome. By explicitly reminding investigators to consider these factors, these guidelines encourage analysts to look beyond the driver behaviour that leads to a collision. They are, for instance, encouraged to identify the reasons why a safety-belt failed or why the emergency response was delayed. The same guidelines also encourage investigators to separate the presentation of primary causes from contributory factors by noting that 'THE FINDING(S) LISTED BELOW DID NOT DIRECTLY CONTRIBUTE TO THE CAUSAL FACTORS INVOLVED IN THIS INCIDENT; HOWEVER, IT (THEY) DID CONTRIBUTE TO THE (SEVERITY OF INJURIES) OR (INCIDENT DAMAGES)' [807]. This quotation shows how it is important not only to consider the information that must be identified by any causal analysis but also the format in which that information is transmitted. The Army handbook requires that such 'contributing' causes can easily be distinguished form the 'primary' causes that directly led to an incident.

Justify excluded factors

Not only is it important to explain the significance of those causal factors that did contribute to an incident, it is also necessary to explain why particular 'causes' did NOT contribute to an adverse occurrence . Investigators must not only explain why recommendations address particular aspects of a system, they must also explain why those recommendation did NOT address other aspects of the system. These excluded causes fall into two categories. Firstly, those factors that did not cause or exacerbate this incident but which have the potential to cause future failures if uncorrected. As before, the products of this form of causal analysis must be clearly distinguished from 'primary' and 'contributory' causes: 'the findings and recommendations fitting this category will be separated from those that caused the incident or those that did not cause the incident but contributed to the severity of injuries / damage' [807]. There is, however, a second class of excluded 'causal' factors that must also be considered in the findings of any causal analysis. These are the factors that might have caused to, or exacerbated, an incident but which were considered not to be relevant to this or future failures. Without such justifications it is impossible for other investigators, for managers and for regulators to distinguish between such those factors that were considered but rejected and those that were never even considered in the first place.

Summarise the evidence that supports or weakens each finding

This book has repeatedly argued that investigators and analysts must justify and document the reasons why particular decisions are taken at each stage of their work. Without this additional information it can be difficult for other investigators, for regulators and for other statutory bodies to understand why an investigation proceeded in a particular manner. It can be difficult to follow the reasons why a secondary investigation was not initiated. It may be difficult to identify the factors that led investigators to commit resources for computer-based simulations in one incident and not another. Similarly, it can be hard to understand why resources were not allocated to support a detailed causal analysis. The US Army handbook recognises the need to justify the outcome of a causal analysis; "Each cause-related finding must be substantiated." [807] The cursory nature of this requirement is, perhaps, indicative of a wider failure to recognise the importance of such justifications. All too often, individuals and groups must endeavour to 're-live' their decision making processes during the course of subsequent litigation. A number of techniques can be used to document the justifications that support particular causal arguments. For instance, Chapter 8.3 introduced Conclusions, Analysis, Evidence (CAE) diagrams. These provide a means of linking the evidence that can be obtained in the aftermath of an incident to the arguments for and against a conclusion. These graphical structures are intended to provide a high-level overview of the justifications that support particular causal findings.

12.1.2 Scoping Recommendations

Causal findings help to guide the drafting of appropriate recommendations. The US Army handbook, cited in previous paragraphs, illustrates this relationship by advising that each finding is printed next to the remedy that has 'the best potential' for avoiding or mitigating the consequences of future incidents [807]. As we have seen, however, it can be difficult to identify appropriate recommendations. In particular, interventions must be pitched at the correct level. They must be detailed enough so that they avoid ambiguity. They must present the organisational, human factors and systems details that are necessary if future incidents are to be avoided. They must not, however, be so specific that the fail to capture similar incidents that share some but not all of the causes of previous incidents. The following paragraphs briefly describe some of the more detailed issues that must be considered when attempting to identify an appropriate scope for the recommendations in an incident report.

By time...

Previous sections have identified important differences between the short-term recommendations that are made in the immediate aftermath of an incident and the longer-term remedies that are, typically, the outcome of more considered investigations. Immediate instructions to alter operating practices may be supplemented by regulatory intervention to ensure that those changes are backed by appropriate sanctions. It is important to recognise, however, that very few recommendations ever provide indefinite 'protection' against future failures. In military systems this is best illustrated by the continuing problem of 'friendly fire' incidents.

	World War II 1942-1945	Korea 1950-1953	Vietnam 1965-1972	Desert Storm/Shield 1990-1991
Accidents	56%	44 %	54%	75%
Friendly Fire	1%	1%	1%	5%
Enemy action	43%	55%	45%	20%

Table 12.1: Battle and Non-battle casualties in the US Army [799].

Table 12.1 presents US Army figures for the changing impact of friendly fire incidents on army casualties in major combat operations since 1942 [799]. Such incidents, however, have a far longer history. One of the most (in)famous incidents occurred in April 1863 when Robert E. Lee's Army of Northern Virginia attempted to halt the Union Army of the Potomac's advance across the Rappahannock River near Chancellorsville. Lee left a small force to contain Major General Joseph Hooker and sent the remainder of his strength with 'Stonewall' Jackson to attack the Union flank. Jackson achieved considerable success and pushed ahead with a scouting party. As the party returned, they were mistaken for Union cavalry. Jackson was wounded and died soon after from complications that followed the amputation of his left arm [23]. Such incidents stem from a lack of situation awareness, often involving scouting parties and other advanced units. They also stem from the development of weapons that are effective at a range which is greater than the range at which combatants can easily distinguish friend or foe.

Such incidents were often seen as the result of undue recklessness, or bravery, on the part of the individuals involved. In the years following the Civil War, greater emphasis was placed on the development of communications systems and protocols that were intended to improve combatants' understanding of their combat situation. For instance, rules of engagement were drafted to identify situations in which it was 'safe' to engage a potential enemy. An example of such procedures can be found in the Rules of Engagement-Southeast Asia (U), JCSM-118-65, 19 February 1965 (Declassified 21 June 1988, NARA) which removed the US military's restriction against pursuit of Vietcong into Communist China. These required that hostile vessels could only be attacked in Vietnamese (RNV) or Thai territorial waters if it had been 'attacking or acting in a manner which indicates with reasonable certainty an intent to attack U.S./friendly forces or installations, including the unauthorised landing of troops or material on friendly territory' or 'engaged in direct support of attacks against RVN or Thailand'. Unfortunately, these new tactics and tools were not always successful in eliminating the problem of friendly fire. For example, the US Naval Institute published an account of an engagement during the Vietnam war. A B-57 from the 8th Bombardment Squadron attacked a US patrol boat after it had dropped its bombs on watercraft just north of demarkation zone. Coordination between the 7th Air Force and the naval forces was particularly poor. The Commander-in-Chief, Pacific, later observed that 'this incident is an apparent lack of tactical coordination between operational commanders'. The 7th Air Force investigation concluded that the vessel did not know the 'correct MAROPS challenge/response for air to surface'. The patrol boat had 'two means of identifying themselves to aircraft' using their running lights or by radio communications but 'the vessel did neither' [382].

'Friendly fire' accounted for some five percent of American casualties during Operation Desert Storm in 1991 [799]. These often had similar causes to incidents in previous conflicts. Many stemmed from communications problems. Deployment information was not passed along the chain of command. Other incidents again revealed the disparity between the range and effectiveness of modern weapons systems when compared to battlefield communications equipment. Following the gulf war, several initiatives started amongst allied armies to lessen the number of these incidents in future conflicts [748]. As can be seen, some of these initiatives focussed on new technologies. Others, however, have more direct parallels with the techniques that were proposed in previous conflicts:

- "Systems that align with the weapon or weapon sight and are pointed at the intended target. The system 'interrogates' the target – a reply identifies it as friendly, otherwise it is identified as unknown.

- 'Don't shoot me' systems use the Global Positioning System and other similar data sources. An interrogation is sent in all directions containing the targeted position. Friendlies present in that position return a 'don't shoot me' response.

- Situational awareness systems rely on periodic updates of position data to help users locate friendly forces.

- Non-cooperative target recognition systems compute a signature using acoustic and thermal signals, radio emissions, and other possible data sources. The system compares the signature in its library database to characterise the target as potentially a friend, foe or neutral." [22]

A number of reasons explain the way in which the similar hazards recur over time even though recommendations provide some immediate protection from a particular failure. For example, previous sections have cited research into risk homeostasis that determines whether or not users will sacrifice safety improvements in order to achieve other objectives. Car drivers will rely on advanced braking systems to save them from hazardous situations. A number of other potential problems can prevent previous recommendations from continuing to protect application processes. For instance, operators and managers may forget the importance of previous remedies as incidents and accidents fade from the 'group memory' [635, 637]. This process of 'forgetting' should not be underestimated given the relatively low frequency of many adverse occurrences. Organisational factors also intervene to increase the speed at which previous recommendations can be lost to those whose actions must be guided by them. The recommendations from less severe incidents may be lost more quickly than those of the ‘friendly fire’ examples, cited previously. The Canadian armed forces have one of the most advanced health and safety infrastructures of any military organisation. Their computer-based General Accident Information System automates the submission and partial filtering of incident and accident reports [148]. These reports are summarised in Safety Digests that are similar to the Aviation Safety Reporting Systems DirectLine publication, introduced in Chapter 4.3. They provide key personnel with ‘first-hand’ accounts of previous incidents. They also communicate the recommendations from investigations in a relatively accessible manner. Such feedback does not always have the strong, long-term remedial effect that might be expected. For instance, there have been several incidents involving the transfer of fuel under pressure between various types of bowser [137]. These have led military safety managers to stress that it is the “duty” of military personnel and civilian sub-contractors to refuse to engage in operations that jeopardise safety during peacetime [135]. Unfortunately, there recommendations have not had the impact that might have been hoped:

> “Training DND military/civilian personnel performing the transfer operation and those in the chain of command didn’t have experience or training to safely conduct this non-standard fuel transfer. Basic/advanced fuel handling training for National Defence military/civilian personnel requires further in-depth evaluation. In the interim, 19 Wing is conducting enhanced local training. The applicable engineering publications governing the safe handling of fuels are outdated, not accessible to all personnel and appear to be technically inferior to industry standards and other Air Forces’ publications.” [140].

This quotation provides several detailed reasons why many of the recommendations from incident reports are limited to a relatively short ‘shelf life’. Personnel may not have been provided with access to the initial information. They may have joined an organisation or have been re-deployed within an organisation well after the findings from an incident have been published. Staff may also be employed by sub-contractors who were not informed of the recommendations that were identified from previous incidents. Conversely, the organisation itself may have fallen behind best-practice in an industry. The previous quotation identifies that military procedures failed to meet civilian standards.

The long-term effectiveness of particular recommendations can also be undermined by changes in working practices. These need not reflect deliberate neglect or the failure to communicate the importance of adopting particular remedies in the aftermath of previous incidents. In contrast, these changes can be forced upon personnel by the introduction to new technologies. Some recommendations that ensure safe fuel transfer from bowsers can also be applied to other fuel storage mechanisms, such as bladders [135]. For instance, it is important to ensure that hoses are hydrostatically tested in both situations. Other recommendations cannot be directly transferred in this way. For example, previous bowser fires have established the importance of using industry-approved flow rates for particular fuel types [140]. This recommendation has some relevance for bladder devices. However, the particular properties of bladder devices require that recommendations from previous bowser fires must be carefully reinterpreted if they are to protect operators using these containers. Personnel must ensure that fuel is pumped to the bladder’s pressure rating rather than at its maximum filling speed.

Changes in the operating environment undermine previous remedies. For instance, many military organisations responded to ‘friendly fire’ incidents by implementing protocols, such as terms of engagement, that guide personnel on the actions to be taken before engaging a potential target. Battlefield communications systems have also been developed to help distinguish friend from foe. These remedies are tailored to meet the specific requirements of particular military organisations. It can be difficult to extend the same techniques to support joint operations by allied forces. For instance, there may not be the political support that is necessary to agree upon common terms of engagement. It is also rare for allied forces to share the same core communications technologies. One consequence of this is that joint operations often result in a large number of friendly fire incidents. Remedies that reduce incidents in particular scenarios may, therefore, not provide protection under changed operational circumstances.

Changing working practices, changing operational contexts and changing technologies create considerable problems for investigators who must ensure that their recommendations continue to protect the safety of a system and its operators. Several techniques have been proposed to reduce the impact of such changes on the remedies that are advocated by incident reporting systems. For example, investigators can explicitly specify the shelf-life of a recommendation. Any remedial actions need only be implemented until an end-date that is specified in the incident report. The regulatory or statutory body is then responsible for explicitly renewing any recommendation that might be made after the initial period of enforcement has expired. This approach has obvious disadvantages for any regulatory body that must constantly review a mass of relatively low priority recommendations. An alternative approach is to require that organisations periodically update their safety cases to ensure that they conform to recommendations that have been made since their previous appraisal. This review also provides an opportunity for companies to argue that previous recommendations may no longer hold given new working conditions or technological innovations. This approach also suffers from a number of limitations. For example, it can be difficult to identify an appropriate renewal period. Alternatively, companies may be required to revise a safety-case whenever new working practices or environmental conditions are introduced. Further technical difficulties complicate the task of updating a safety case, see for example [434].

Some incidents raise a variety of more 'pathological' temporal issues that exacerbate the problems of drafting and implementing appropriate recommendations. For example, the Singaporean army has made a number of recommendations that have reduced the number of heat related injuries reported in recent years:

> "During the first two days of heat exposure, light activities would be appropriate. By the third day of heat exposure, 3 kilometer runs at the pace of the slowest participant are feasible. Significant acclimatisation can be attained in 4 to 5 days. Full heat acclimatisation takes 7 to 14 days with carefully supervised exercise for 2 to 3 hours daily in the heat. The intensity of exercise should be gradually increased each day, working up to an appropriate physical training schedule adapted for the environment." [742]

As mentioned, these recommendations have encouraged a general decline in heat related injuries within the Singaporean defence forces since 1987. If we follow the argument that has been presented in previous paragraphs then it might be argued that greater concern should be devoted to other, potentially more pressing, safety recommendations. A number of factors have, however, combined to increase the salience of there recommendations. Since 1995 the army has continued to report approximately 3.5 cases per 1000 soldiers. These cases are not evenly distributed across all units. Training schools continue to suffer the highest incidence of heat-related injuried as new soldiers transition from civilian life. The political and social impact of these incidents is exacerbated by the Singaporean army's continued use of enlistment. In consequence, the 'shelf-life' or duration of a recommendation can be determined by a range of factors that may have relatively little to do with the relative frequency of particular incidents.

The previous example can be used to illustrate a number of further problems that complicate the task of drafting appropriate recommendations. For instance, the previous remedies are increasingly important at particular times in the year. The Singaporean army reports the highest number of heat injuries in April and May. This reflects increases in heat and humidity during those months. As we have seen, the salience of particular recommendations can decline when they are not perceived to be important to an operator's immediate task. In consequence, safety managers must make particular efforts to reinforce the importance of these guidelines during March and early April. The complexity of drafting appropriate recommendations is further complicated by the bimodal distribution of these incidents within the day. Peaks occur in the reporting patterns from 08:00 to 09:59 hrs and from 16:00 to 17:59 hrs. These peaks straddle the interval between 11:30 and 15:30 hrs during which formal physical training is prohibited according to Singaporean army regulations. Further complexity is introduced by the time-limits that determine appropriate mitigating actions. If an individual's heat exposure is less than 90 minutes then they should be offered plain, cool water during a recovery period. If the heat exposure exceeds 90 minutes then they should be offered a "cool, suitably flavoured carbohydrate-electrolyte beverage" with no more than 8%, or 2 table spoons of sugar per litre [742]. If the soldiers' heat exposure exceeds 240 minutes then they should be provided with a flavoured "carbohydrate-electrolyte beverage supplemented with one tea spoon of salt per litre".

By place...

The previous section has argued that it can be difficult to draft recommendations that can continue to have a medium or long-term effect on the safety of an application. Memories fade, working practices change and technology is seldom stable beyond the short-term. In consequence, regulatory or statutory intervention may be required to ensure continued compliance. Investigators may also be forced to draft their recommendations so that they are 'future proof' against these changes. Unfortunately, remedies that avoid reference to particular technologies and working practices are likely to be of little practical benefit. Lack of detail encourages ambiguity and safety managers may find it difficult to know how to implement remedial actions. These problems are compounded by the need to ensure that recommendations can be implemented in many different working environments that are often distributed across many different geographical locations. This is an increasing problem given recent initiatives to increase the coverage of national and international reporting systems. For instance, the initiatives of individual airlines led to the development of United States' Aviation Safety Reporting System (ASRS) in 1976. In the last five years this has, in turn, motivated attempts to establish a Global Aviation Information Network [310]. Similarly, medical reporting systems that were initially established in individual units within individual hospitals are now being extended to regional and national systems. For example, the UK's Royal College of Anaesthetists has introduced guidelines to encourage recommended practice in incident reporting within their specialism [716]. Both the UK Government [635] and Presidential initiatives [453] have advocated the expansion of these systems beyond the local and regional levels.

It is important to emphasise that national and international initiatives to expand the geographical coverage of incident reporting systems do not remove the need to draft recommendations that focus on particular local needs. For example, the Canadian Commander of the National Support Element Services Platoon and of Camp Black Bear in Bosnia-Herzegovina reported that the following actions had been taken to address previous safety recommendations:

> "First of all, we replaced three propane gas ranges in the kitchen and took steps to replace one tilting frying pan and procure another. The ranges in use were extremely old and beat up. In fact, the burners were cracked and the wire insulation was torn. New safety equipment in the kitchen at Camp Black Bear. Moreover, the plates inside the stoves had been removed, leaving the propane gas tubing unprotected. Hence, this equipment posed a serious risk to the people working in the food section. Our chief cook, Sgt Élément, is exceedingly proud of his new equipment." [143]

The importance of such local recommendations and actions cannot be exaggerated. They provide immediate and direct feedback to the individuals and groups who contribute to incident reporting systems. This is particularly significant for work groups that perceive themselves to be isolated from administrative centres. The Canadian units in Bosnia-Herzegovina provide a good example of groups who most need to be reassured that their potential problems are receiving prompt and direct attention.

There are also less obvious reasons for ensuring that recommendations address particular local concerns. If remedies are couched in abstract terms that can be applied to many different contexts they often lose the impact that can be observed from more direct and locally relevant recommendations. For instance, the previous actions might have addressed a requirement to 'review the safety of cooking appliances in all military camps'. Such generic recommendations can often be lost amongst the plethora of similar high-level guidance that is issued from 'lessons learned' systems. The introduction of particular local details can, arguably, provide more salient reminders even though the exact circumstances are not replicated in other working environments. This is an important feature of the anecdotes and 'war stories' that provide a critical learning resource for workers in a vast range of occupations. This analysis was confirmed during the interviews that help to form the EUROCONTROL guidelines for incident reporting in air traffic management [423]. Many controllers specifically asked that details about specific airports and shift patterns should be left in both the causal analysis and recommendations associated with individual incidents. They argued that this increased the perceived relevance of the analysis. These local details helped them to re-interpret particular recommendations within the often different context of their own working environment. The controllers who were interviewed continued to support these arguments even after it was suggested that such local details might compromise the anonymity of some reports. It remains to be seen whether the same opinions would be expressed by those individuals who are involved in an incident.

It is possible to identify a paradox that affects the drafting and implementation of recommendations from incident reporting systems. The effectiveness of such systems depends upon identifying remedies that can be applied well beyond the scope of the application or working group that first identified a potential problem. On the other had, drafting recommendations that can be applied beyond the context of particular working group often implies that investigators must strip out the contextual details that help operators understand the significance of an incident. There is also a danger that by expanding the scope of a recommendation, investigators will address propose remedies for problems that do not exist beyond the boundaries of a local system. This is a significant concern given that each recommendation is likely to carry significant costs in terms of the time and money that may be required to implement them. There is a further danger that by addressing these spurious recommendations, working groups may divert resources away from more critical remedies. Many organisations, therefore, impose triggering conditions that must be satisfied before an incident must be addressed by both local and regional recommendations. For example, the Canadian forces in the Former Republic of Yugoslavia investigated a total of 250 different topics during initial investigations into incidents during 1996. The 'Lessons Learned Information Warehouse' of the Army Lessons Learned Centre identified 142 possible areas of study but only 34 of these subjects were common to the majority of operations and rotations. There were identified using the following heuristics. Firstly, if an issue was identified during the early stages of the army's involvement in the region but ceased to be reported in latter stages then it was assumed that appropriate changes had been made and that no further recommendations need be made. This is a strong assumption. In other contexts, it would be necessary to seek further reassurance that such initial reports had been rectified. For example, the last heuristic represents such an approach. This is a further illustration of the temporal problems that arise when investigators attempts to assess the 'shelf-life' of a recommendation. Secondly, if an observation was made twice in the latter operations then it was retained as an issue for further investigation. The military reports do not state whether an issue would be retained if these reports were submitted by the same units on two different occasions. As with the previous heuristic, additional requirements might be necessary in other contexts to ensure that such generic issues did stem from more than one independent source. Finally, if an observation was made three times at any stage of the operations then it was retained as an issue. This increases the likelihood that high frequency reports, even in the early stages of the operation, will be addressed during subsequent investigations [134]

As mentioned, these criteria were used by the Canadian military as a means of filtering the 250 topics that were identified by individual reports from the units in the Former Republic of Yugoslavia. Only those issues that satisfied these various criteria were passed for the next level of analysis. In other words, they ceased to be considered as isolated examples that could be addressed by local recommendations. They were, in contrast, considered as more generic issues that required national or regional remedies. This distinction can be illustrated by the contrast between the general health and safety issues that affected Camp Black in the previous quotations and the following issues that emerged from this higher level analysis of more generic issues:

- "*Operations - Maps (Issue 26, page A-13):*
  Although units had adequate map coverage, the two map scales in use (1:50,000 and 1:100,000) did not coincide. Reporting of a grid on one scale produced an error in plotting on the other due to a difference in data.

- *Operations - Mines (Issue 32, page A-16):*
  Mines were the single largest producer of casualties on operations in the Former Republic of Yugoslavia. All [reports] indicated that units conducted extensive mine awareness training prior to and during the operation. Despite this training, the vast majority of mine incidents were directly attributable to a lack of situational awareness, understanding risks and recognising

the indicators of a mined area." [134]

Many organisations operate similar filtering processes to those implemented by the Canadian defence forces. Incidents that are reported at a local level are collated and then assessed to determine whether they have regional or national significance. If an issue is considered to be sufficiently serious according to the filtering criteria, or subjective judgement of the gatekeeper [423], then more generic recommendations are drafted. This, typically, implies a process of abstraction that strips out the contextual details that have been noted in the previous citations. This can be illustrated by the US Army's response to repeated incidents involving poor situation awareness; 'many platoons continue to experience difficulty with situational awareness because they do not have a system in place to properly battle track and manage information' [801]. The perceived importance of this continuing problem ensures that any recommendation must be directed to all battlefield personnel rather than those who are engaged in regional operations. This contrasts with the previous quotation that focussed on incidents involving maps and mines that were specifically encountered by the Canadian element of the UN forces in the Former Republic of Yugoslavia. Incidents involving poor situation awareness cannot be viewed as local issues because similar problems led to the friendly fire incidents mentioned earlier. An analysis of previous incidents determined that battle tracking in platoon command posts failed to provide squad leaders with necessary details about enemy locations, friendly unit dispositions and the current state of combat operations in their area. Squad leaders, in turn, rarely provided sufficient detail for platoon leaders to gain a clear understanding of the significance and context of their objectives. The US Army responded to repated reports of similar incidents by directly considering situation awareness issues within its national training programmes:

1. "The platoons must provide brigade combat teams with the information necessary to have resolution of location, current status and missions of the Military Police units.

2. Military police platoons should be considered during the brigade combat team's clearance of fires drills. The platoon command post must track the current brigade operation to the resolution necessary to provide squad leaders with information to plan and conduct operations.

3. Prevent fratricide. The platoon command post must also disseminate and provide feedback on the Commander's Priority Intelligence Requirements and Critical Information Requirements. Platoon leaders must require squad leaders to submit timely situation reports and route reconnaissance reports." [801]

As can be seen, there recommendations have moved away from the specific problems encountered by particular units. They have also abstracted away from the more regional problems that are associated with a particular theatre of operations. In contrast, the recommendations are expressed in a generic manner that might be used to inform battlefield operations in any anticipated conflict. It is important to emphasise that investigators must be aware of the different strengths and weaknesses of recommendations that are pitched at a national rather than a local level. The benefits of extending the scope of any remedy are obvious. However, the sense of engagement that stems from addressing specific local concerns is difficult to obtain from this more generic approach. The previous recommendations could be aimed at any combat platoon in the US Army. The insights gained from the analysis of particular incidents are distilled into a format that resembles standard training manuals that lack the immediacy of more local approaches. This effect is more readily apparent in the recommendations that are intended to avoid administrative or financial 'incidents'. For instance, the following quotation is taken from the US Office of the Assistant Secretary of the Army's proposals to avoid problems in the acquisitions process:

> "People who show active hostility to changes are easy to spot and deal with. If they express their dissatisfaction honestly and openly, then their objections can be addressed. The agreement may be stronger for having resolved the points troubling such a person. Conflict resolution, after all, is one of the primary reasons for forming a partnering agreement. More difficult to deal with are those individuals who pay lip service to the partnering agreement while they quietly work against it. Their hostility is expressed with

> subtlety through stubbornness, procrastination, and inefficiency. While the agreement encourages actively working to find solutions to problems, a passive-aggressive person does nothing to further the process. Quite the contrary, they do whatever they can to wreck it. Reassign such a person to a job where they cannot block progress." [802]

Such advice is deliberately pitched at a very high level of abstraction. In consequence, it can appear to be little more than 'common sense'. Such advice can have potentially adverse consequences if offered to personnel who are faced with more direct and apparently pressing problems in their working lives [840].

The previous paragraphs have argued that there is a tendency for national and regional reporting systems to remove the local and contextual details that often increase the immediacy of particular incident reports. In consequence, recommendations can be seen as abstract requirements that have little relevance to more immediate problems. At worse, they can be resented as unwarranted impositions by external agencies that are intent on hindering the normal working practices of local teams. It is important to emphasise that this process of abstraction is not a necessary result of attempts to increase the scope of an incident reporting system. It is still possible to implement national and international systems that provide focussed information about detailed incidents. Unfortunately, this raises a number of fresh problems that must be addressed by investigatory and regulatory authorities. In particular, given that national and international systems may generate a large number of potential recommendations it can be difficult to ensure that particular members of staff can easily access all relevant recommendations. Several techniques have been developed to address this problem. Journals such as the ASRS' DirectLine or the Canadian National Defence forces' Safety Digest can publish information about individual incidents in 'key areas' that are selected by the staff who are responsible for running the system. These publications are then distributed to appropriate members of staff. Unfortunately, this approach can be extremely costly. Paper-based publications must, typically, be distributed to many different regions. It also relies upon investigators to identify a subset of incidents that should be publicised at a national level. The difficulty of this task increases in proportion to the scale of the reporting system.

Electronic publication techniques provide alternative means of providing key members of staff with access to the recommendations that affect their particular tasks. This avoids the problems associated with making an explicit decision only to publicise a small number of the insights that can be gained from a national reporting system. With appropriate tool support, this approach also avoids some of the overheads associated with the costs of updating and distributing paper based journals. This approach has been successfully exploited by a range of armed forces [802, 148]. Preliminary steps have also been taken to extend this approach as a means of encouraging international cooperation. The ABCA Coalition Operations Lessons Learned Database is a notable example of this approach. This database was established in 1999 as a joint venture between the American, British, Canadian and Australian armed forces. It was intended to "identify and resolve those key standardisation issues which would affect the ability of a military force, comprising two or more of the ABCA nations, to operate effectively and to the maximum ability of its combat power" [800]. The password-protected web-site provided user with the ability to perform full-text searches. They could also browse a full listing of documents by country of origin. Chapter 14.5 will describe some of the technological limitations that reduce the utility of this approach and will introduce a number of further solutions to these problems. For now it is sufficient to observe that there may be few guarantees that any particular member of staff will be able to access all of the recommendations that are relevant to their working tasks using computer-based systems.

It is important not to underestimate the problems that arise when attempting to draft recommendations that might usefully be applied across national boundaries. Previous chapters have argued that the increasing scope of an incident reporting system can result in a process of abstraction that hides contextual information. Cultural differences have the paradoxical effect of focusing international exchange almost exclusively on detailed technical issues. For example, it is difficult to translate previous advice on US Army acquisitions policies into cultures in which 'apparent acceptance and covert opposition' are acceptable and even anticipated forms of disagreement [879]. It is for these reasons that the exchange of safety-related recommendations can yield deep insights into the alliances that exist between national organisations. Cultural similarities arguably explain the

United Kingdom's participation in the ABCA coalition rather than a coalition with other European defence forces.

The previous analysis has argued that the effectiveness of an incident reporting system can be increased if investigators increase the scope of its recommendations. This, typically, involves abstracting away from local, contextual details so that lessons can be applied by operators working in different regions and even different countries. It is important to stress, however, that there are some situations in which there is a deliberate policy not to exchange information about safety related incidents. For example, the South African National Defence Force is still adjusting to the changes that were introduced when it was first made subject to both the Machinery and Occupational Safety Act, 1983 and the Occupational Health and Safety Act, 1994. For the first time, the Department of Defence has an explicit obligation to demonstrate compliance with the law, "or with the spirit of the law", in health and safety matters [709] Prior to the end of apartheid, there was a deliberate political motivation to promote self-sufficiency. This implied a willingness to learn from the mistakes of others but did not imply a willingness on the part of many governments to share those lessons. Even in the post-apartheid era, there are limits to the free exchange of information in military and strategic matters. This was implied in the recent White Paper on South African Defence Related Industries:

> "It is neither affordable nor necessary to strive for complete self-sufficiency in armaments production and all the technologies to support it. However, the South African National Defence Force requires that in certain strategic areas, limited self-sufficiency must be retained and maintained and that in others, the South African National Defence Force needs to remain an informed buyer and user of equipment" [26]

Similar tensions exist in the wider commercial and industrial environment. Organisations must balance their need to learn from the mistakes of others against the potential consequences of disclosing information about their own past failures and successes. Sharing the recommendations that emerge from such incidents may result in the loss of competitive advantage that could otherwise be obtained from these insights. These tensions increase as recommendations are passed across geographical and organisational boundaries. Individual operators may see the benefits of sharing their insights with their fellow workers. Management may be less motivated to share those recommendations with commercial rivals. Ultimately, national political and strategic interests can intervene to prevent the exchange of insights from past failures.

By function...

The previous section has identified some of the problems that arise when investigators draft recommendation that must be applied by colleagues who are not part of the working group that reported an incident. It can be difficult to draft generic remedies that can be applied by groups in other areas. A lack of specific details can remove the directness that characterises many local incident reports. In consequence, particular recommendations can appear to be impositions from external agencies that cannot easily inform the daily working lives of their recipients. These problems that complicate the exchange of information within national boundaries are further exacerbated by the cultural differences that exist between the partners of international systems. These issues can be partly resolved if investigators ensure that recommendations are drafted to target specific functional issues. Less emphasis is placed on generalise from a particular incident so that it can inform a wide range of tasks that are performed throughout an organisation. Greater emphasis is placed on ensuring that similar incidents do not affect the future performance of *the particular task* that was affected by a previous incident.

At the lowest level, task based recommendations can be drafted to support particular working groups within particular units or factories. For example, the following excerpts are taken from the Picatinny Arsenal newsletter published for technicians working on the US 155mm M109A6 self-propelled howitzer, known as the Paladin:

> "An inoperable drivers hatch stop inhibits the ability to properly secure the drivers hatch cover, forces non-operational vehicle status as prescribed in Paladins Operators

> Manual (TM 9-2350-314-10, Feb 1999, Page 2-70, Item 77), and could cause injury if not corrected. Yet, some Paladin personnel improperly use unauthorised field fixes to correct the problem and by doing so promote a potentially dangerous situation. Typically, problems begin when the Grooved, Headless, Pin (NSN 5315-00- 584-1731) breaks (usually when the hatch cover is inadvertently swung open with more than necessary force) then, rather than correcting the problem with authorised parts, a makeshift solution is applied to connect the hatch stop to its shaft. Poorly fitted cotter pins, nails, and similar devices, have been used in place of the Fan Impeller. After continued use, damage to the hatch stop usually occurs causing the hatch stop assembly to become totally inoperable. Units using a Lessons Learned approach to the problem generally maintained a small number of the inexpensive Grooved Pins on hand ($1.78, April 00 Fedlog). When pins were damaged, broken, or became loose, they were quickly replaced. This practice precluded unnecessary damage and replacement of parts, but more importantly a higher degree of operational safety was maintained." [803]

These recommendations illustrate a number of important strengths that can be derived from task-based, local incident reporting. For example, this guidance assumes a high degree of common understanding about the nature of the systems being maintained. Although reference is made to the operators manual and part identifiers, a range of technical terms such as 'fan impeller' or 'grooved pins' can be used without further elaboration. These recommendations dispense with the additional contextual information that is necessary for recommendations that have a wider scope beyond local working groups. Similarly, there is little need to expand on the details of previous violations. It is sufficient to summarise the 'makeshift solutions' for the readers to understand the nature of the incidents that are being addressed. The previous quotation also illustrates some of the weaknesses that limit the utility of such task-based approaches to incident reporting. In particular, the recommendations tend to focus on 'cheap fixes' rather than the large scale investment that may be required to address more systemic failures. Elsewhere, we have reviewed the way in which many aviation and medical incident reporting systems will repeatedly remind staff to 'do better' rather than invest resources in addressing the conditions that led to particular failures [411]. The tendency to rely upon short-term measures is particularly apparent when recommendations are targeted on the tasks or activities performed by individual groups of workers.

We can define a task to be the activities that are required to achieve a particular set of goals [687]. The previous quotations, therefore, examined a very specific and detailed task from the perspective of US Army Engineers at the Picatinny Arsenal. This task focussed approach can also be applied to national and internation objectives. When failures occur at this level, the proposed remedies tend to avoid the short-term solutions that typify more local initiatives. This can be illustrated by the NATO recommendations that were compiled from detailed incident reports and interviews with the personnel who contributed to the peace-keeping missions in Somalia:

> "The evaluation noted many troop contributors' complaint that they were not sufficiently consulted during the formulation stage of the mandate and, thus, had varying perceptions and interpretations during its execution. Many participants in the exercise considered that the original UNOSOM mandate was formulated on political, humanitarian and military assessments, and was prepared, using insufficient information, by officers borrowed for short periods from Member Governments and other peace-keeping operations. Some participants observed that although it was well known that a crisis was unfolding in Somalia, its seriousness and magnitude in humanitarian terms were not fully appreciated. " [626]

It is important to emphasise that even though international organisations may take a more system view of the causes of particular incidents, there is no guarantee that they will be able to solve the problems that complicate high-level tasks such as peace-keeping. Sadly, this point is reinforced by NATO's Department of Peace-keeping Operations review of the Rwanda missions. It was argued that many of the problems and incidents report by NATO forces stemmed from a 'fundamental misunderstanding' of the nature of the conflict [627]. Analysis of individual incidents raised concerns that 'the internal political conflicts within the Government of Rwanda, and the mounting evidence of politically motivated assassinations and human rights violations in the country, were ignored or not explored'.

Previous sections have argued that task focussed recommendations often lead to short-term fixes that ignore more systemic problems. The United Nations recommendations have, however, provided a counter-example. This apparent contradiction can be explained by the very different nature of the tasks that we have considered. Clearly, there are considerable differences between maintaining a driver's hatch and coordinating international peace-keeping operations. It might, therefore, be argued that it is the combination of task-focussed recommendations within a local reporting system that tend to lead to short-term remedies. Task-focussed recommendations at a national or international level are less susceptible to this problem. Previous studies have shown, however, that large-scale systems are far from immune from this problem [411]. There is still an understandable tendency to recommend improved training rather than reassess acquisitions policy.

A number of further limitations affect recommendations that reflect this task-focussed approach to incident reporting. In particular, there is a danger that investigators will fail to consider the importance of particular incidents within the context of a larger operation or production process. For instance, the previous recommendation does not consider the possible acquisition or training problems that led staff to adopt 'makeshift solutions' in the first place. An alternative approach is to embed task-specific recommendations within longitudinal accounts of particular operations. This approach weaves together the findings from a number of different incidents. Any individual may only be directly involved in a small number of the tasks that contribute to the overall operation. However, this longitudinal approach enables them to see how incidents that occur earlier in a process have 'knock on' effects for their own tasks. It also demonstrates that the effects that potential failures in their tasks can have upon the subsequent activities of their colleagues. This 'process-based' approach can be illustrated by the US Army's Engineering Groups analysis of bridging operations. This draws together diverse recommendations from many different stages in a particular bridging operation. Initially, a small 'S3' group compared the tools that the 1st Cavalry Division and the 937th Engineer Group would need to plan and control the operation. This planning exercise identified a number of limitations with current synchronisation techniques and new tools were developed based on 'off-the-shelf' software. Task focussed approaches to incident reporting might have simply presented these recommendations as isolated guidance on the synchronisation of river crossings. This approach is widely adopted in other areas of the US military [803]. In contrast, the engineers of the 937th extended their analysis to integrate it with the recommendations that emerged from the subsequent execution of their plans with the 1st Cavalry Division. Although the tools enabled the engineers to calculate crossing times and schedules for both rafting and bridging, the eventual joint plans did not adequately address some of the fundamental problems that exacerbate the execution of such crossings:

> "A bypassed Orangeland special-forces team on the near shore observed and directed accurate artillery and close air support to destroy the bridge. During the after-action review, it was determined that the critical friendly zones had not been set properly and that the high-to-medium-altitude air defence coverage was inadequate. This action demonstrated that clearing the near and far-shore lodgements is a tenuous and difficult task. One lone member of an opposing force with a radio is the most dangerous person in the crossing area. In an effort to take advantage of the surprise created by the virtually unopposed crossing at Kaw, the division accepted risk by not absolutely ensuring that the crossing site was secure from observed indirect fire before beginning bridging operations. This allowed the division to quickly cross two mechanised task forces but left the ribbon bridge at Kaw vulnerable." [463].

Chapter 2.3 introduced Perrow's argument that technological failures are unavoidable given that designers are forming increasingly complex interconnections between component systems. For this it follows that even if one organisation has implemented a particular recommendation, there is no guarantee that others will have met the same requirements. This has important implications because failures from one area of a system can propagate through an application to effect later processes that might, themselves, meet the most stringent safety standards. This process-based approach to the presentation of recommendations, therefore, provides eloquent reminders of the mutual dependencies that exist between the component tasks of complex systems. It is important to note, however, that there is still a strong functional bias to the engineer's recommendations. They focus on the particular challenges of the bridging operation and are written from the perspective of those who are tasked to construct and maintain the river crossing. The recommendations do not address the wider strategic significance of the crossings within an exercise as a whole. For example, there is only a cursory description of the problems that the other units in the 1st Cavalry Division faced in exploiting the opportunities, or addressing the threats, that were created at the various crossing points. In other words, the recommendations reflect the functional preoccupations of the engineering group. They propose solutions to incidents that jeopardised their particular tasks. Incidents that occurred elsewhere on the battlefield are not considered. Again, it is important to stress that this example represents a far more general trend. For example, the US Army maintains a number of incident reporting systems that form part of 'Lessons Learned' initiatives. These are organised along functional lines. In addition to the general Center for Army Lessons Learned there is a Center for Engineer Lessons Learned. As we have seen, there is a Contracting Lessons Learned Centre (http://acqnet.sarda.army.mil/acqinfo/lsnlrn/index.htm) and a Medical Lessons Learned unit . The Marine Corps also reflect these functional distinctions by operating separate systems for their combat personnel and for their maintenance staff. The obvious criticism to make of these systems is that there may be important lessons that cross functional boundaries. Some of these are address by Joint Center for Lessons Learned which covers joint forces operations. Other issues that cut across functional boundaries are captured by the US Army Safety Centre. This publishes the safety notices that have been mentioned in previous chapters. It should be stressed that the objectives of these different systems are quite different. For example, the reporting systems maintained by the Safety Centre do not issue the sorts of functional recommendations, for instance on fording tactics, that might appear in the systems operated by the combat engineers. It is important to stress, however, that safety-related incidents and recommendations appear in all of these systems.

This section has argued that the process of drafting effective recommendations is complicated by the geographical scope, the timing and the functional focus of the proposed remedies. Some incidents provide universal insights that can be applied across many different workgroups in particular geographical regions. The Singaporean guidelines on heat injury provide an example of this form of recommendation. Other remedies, such as the proper insertion procedures for the Paladin hatch pin, relate to specific workers performing specific tasks in a few locations throughout the world. It should be stressed that these are not the only distinctions that complicate the drafting of recommendations from incident reports. For example, there are some notable situations in which potential remedies for previous incidents will not be acceptable to both genders. This is illustrated by the guidance provided in the US Army's 'Female Soldier Readiness' [846]. These distinctions have important consequences and investigators must carefully consider their impact on any potential recommendations. For example, a mailshot about the dangers of heat exhaustion may have limited benefits for US Army personnel working at Fort Wainwright in Alaska. Similarly, information about the Paladin hatch mechanisms is of little interest to combat engineers engaged in bridge construction. These geographical and functional distinctions have a profound impact upon many reporting systems. For example, the following list summarises the current titles published in the US Army Safety Centre's leadership guides. As can be seen, some documents provide recommendations that apply to particular geographical regions, including Southwest Asia, Korea, Iraq and the Caribbean. Others relate to particular functions, such as force protection and civilian work force management:

- Annual Training Leader's Safety Guide
- Back Injury Prevention Leader's Safety Guide
- Caribbean Risk Management Leader's Guide
- Civilian Work Force Leader's Safety Guide
- Desert Shield Leader's Safety Guide

- Force Protection Leader's Guide
- Korea Leaders Safety Guide
- Operation Provide Promise Risk Management Leader's Guide
- Operation Support Hope Risk Management Leader's Guide
- Redeployment & Port Operations Leader's Safety Guide
- Southwest Asia Leaders Safety Guide

This list reflects one of the simplest ways in which information can be structured so that users can identify which recommendations are most relevant to their everyday tasks in a particular working environment. Many organisations have developer far more elaborate means of collating and disseminate recommendations. For instance, previous paragraphs have briefly described the US Army's plethora of 'lessons learned systems'. This mixed approach to the dissemination and implementation of recommendations will be the focus of Chapter 13.5. For not it is sufficient to realise that these diverse information sources provide means of tailoring the presentation and dissemination of recommendations so that they support particular user groups. Unfortunately, they can also create artificial barriers that prevent the free exchange of information about similar incidents between different groups in the same organisation. If any reader believes that these problems are unique to the US Army, it is worth considering the functional and geographical distinctions that are appearing within many healthcare systems. In the UK, different medical specialisms are developing their own guidelines on incident reporting. The Royal College of Anaesthetists' are, arguably, the more well known [716]. At the same time, individual hospitals, NHS trusts and national schemes are all being developed in parallel. This is hardly a situation designed to inspire confidence in the free exchange of information across different organisational boundaries [635].

12.1.3 Conflicting Recommendations

Previous sections have argued that the task of identifying appropriate recommendations is complicated because any remedies may have support a range of tasks that are performed by different operators in many geographical regions. It is further complicated by the ways in which working practices, procedures and technological systems will change over time. Recommendations may, therefore, have to be continually updated if they are to continue to support the safe operation of complex applications. The task of drafting recommendations is further complicated by potential disagreements between investigators, safety managers and national organisations. It is possible to identify at least three different forms for such potential conflict. Firstly, investigators may disagree about the remedies that are appropriate for superficially similar incidents. Secondly, investigators and their managers may disagree over the recommendations that emerge from a particular incident. Finally, safety managers can disagree over the interpretation of particular recommendations. The following paragraphs describe these problems in further detail and provide case studies to illustrate their impact on a number of incident reporting systems.

Different Recommendations from Similar Incidents

Different recommendations are often proposed for incidents that have strong apparent similarities [411]. For example, the US Army's 'Countermeasure' provides military personnel with feedback about a range of safety related incidents. The following incidents appeared in successive numbers of this journal. Both describe two fatalities that resulted from tank drivers using excessive speed during hazardous maneuvers. In the first incident, rapid lateral momentum over a steep slope helped to overturn a seventy ton M1A1. The recommendations paid particular attention to the position of the crew during this incident:

> "Once again, human error became a contributing factor in the loss of a soldier. Leaders must ensure that they and their crew members are positioned correctly in their

> vehicles and are taking advantage of all safety features. The nametag defilade position increases your ability to lower yourself safely inside the vehicle and prevents excessive exposure of body parts to the elements outside. Seatbelts (if provided), guards, clothing and securing equipment enhance your survivability if your vehicle should happen to invert or strike a solid object." [817]

In the second incident, the driver of an M551A1 inadvertently drove into their excavated fighting position so that their vehicle also overturned. Again, the fatality resulted from crust injuries sustained by a soldier who was standing in the hatch above the nametag defilade in the vehicle. In contrast to the previous incident, however, the recommendations did not address the US Army's requirement that all personnel must assume a correct, secured position within any combat vehicles [810].

This apparent difference between the recommendations from two similar incidents can be explained in a number of ways. Firstly, although these incidents resulted in similar outcomes and shared several causes there were also important differences. In the former case, the incident occurred during a daytime exercise. In the second case, the personnel were operating using night vision devices. The recommendations, therefore, focused on the additional requirements for working with limited visibility rather than the requirement to obey seating regulations for combat vehicles. Such differences are not the only reasons why superficially similar incidents might elicit very different remedies. As we have seen in Chapter 10.4 there are a host of individual and social biases that can affect the analysis of individual failures. These biases may it likely that different investigators may identify different causes for similar incidents. Such problems are further compounded when recommendations are identified in an ad hoc manner without the support of any shared methodology. Later sections in this chapter will describe techniques that have been specifically developed to reduce such apparent differences between the analysis of similar incidents.

A number of further reasons help to explain why investigators derive different insights from similar incidents. New evidence can encourage analysts to revise previous advice. Investigators may also change their recommendations to focus operator attention on particular causes of subsequent incidents. This provides an important communication tool. Over time, the hope is that the readers of Countermeasure and similar journals will learn to recognise the diverse causes of many safety-critical failures. The changing emphasis of particular recommendations can also reflect changes in particular forms of risk assessment. They may signify a decision to focus more on limiting the consequences of an incident rather than reducing incident frequencies. For example, previous speed-related collisions involving combat vehicles had led the Army Safety Centre to reinforce the importance of enforcing recommended speed limits. Subsequent articles focussed more on protective measures that might mitigate the consequences of any collision if a speed-related incident should occur.

It is, therefore, possible to distinguish between inadvertent and deliberate differences between the recommendations that are derived from superficially similar incidents. Inadvertent differences stem from the managerial problems of ensure consistency between the remedies that are proposed for complex events. Investigators often rely on ad hoc methods and do not share the common techniques that might encourage greater agreement. Later sections in this chapter introduce a number of techniques that are deliberately intended to ensure that similar recommendations are derived from similar incidents. However, the large number of incidents that must be investigated by national and international system make it unlikely that such tools will ever provide an adequate solution to this problem. In consequence, Chapter 14.5 describes a range of search and retrieval software that can be recruited to improve quality control in this domain.

As we have seen, some investigators may deliberately introduce differences between the recommendations that are intended to resolve similar incidents. These differences may stem from individual or group biases that can compromise the value of any subsequent remedial actions. alternatively, deliberate differences may reflect a policy of gradually exposing operators to the underlying complexity of the causes that characterise many incidents. These differences may also reflect the previous success of a system in addressing some of the causes of similar failures. Conversely, they may reflect an apparent failure to address the causes of an incident. Investigators may subsequently focus attention on mitigating the consequences of particular failures. Whatever the justification, it is important that analysts consider presenting the reasons for such apparent differences. For example, the Countermeasure journal dealing with the second incident, described above, deliberately informs its readers that incidents in the special edition will present the diverse range of causal factors that contribute to 'night vision' incidents. This justifies and explains why different recommendations are made after each incident is described. Unfortunately, such contextual explanations are often omitted so that readers have no means of distinguishing deliberate differences with benign explanations from inadvertent differences or differences that are due to the deliberate bias of particular investigators.

Debate Between Investigators and Higher-Level Administration

Previous paragraphs have argued that it is difficult for investigators to ensure that their recommendations are consistent with those of their colleagues. These problems are exacerbated when analysts may deliberately choose to emphasise certain aspects of an incident in their findings. It is also difficult to under-estimate the problems that arise from the sheer scale of many national and international systems. Analysts must ensure consistency between thousands of different reports.

As we have seen differences can arise between recommendations for similar failures. They can also stem from different interpretations of the same incident. One important potential source of dispute stems from the nature of the recommendation 'process' itself. It should be apparent from the use of the term 'recommendation' that these findings are usually recommended by investigatory organisations to a supervising body. For instance, the findings of US Coast Guard reports are typically passed from an individual investigating officer via the Officer in Charge of Marine Inspection to the Commander of the relevant Coast Guard District. Australian Military Boards of Inquiry present their findings to the Minister of Defence and the Federal Government. This process of recommending corrective actions creates the opportunity for disagreement. The Australian Minister of Defence may reject some of the findings made by a Board of Enquiry. Similarly, the Commander of a Coast Guard district may present his reasons for choosing not to implement the findings of an investigating officer. More elaborate mechanisms are also used to approve the recommendations from accident and incident investigations. For instance, the Investigating Officer's Report into the terrorist actions against USS Cole was endorsed by the Commander of US Naval Forces Central Command, by the Chief of Naval Operations and by the Commander in Chief of the US Atlantic Fleet. They 'must approve findings of fact, opinions and recommendations' [837]. Each of these endorsements occurred in a specified order. The Commander of US Naval Forces Central Command provided the initial endorsement, the Commander in Chief of the US Atlantic Fleet was second and the Chief of Naval Operations was last. Subsequent reviewers could not only comment on the report itself but also on the opinions of their colleagues. Most of the comments supported the findings of the investigation. For example, the Chief of Naval Operations stated that "after carefully considering the investigation and the endorsements, I concur with the conclusion of the Commander in Chief, US Atlantic Fleet, to take no punitive action against the Commanding Officer or any of his crew for this tragedy" [837]. There were, however, some disagreements over particular recommendations. There were also disagreements between the endorsing officers! For example, the Commander in Chief of the US Atlantic Fleet observed that:

> "The Investigating Officer and the First Endorser fault the Commanding officer, USS Cole for deviating from the Force Protection Plan he had submitted to his superiors in the chain of command. The Investigating Officer states that had these measures been activated, the attack 'could possibly' have been prevented. I disagree with this opinion, given that those measures would have been inadequate against attackers who were willing to, and actually did, commit suicide to accomplish their attack. I specifically find that the decisions and actions of the Commanding Officer were reasonable under the circumstances." [838]

Other organisations can be commissioned by the ultimate recipients of incident reports to monitor the recommendations that are proposed. For instance, the United States' General Accounting Office was commissioned by members of the senate to review training related deaths. The resulting analysis was not only critical of the recommendations for improving training safety but also uncovered problems with the basis on which those recommendations were made:

> "Our analysis revealed that six deaths categorised by the services as resulting from natural causes occurred under circumstances that could be related to training activities. These were primarily cardiac arrests that occurred during or shortly after the service members had performed required physical training exercises. A typical example of these was a Marine who died from cardiac arrest after completing a required physical fitness regimen. Although he had just completed 5 pull-ups, 80 sit-ups, and a 3-mile run, his death was not considered to be a training death, but rather was classified as a natural cause death." [288]

The Department of Defence responded, in turn, to defend the processes that had been used to investigate particular incidents and the recommendations that had been derived from them. In the final report, the General Accounting Office continued the dialogue by countering these comments with further points about the need to trace whether those recommendations that were proposed had been effectively monitored within individual units.

The complex nature of many incidents often creates situations in which organisations, such as the Department of Defence and the General Accounting Office, hold opposing views about recommendations to avoid future incidents. These conflicts can be difficult to arbitrate. Regulatory or governmental bodies often cannot resolve the differences that exist between the various parties that are involved in the analysis of safety-critical incidents. This point can be illustrated by the Canadian Army's Lessons Learned Centre investigation into their involvement in the NATO Implementation Force and Stabilization Force in Bosnia-Herzegovina (Operation Palladium). They analysed the individual incident reports that had been received during the initial stages of their involvement and made a systematic response to the recommendations that had emerged. The following quotation illustrates how it can be impossible to comply with the competing recommendations that can be made from the different parties who are involved in the analysis of specific incidents:

> "(Reports from Units)...Many units stated that the standard first aid training package (a holdover from Warrior training) lacks realism and that training should be oriented to treating injuries that would be sustained in combat. Many agreed that IV and morphine training were essential components to this training... " During the six months in theatre, no soldier had to give artificial respiration, treat a fracture or do a Heimlich manoeuvre. However, our soldiers did give first aid to 17 bullet-wound cases, 3 shrapnel-wound cases and 7 minefield cases (foot or leg amputated)." As the threat level dropped for latter rotations, unit comments on the need for IV and morphine training waned, there seems to be much debate on the usefulness and dangers of teaching this subject. All unit medical staff strongly recommended that it not be completed because of the inherent dangers that administering IVs or morphine entails...
>
> *(Army Lessons Learned Centre Observation) ...This issue can only be resolved at the highest levels of command in the Canadian Forces and a balance between operational imperatives and medical caution must be found.*" [129]

This quotation provides a detailed example of how it can be necessary to mediate conflicting recommendations. In this instance, the Army Lessons Learned Centre must arbitrate between operational requests for training in the application of morphene and the unit medical staff's concerns about the dangers of such instruction. This example shows how particular recommendations often form part of a more complex dialogue between investigatory bodies and the organisations who are responsible for implementing safety policy. The previous quotation also demonstrates that the political and organisational context of incident reporting systems has a strong influence on the response to particular recommendations. The Canadian Army's Lessons Learned Centre could not reconcile recommendations to expand the scope of trauma training with the medical advice against such an expansion. The fact that they felt uncomfortable with making a policy decision about this matter provides an eloquent insight into the scope of the reporting system and the role of the Centre within the wider organisation. This is not a criticisms of the unit. It would have been far worse if a particular recommendation had been adopted that compromised the reputation of the system or alienated groups who had contributed to the 'lessons learned' process that is promoted by incident reporting.

It is, perhaps, unsurprising that the Lessons Learned Centre should pass such policy decisions to a higher level of authority.

There can, however, also be disagreement at a governmental level. For example, the UK Defence Select Committee examines the expenditure, administration and policy of the Ministry of Defence on behalf of the House of Commons. As part of this duty, it monitors incidents and accidents within the armed forced. The following quotation is taken from the Defence Committee's report into the UK involvement in Kosovo. The first paragraph expresses the Committee's concern about a number of incidents involving Sea Harrier missile configuration. The second paragraph presents the government's response to the Committee's recommendations. The Committee's request for further monitoring is parried by the Government's observation that the problem is not as bad as had been anticipated:

> *"(Committees' recommendation): The resort to cannibalising front-line aircraft in order to keep up the deployed Sea Harriers' availability is clearly a matter to be taken up by the new joint Task Force Harrier's command. We expect to be kept informed of any continuing incidents of damage to the Sea Harrier's fuselage-mounted missiles. (Paras 153 and 176).*
>
> (Government response 57): The Joint Force Harrier is addressing these issues, and the Committee will be kept informed of developments. The problem of AMRAAM carriage in certain Sea Harrier weapons configurations is the subject of continuing in-service trials work, but trials since the potential problem was first identified, together with a longer period of time carrying the missiles, have shown the damage to be much less than feared, and containable within current stock levels and maintenance routines." [793]

This quotation again illustrates the way in which the response to particular recommendations can provide useful insights into the political and organisational context of many incident reporting systems. In this case the government accepts the Committee's request to be informed of subsequent damage to the fuselage-mounted missiles. This acceptance is, however, placed in the context of continuing work on the platform and of the relatively small number of incidents that have been observed. The quotation, therefore, captures the Committee's inquisitorial role and the Government's concern to counter any comments that might be interpreted as politically damaging.

Previous sections argued that investigators must justify any differences between the recommendations that are drawn from similar incidents. Statutory or governmental bodies might also be required to explain why they support particular recommendations and reject others. This was illustrated by the detailed justifications that the US General Accounting Office provided in their rejection of US Army recommendations for training-related deaths. There are, however, situations in which governmental and regulatory bodies are forced to mediate between conflicting recommendations. The Canadian Army's Lessons Learned Centre could not resolve the apparent contradiction between advice for and against specific training in trauma medication. Under such circumstances, particular recommendations must be referred to a higher policy-making body if the position of the regulatory agency is not to be compromised. Even at the highest levels, however, it is important that governmental organisations explicitly justify their response to particular recommendations. For example, the UK Government accepted the Defence Select Committee's request for further information about incidents involving fuselage mounted missiles. It was also careful to explain its response in terms of the most recent evidence about the frequency of such incidents. These explanatory comments can equally be interpreted as political prudence. This underlines a meta-level point; the response to particular recommendations often provides eloquent insights into the political and organisational context of an incident reporting system.

Correctives and Extensions From Safety Managers

The previous section described how differences arise between investigators and the regulatory or governmental organisations that receive their recommendations. Most of the examples, cited above, focus on high-consequence failures rather than the higher frequency, lower severity incidents that are the focus of this book. Similar differences of opinion can, however, be identified over the recommendations that are derived from these failures. These disputes can often be seen in the correspondence that takes place after a report has been published. For instance, most military incidents and accidents are not directly related to either combat or combat training. A large proportion of work-related injuries stem from slips, trips and falls. Others are related to the road traffic incidents that affect the wider community. For this reason, the Canadian National Defence Forces' Safety Digest reported a number of recommendations that were based on several detailed studies of previous incidents [139]. The main proposition in this summary was that car buyers should balance the fuel economy of a vehicle against potential safety concerns. The report argued that the fatality rate for passenger cars increases by 1.1% for every 100-lb decrease in vehicle weight and that in an accident between a Sport Utility Vehicle (SUV) and a car, the occupants of the car are four times as likely to die. Subsequent editions of the Safety Digest carried dissenting opinions from readers who disagreed with the recommendations drawn from previous incidents:

> "(The report) infers that 'bigger' is 'better' for vehicle safety, encouraging readers to buy large automobiles, SUVs, or trucks by feeding their fears. I don't dispute the fact that the larger the vehicle, the higher the chances of occupant survivability in crashes. However, following (this) logic, our family car should be a multi-wheeled armoured fighting vehicle." [141]

The respondent cited studies in which front-wheel drive vehicles with good quality snow tires had outperformed all-season tire-equipped SUVs. They pointed to the problems of risk homeostasis and of decreased perception of risk in larger vehicles. Finally the correspondent argued that the recommendations from the study of previous incidents should have focussed on motivating 'drivers to be more alert, attentive and polite, to practise defensive driving techniques, and to avoid distractions (such as cell phones) and road rage' [141]. This dialogue illustrates the way in which publications, such as the Safety Digest, can elicit useful correctives to the recommendations that can be drawn from previous incidents. Similar responses have addressed more fundamental misconceptions in safety recommendations. For instance, an article about the lessons learned from previous incidents involving electrical systems provoked correspondence that can be interpreted in one of two ways. Either the original recommendations failed to consider the root causes of those failures, as suggested by the respondent, or the respondent had misunderstood the original recommendations:

> "(the report) may leave the erroneous impression that they have discovered new procedures to prevent these types of accidents. The simple fact is that management, supervisors and employees were in violation of numerous existing rules, regulations and safe work practices. Like so many others, this accident was the result of a chain of events which, if carefully examined, often includes all levels - workers, supervisors and management... I have reviewed thousands of accident reports ranging from minor to serious and yes, some fatalities. The vast majority of these reports identify the employee as the cause of the accident. However, study after study has shown that the root cause of accidents is usually somewhere in the management chain. Unless management creates a safety culture based on risk management and unless supervisors instill this workplace ethos in their workers: 'In my shop everyone works safely, knows and follows the rules, and has the right to stop unsafe acts,' and then enforces this view consistently, we will never break the chain and accidents will continue to occur." [136]

As mentioned this correspondence might indicate that the original recommendations did not take a broad enough view of the causes of previous incidents. If subsequent enquiries concurred with this view then additional actions might be taken to ensure that investigators and safety managers looked beyond the immediate causes of electrical incidents. Alternatively, it might be concluded that the respondent had misunderstood the intention behind the original report. In such circumstances, depending on the nature of the reporting system, actions might be taken to redraft the recommendations so that future misunderstandings might be avoided. The previous response not only illustrates how disagreements can emerge over high-level issues to do with the recommendations in an incident report, it also demonstrates the way in which such feedback can challenge more detailed technical advice. The correspondent challenged 'the recommendation that an electrical cane could have been used to effect rescue' during a particular incident [136]. Untrained personnel must not approach any closer than 3.0 meters for voltages between 425V and 12,000V. The national recommendation for trained personnel is no closer than 0.9 of a metre. The respondent concluded that 'the electrical cane shown (in the report) would clearly not be suitable for untrained personnel and only marginal for trained personnel in such a scenario' [136].

Both road safety and the precautions to be taken following electrical incidents are generic in the sense that they affect a broad range of industries. Incident reporting systems also reveal how particular 'failures' can trigger more specialised debates that relate to particular safety issues. For example, the Canadian National Defence Forces' Safety Digest described a series of incidents that stemmed from the need or desire to directly observe particular forms of explosion. One incident occurred during a basic Engineering Officer training exercise. After a number of demonstrations by a tutor, each student prepared and destroyed a piece of ordnance. A student was injured when a fragment shattered a bunker viewport. The subsequent investigation found that the viewports were constructed using four-ply laminated glass. It was designed to withstand a blast equivalent to the detonation of 100 kg of TNT at 130 metres distance with less than 2% glass loss to the inside of the structure [144]. In this case, the glazing performed as designed. Unfortunately, some of the 2% of glass lost to the inside of the bunker lodged in the eye of a student. The recommendations from this analysis focussed on two areas. The first concerns the use of a sacrificial layer of polycarbonate material on the inside of the glazing, not simply to protect against scratches and damage on the external surface. The material would be 'easy to replace when scratched, discoloured or UV degraded, a nd would provide a failsafe final protection for the viewer's eyes' [144]. The second recommendation focussed on the use of periscopes. The offset of the glass elements prevented fragment impact from translating to the viewing side of the optics; "one type of offset viewblock that is in plentiful supply is NSN 6650-12-171-9741 periscope, tank." [144] These recommendations helped to trigger a more general discussion about the technologies that might help to reduce injuries caused by the use of viewports to observe explosions. One correspondent argued that the introduction of sacrificial layers compromised the utility of viewports in other applications. The increasing thickness of the glass 'precluded observation'. In consequence, they recommended the use of video technology:

> "I have seen technology advance to the point where miniature cameras now can be positioned in strategic locations with minimal exposure to blast and fragment impact. Should a lens suffer a direct hit, the replacement cost would be minimal. Lessons learned involving the Coyote vehicle in Kosovo revealed that crews used their digital video cameras to obtain a colour picture rather than relying on the vehicle's integral observation system with its limited monochrome rendering. Closed-circuit TV or a variation thereof permits easy zooming in from a safe distance. It would also be possible to view the demolition site on a number of screens and to record the process for other purposes, including training, slow-motion analysis, replays, and engineering. I have seen video camera lenses smaller than the tip of a pen (using fibre optics) for underwater or high-risk areas (pipeline)." [145]

Such debates can help to increase confidence in particular recommendations. Dissenting opinions and alternative views can be addressed in subsequent publications either by revising previous recommendations or by rebutting the assertions made in critical commentaries on proposed remedies. There is a danger, however, that the results of such dialogues will be lost in many reporting systems. This would happen if the dissenting opinions were not explicitly considered during any subsequent policy decisions. It can be difficult to ensure that such dialogues are both reconstructed and reviewed before any corrective actions are taken. For instance, there is currently no means of reconstructing the thread of commentaries on previous incidents involving the direct observation of explosions. In consequence, safety managers must manually search previous numbers of the Safety Digest to ensure that they have extracted all relevant information. Search tools are available, however, Chapter 14.5 will describe how these might be extended with more advanced facilities that support the regeneration of threads of debate following from safety-critical incidents. For now it is sufficient to realise that some organisations have devised procedures and mechanisms that are intended to explicitly introduce such debate into the production of incident reports. For instance, sub-regulation 16(3) of the Australian Navigation (Marine Casualty) Regulations, requires that if a report, or part of a report, relates to a persons affairs to a material extent, the inspector must, if it is reasonable to do so, give that person a copy of the report or the relevant part of the report. Sub-regulation 16(4) provides that such a person may provide written comments or information relating to the report. The net effect of these regulations is to ensure that dissenting opinions are frequently published as an appendix to the recommendations in the investigators' 'official' report.

It is important to mention that these dialogues that are often elicited by particular recommendations not only play a positive role in challenging the proposed remedies for particular types of incident. They can also elicit praise that both motivates the continued operation of an incident reporting system and can encourage others to contribute their concerns. There may also be other more specific safety contributions. For instance, one respondent to the Canadian National Defence Forces' Safety Digest publication expressed 'delight' at a report about explosives safety. They then went on to express their disappointment that there had not been any subsequent articles on explosives incidents in the five months since the report had been published; 'Is the world of ammunition and explosives so safe that there is nothing else to write about?' [146]. The correspondent praises the previous article on the causes of explosives incidents. They are also concerned by the relatively low frequency of reports in this area that are summarised in the Canadian National Defence Forces' Safety Digest. This response, therefore, reflects pro-active attitudes to both the underlying safety issues and to the operation of the reporting system. Although such measured reactions are quite rare, they often indicate that an incident reporting system is in good health. If recommendations are challenged then at the very least there is direct evidence that they are being read by the intended audience. If respondents notice that certain types of incidents are under-represented then this can provide evidence of reporting bias. Such responses can also provide valuable feedback about the mechanisms that are used to publicise those recommendations that are derived from previous incidents.

The Dangers of Ambiguity...

Previous sections have argued that the task of drafting appropriate recommendations is complicated by the various correctives that can be issued to address perceived short-comings in the remedies that are proposed in the aftermath of particular incidents. We have described how investigators often issue different recommendations for similar incidents. Such inconsistencies can be intended. For example new remedies may be proposed if previous recommendations have proved to be ineffective. Differences between recommendations can also be unintended. Investigators may not be aware that an incident forms part of a wider pattern of similar failures. Previous sections have also described how regulatory bodies and higher levels of management issue correctives to the recommendations that are proposed by incident investigators. These correctives may directly contradict particular findings. They may also change the emphasis that it placed on particular remedies. Finally, we have argued that well-run reporting systems often elicit debates about the utility of particular recommendations. Operators and managers may also propose ways in which previous remedies might be extended or tailored to meet changing operation requirements. They may also directly contradict the recommendations that have been proposed to address future failures.

The task of drafting effective recommendations is further complicated by the difficulty of ensuring that they can be clearly understood and acted upon by their intended audience. Chapter 13.5 will describe a range of paper and computer-based techniques that can be used to support the effective communication of particular recommendations. For now, however, it is important to emphasise that there must be stringent quality control procedures to help ensure that the advice that its presented to operation units is unambiguous. This raises an important issue. We have already argued that recommendations must, typically, be expressed at a high level of abstraction if they are to inform the safety of a wide range of different applications. Unfortunately, this also creates opportunity for ambiguity as individual managers have to interpret those recommendations within the context of their own working environment. Peer review and limited field testing can be used to increase confidence that others can correctly interpret the actions that are necessary to implement particular recommendations. If such additional support is not elicited then there is a danger that specific recommendations will be rejected as inapplicable or, conversely, that generic recommendations will be result in a range of potentially inappropriate remedies. At the very least, scrupulous peer review should help to identify 'gross level' inconsistencies. For instance, the US Army Safety Centre reported an incident in which a soldier fell while attempting to negotiate an 'inverted rope descent' [814]. The subsequent investigation a discrepancies between the recommended practices for the construction and use of the obstacle. For example, previous training related incidents had led to the development of standard FM 21-20. This requires that the obstacle should include a platform at the top of the tower for the instructor and the student. A safety net should also be provided. This standard also requires that the obstacle should be constructed to reflect the Corps of Engineers drawing 28-13-95. Unfortunately, this diagram does not include a safety net or a platform. The incident investigators, therefore, concluded that 'confusion exists concerning the proper design and construction of this obstacle'. Following the incident, the army had to suspend the use of their inverted rope descent obstacles until platforms and safety nets had been provided in accordance with FM 21-20. The 28-13-95 diagram was also revised to remove any potential inconsistency.

The previous incident shows how particular failures often expose inconsistent recommendations. Fortunately, many of these problems can be identified before an incident occurs. For example, the US General Accounting Office was requested to monitor the implementation of recommendations following Army Ranger training incidents [290]. They identified a range of problems, not simply in the implementation of those recommendations but also in the way in which those recommendations had been drafted in the first place. For example, one recommendation required that the Army development 'safety cells' at each of the three Ranger training bases. These were to include individuals who had served long enough at that base to have developed considerable experience in each geographic training area so that they understood the potential impact of weather and other local factors on training safety. Safety cells were also to help officers in charge of training to make go/no go decisions. However, the National Defence Authorisation Act that embodied these provisions did not establish specific criteria on the makeup of a safety cell. The General Accounting Office concluded that the approach chosen by the Army 'represents little change from the safety oversight practice that was in place' at the time of the incidents [290]. They also found more specific failures that relate to the implementation of previous recommendations rather than to potential ambiguity in the proposals themselves. For example, the Army Safety Program recommended that safety inspections are conducted on an annual basis. The Fort Benning Installation Safety Office failed to conduct any inspections of training operations safety at the Brigade or its battalions between March 1993 and March 1996.

Chapter 14.5 addresses the problems and the benefits of monitoring incident reporting systems. It is important to stress, however, that inspections such as that performed by the US General Accounting Office on Ranger Training, can satisfy several objectives. These inspections can be used to expose deliberate failures to implement particular recommendations. They can identify inadvertent neglect; situations in which staff did not know that particular recommendations had been made. These audits also help to recognise genuine difficulties in the interpretation and implementation of remedial actions. Arguably the most significant benefit of such monitoring is that it can be used to institutionalise procedures that help to ensure compliance with key recommendations. For example, the Ranger investigation found that inspections by the Infantry Center, Brigade, and the Fort Benning Safety Office did not monitor compliance with safety controls. In particular, they failed to check that training officers set up minimum air and land evacuation systems before daily training. They also failed to monitor whether instructors adhered to rules prohibiting deviations from planned swamp training routes. The General Accounting Office report concluded that:

> "The inspections are focused instead on checklists of procedural matters, such as whether accidents are reported and whether files of safety regulations and risk assessments are maintained. If the important corrective actions are to become institutionalised, we believe that formal Army inspections will have to be expanded to include testing or observing to determine whether they are working effectively." [290]

The previous paragraphs have argued that monitoring programs can be used to detect potential ambiguity in the recommendations that are issued by incident investigators. They can also assess whether or not those recommendations are being acted upon. This approach does, however, suffer from a number of limitations. Unfortunately, the US General Accounting Office's review of Ranger training only provide a very limited snapshot of one particular area of activity. It ran from September through November 1998 'in accordance with generally accepted government auditing standards' [290]. It involved briefings from Brigade officials. Inspectors observed training exercises and reviewed safety procedures at each battalion's facilities. To determine the level of compliance, they interviewed Brigade officials. They also reviewed Army and Infantry Center inspection regulations, procedures, and records. Personnel were deployed to the Department of the Army headquarters, Army Infantry Center, Ranger Training Brigade headquarters, and the Ranger training battalions at Fort Benning, Dahlonega, Georgia, and Eglin Air Force Base, Florida. The extensive nature of such investigations helped to improve the quality of the eventual report. It also, however, contributed significantly to the costs associated with ensuring compliance. Such techniques cannot easily be applied to support local incident reporting systems where funds may be very tightly controlled. Conversely, they cannot easily be applied to monitor the implementation of recommendations throughout large-scale national systems. For instance, the Modification Work Order (MWO) program was intended to ensure that safety alerts and other maintenance notices were consistently implemented across the US Army [289]. The objective was the enhance fielded weapon systems and other equipment by correcting 'any identified operational and safety problems'.

The implementation of this program was complicated by the number of advisories that it had to track. For example, the US Army approved 95 Modification Work Orders for its Apache helicopter between 1986 and 1997. The implementation of this program was further complicated by the diverse nature of these recommendations. For example, one procedure introduced a driver's thermal viewer, a battlefield combat identification system, a global positioning receiver and a digital compass system into Bradley Fighting Vehicles. The introduction and integration of such relatively sophisticated equipment poses considerable logistical challenges. The MHW program was also intended to monitor less complex modifications. For example, early versions of the Army's High Mobility Multipurpose Wheeled Vehicles utilised a two-point seatbelt restraint system. This did not contain the inertial stopping device that is a standard feature of most civilian vehicles [815]. In consequence, users must remember to remove all of the slack from the retractor and to tighten the seatbelt. This procedure was described and recommended in a safety advisory (TM 9-2320-280-10). Modification Work Order 9-2320-280-35-2 then recommended the installation of a three-point seatbelt system.

A centralised database was developed to record the progress of different maintenance recommendations. Queries could be issued by Army headquarters officials and Army Materiel Command officials to ensure that individual units met the timescales and objectives that were recommended in safety notices. Unfortunately, the centralised database was discontinued following a structural reorganisation in 1990. Control over modification installation funding was transferred from the headquarters level to the individual program sponsors who are responsible for major weapon systems, such as the Abrams tank, or for product centres that support particular pieces of equipment, such as the Squad Automatic Weapon. The result of this decentralisation was that 'Army headquarters and Army Materiel Command officials do not have an adequate overview of the status of equipment modifications across the force, funding requirements, logistical support requirements, and information needed for deployment decisions' [815].

This lack of information also affected field units. It was difficult for maintenance personnel to known which modifications should have been made to particular items of equipment. Similarly, it was difficult to determine which modifications had actually been made. For instance, depot personnel at Anniston Army Depot, Alabama, had to visually inspect 32 National Guard trucks because they had no way of knowing whether two authorised modifications had been made when the vehicles arrived. The difficulties associated with tracking modification recommendations also had knock-on effects. Engineers did not always receive necessary technical information. A General Accounting Office report described how division maintenance personnel did not receive revisions to the supply parts manual for the fuel subsystem on Apache attack helicopters. The aircraft were then grounded and the maintenance team wasted many hours troubleshooting because the old manual did not provide necessary information about a new fuel transfer valve [289]. The lack of an adequate monitoring system created a number of additional logistical problems. For example, it was difficult for engineers to coordinate the implementation of multiple modifications to individual pieces of equipment. In consequence, the same item might be repeatedly removed from service while multiple modification orders were completed. Maintenance teams did not receive adequate notice of modifications. Some items of equipment did not always work together after modifications. This loss of integration further delayed other maintenance procedures and reduced operational capability. For instance, modified parts were removed from Huey utility helicopters. Non-modified parts were then reinstalled because there were no modified parts in stock when the new parts broke. Such practices further exacerbated the problems that were created when responsibility for the database was distributed from headquarters control. The configuration of equipment was not always accurately portrayed in the database used by the maintenance personnel and Army headquarters officials.

A number of recommendations were made as a result of the General Accounting Office report. These included steps to ensure that program sponsors and supply system personnel supported modification orders by providing appropriate spare parts after the initial order had been implemented. The report also recommended that personnel should update technical information whenever a modification order was being performed. Old spare parts were to be 'promptly' phased out and new items were to be added to the units supply system. One of the ironies of incident reporting is that the Accounting Office does not propose monitoring mechanisms to ensure that its recommendations about monitoring practices are effectively implemented!

This section has shown the difficulties of ensuring that the recipients of particular recommendations can unambiguously determine their meaning. It has also illustrated the technical and logistical problems of ensuring that safety recommendations are implemented in a uniform manner across complex organisations. Companies that lack the technological and financial infrastructure of the US Army are likely to experience even greater problems in ensuring that recommendations are successfully implemented. Chapter 14.5 will describe a number of tools that can be used to address these problems. In contrast, the following sections present techniques that are intended to help investigators identify the recommendations that are intended to combat future failures.

12.2 Recommendation Techniques

A range of techniques have been proposed to help investigator determine the best means of reducing the likelihood, or of mitigating the consequences, of safety-critical failures. Many of these approaches address the problems that were identified in previous sections. For example, some techniques provide methodological support so that the analysis of similar incidents should yield similar findings. They provide a template for any analysis so that disputes can be mediated by reference to the approved technique. Ambiguity can be resolved by encouraging a consistent interpretation of recommendations that are derived from the approved system. The following paragraphs briefly introduce a number of different approaches. These are used to identify potential recommendations from an explosives incident that took place during a nighttime training exercise. The intention was that two maneuver platoons would lead supporting engineer squads across the line of departure. These elements would be followed by a third maneuver platoon. The two lead platoons were to occupy support-by-fire positions. The engineers and the third maneuver platoon were then to occupy 'hide' positions some twenty-five meters from a breaching obstacle. This was to be a triple-strand concertina wire barricade.

The breach exercise was rehearsed a number of times. There was a daytime walkthrough without weapons, munitions or explosives. This was followed by a 'dry fire' exercise in which the plan was rehearsed with weapons but without munitions or explosives. A team leader and two team members would use 1.5 meter sections of M1A2 Bangalore torpedoe to breach the concertina obstacle. The team leader would then pass elements of the initiation system to the team members. They were to tie in the torpedoes to the detonating cords. The initiation system 'consisted of a ring main (detonating cord about 3 to 4 feet formed into a loop) with two M14 firing systems (approximately 4 feet of time fuse with blasting cap affixed to one end) taped to the ring main' [819]. At the opposite end of the M14 firing systems was an M81 fuse igniter that had been attached before the start of the operation. The intention was that the team leader would give each team member one of the M81 fuse igniters. On his command, they were then to pull their M81 and initiate the charge. The breaching team were then to retreat to their original hiding place. The detonation was to act as a further signal for a marking team to use chemical lights to help the following platoons locate the breach.

The actual exercise began when the breaching team approached the concertina objective. The two team members successfully placed their Bangalore torpedoes on either side of a potential breach site. The leader then handed the initiation system to them so that they could tie-in the Bangalore detonating cord lines. The team leader then handed one of the two M81 igniters to the team member on the left-side of the breach. The team leader departed from the original plan when he placed the second M81 on the ground between the two team members. Instead, he handed a bag containing approximately eight meters of detonating cord and an extra M14 initiation system to the team member on the right-hand side of the intended breach. The team leader then radioed the platoon leader to inform them of his intention to fire the charges.

The left-side team member picked up the M81 fuse igniter that had been left on the ground. He also had the original M81 that had been given to him by the team leader. The right-hand team member held the two M81s from the bag. The team members pulled the M81 fuse igniters on the leader's order 'three, two, one, PULL'. A Battalion S3 (operations, planning, and training officer) observed the burning fuses and the added charge in the bag which had been placed to the right of the Bangalore torpedoes. He asked about the additional charge but did not receive any reply. The demolition team and the S3 then moved back approximately twenty-five meters to separate hiding locations. As intended, the detonation acted as a signal for the marking team and a security team to rush towards the intended site of the breach. A second, larger, detonation occurred some three to five seconds after the first. Both of the approaching teams were caught by the resulting blast. The initial detonation had been caused by the additional charge in the bag that had been handed to the team member on the left of the breach. The second explosion was caused by the Bangalore torpedoes.

Chapters 9.3 and 10.4 have introduced a number of analysis techniques that can be used to identify the causal factors from this incident. For instance, ECF charts might be used to reconstruct the flow of events leading to the failure. Counterfactual reasoning can then be applied to distinguish causal from contextual factors. Table 12.2 illustrates the results of such an analysis. This tabular form is based on the ECF summaries shown in Tables 10.16 and 10.17. Only causal factors are shown, contributory factors are omitted for the sake of brevity. As might be anticipated, the results of this analysis are similar to the causal findings produced by the US Army technical Centre for Explosives Safety [819]. The original reports do not, however, state whether any particular analytical techniques were used to support the causal analysis of this incident. The justifications associated with the causal factors in Table 12.2 must, therefore, be inferred from the supporting documentation.

The following paragraphs illustrate a range of techniques that can be used to identify particular recommendations once investigators have conducted an initial causal analysis. As will be apparent, there is a considerable imbalance between the number of techniques that might help to identify the causes of an incident and the number of approaches that support the identification of particular recommendations. A cynical explanation for this might be that there is a far greater interest in diagnosing the causes of managerial failure or human error than there is in divising means of addressing such incidents [410]. Alternatively, it can be argued that the identification of recommendations depends so much on the context of an incident and upon the expertise of the investigator that there is little hope of developing appropriate recommendation techniques. However, ad hoc approaches have resulted in inconsistent recommendations for similar incidents. We have also seen ambiguous guidelines that have contributed to subsequent accidents.

The following pages introduce five distinct types of recommendation technique. These distinctions reflect important differences in the role that the particular approaches play within the reporting system as a whole. Some techniques embody the idea that recommendations are imposed upon those who are to 'blame' for an incident. Other techniques reject this approach and provide more general heuristics that are intended to link recommendations more directly to the products of causal analysis techniques, such as ECF analysis. This opens up the scope of potential recommendations; operator failure and human error are not the focus for any subsequent analysis. Other techniques have built upon this link between recommendations and causal analysis by explicitly specifying what actions

Cause	Justification
The breaching team leader failed to turn in excess demo material to the ammunition supply point.	The incident would not have happened if the bag containing the additional M14 initiation system and detonating cord had been handed in.
Excess demolition material was not tied into the ring charge.	The incident would not have happened if all charges had been detonated together.
Addition of the second charge was not planned, practiced or communicated to the other participants.	The incident might not have occurred if the marking and security teams had been aware of the second charge.
There was no appointed command-directed observer/controller at the breaching site.	The incident might not have occurred if a controller had been monitoring the use of the second charge. They might have intervened to prevent the separate detonation of this material.
Breaching team members failed to question or stop the deviated and unpracticed operation.	The incident might not have occurred if team members had questioned the use of the M14 initiation system and detonating cord in the bag.
Battalion S3 (operations, planning, and training officer) recognised but failed to stop the deviated and unpracticed operation.	The incident might not have occurred if they had intervened more directly when their question about the bag went unanswered.
Marking team leader took up hide position closer than the authorised 50 meters to the breaching site.	The consequences of the incident might have been significant reduced if they had been further from the detonation site.
Marking team leader unable to distinguish between the initial (smaller) detonating cord detonation and the larger Bangalore detonation.	The incident might have been avoided if the marking team leader had been able to recognise that the initial detonation was not large enough to have been the Bangalore torpedoes.

Table 12.2: Causal Summary for Bangalore Torpedo Incident.

should be taken whenever particular causal factors are identified. A further class of techniques exploit accident prevention models to identify potential remedies. For instance, barrier analysis approaches look beyond the ‘source’ of an incident to analyse the defences that fail to mitigate the consequences of particular failures. Unfortunately, a number of practical problems can complicate these broader approaches. Financial and technical constraints can prevent commercial organisations from implementing all of the recommendations that might prevent the causes of an incident and might provide additional protection against the adverse consequences of those failures. A final group of techniques, therefore, exploits concepts from risk assessment to help identify and prioritise the interventions that might safeguard future operations:

1. *recommendations based on blame or accountability.* These recommendation techniques help investigators to remedy the failings of groups or individuals who are ‘at blame’ for an incident or accident. The intention is to ‘put their house in order’. As we shall see, these recommendation techniques are consistent with legal approaches to accident and incident prevention. Prosecution is perceived to have a deterrent effect on future violations. In consequence, recommendations may include an element of retribution or atonement in addition to any particular actions that are intended to have a more direct effect on the prevention of future failures.

2. *recommendation heuristics.* A second class of recommendation techniques take a broader

view both of the causes of incidents and the potential recommendations that can be used to combat future failures. These techniques draft high-level heuristics that are designed to help investigators derive appropriate remedies from the findings of any causal analysis. They provide guidelines such 'ensure that a recommendation is proposed for each causal factor that has been identified during the previous stages of analysis'. Other heuristics describe appropriate implementation strategies. For instance, it might be recommended that 'an individual or organisation is associated with the implementation of any recommendation'. Unfortunately, such ad hoc heuristics provide few guarantees that individual investigators will propose similar remedies for similar failures. There is a danger that inconsistent recommendations will be made within the same reporting system.

3. *navigational techniques (enumerations, lists and matrices).* Instead of focusing on notions such as retribution or blame, a further class of techniques are specifically intended to improve the consistency of particular recommendations. These approaches often enumerate the interventions that investigators should approve in the aftermath of particular failures. For instance a list of recommendations may be identified for each class of causal factors. One consequence of this is that the utility of these techniques is often determined by the quality of the causal analysis that guides their application.

4. *generic accident prevention models.* It can be difficult to enumerate appropriate recommendations for classes of incidents that are still to occur. The dynamism and complexity of many working environments can prevent investigators from identifying effective interventions from pre-defined lists. In consequence, a further class of techniques provides general guidance about ways of improving the barriers and defences that may have been compromised during an incident. Investigators must then interpret this general information within the specific context of their system in order to draft recommendations that will preserve the future safety of an application process. Accident prevention models, including barrier analysis, have been extended to consider mitigating factors. This is important because investigators can use these extended models not simply to consider ways of addressing the causes of complex failures, they can also use them to consider ways of control the consequences of incidents whose causes cannot be either predicted or eliminated [677, 315].

5. *risk assessment techniques.* A number of problems complicate the application of ad hoc approaches and techniques that rely upon accident prevention models to identify incident recommendations. In particular, they provide little guidance on whether particular recommendations ought to have a higher priority that other potential interventions. This is important given the finite resources that many commercial organisations must allocate to meet any necessary safety improvements. It can be argued that such priority assessments are the concern of the regulatory organisations that approve the implementation of investigators' findings. Such a precise division of responsibilities cannot, however, be sustained in more local systems. In consequence, the closing paragraphs of this section consider ways in which risk assessment techniques can be used to identify the priority of particular recommendations. Subsequent chapters consider the regulatory use of these approaches to monitor the overall performance of incident reporting systems.

The following paragraphs assess the strengths and weaknesses of these different approaches in greater detail. Subsequent sections examine the problems of validating the particular remedies that are identified by such recommendation techniques.

12.2.1 The 'Perfectability' Approach

The simplest recommendation technique is to urge operators to do better in the future. In this view, it can be argued that 'if a system demonstrates its underlying reliability by operating without an incident for a prolonged period of time and given that no physical systems have failed then any subsequent failure must be due to operator error'. Such human failures can be corrected by reminding users of their responsibility for an incident. Changes can be made to training procedures and recommended working practices to help ensure that an incident does not recur. Such recommendations are based on the idea that it is possible to avoid future incidents by perfecting previous human 'errors'. This 'perfectability' approach has numerous advantages beyond its apparent simplicity. For instance, reminders are often the cheapest form of remedial action [479]. One consequence of electronic communication facilities is that there be almost no marginal cost associated with sending safety-related emails to members of staff. Of course, such repeated reminders can impair the effectiveness of a reporting system if staff are alienated by repeated reminders about well-known topics [411]. On the other hand, reminders can also be issued more quickly than almost any other safety recommendation. This offers considerable advantages over the length of time that is typically required to implement the re-design of key system components.

Elements of the perfectability approach can be identified in most military regulations. For instance, punitive actions are often prescribed as appropriate remedies when personnel disregard the permits and mandatory obligations that are imposed upon them:

> "the revocation ... of permits to conduct nuclear activities or hold ionizing radiation sources (and) the removal of inventory of ionizing radiation emitting devices from an organisation; and disciplinary or administrative action under the National Defence Act in the case of Canadian Force members and the application of all available administrative measures in the case of Department of National Defence employees. Director General Nuclear Safety may also recommend criminal prosecution." [132]

Similar injunctions have been drafted to ensure that personnel take necessary safety precautions during more mundane activities. For example, the Canadian military stipulates the circumstances in which individuals must wear safety helmets and goggles when operating snowmobiles. Departures from these regulations can be interpreted as instances of individual negligence or of willful violation [133].

Previous researchers have focussed almost exclusively on the use of punishments to 'perfect' operator behaviour in the aftermath of incidents and accidents [701]. It is important to recognise, however, that many organisations operate more complex systems in which rewards may also be offered for notably good performance during near-miss occurrences. For example, the US Army operates a range of individual awards that recognise notably good performance in avoiding incidents and accidents. These include the Chief of Staff Award for Excellence in Safety Plaque, the United States Army Safety Guardian Award, the Army Aviation Broken Wing Award, the Director of Army Safety Special Award of Excellence Plaque, the United States Army Certificate of Achievement in Safety and the United States Army Certificate of Merit for Safety [798]. Such recognition need take little account of the context that may have created the need for individuals to display such acts of bravery and initiative.

Table 12.3 illustrates how the perfectability approach can be applied to the Bangalore case study. As can be seen, each cause describes a failure on the part of an individual. Recommendations are then drafted to ensure that those individuals learn from their apparent mistakes. For instance, the breaching team leader failed to turn in excess materials during the exercise. They should, therefore, be trained in the importance of following such turn-in procedures. Similarly, the marking team leader failed to distinguish between the smaller initial explosion of the detonating cord and the main charge provided by the Bangalore torpedoes. They should, therefore, receive training that might help them discriminate between such different types of detonation.

Table 12.3 deliberately provides an extreme example of the 'perfectability' approach. It illustrates some of the practical problems that arise during the application of this approach. For example, each recommendation is focussed on a particular individual. They, therefore, do not draw out more general lessons. These recommendations neglect the opportunities that an incident might provide for revising the training of all personnel involved in breaching and marking exercises. Further problems stem from the limited effectiveness that such individual recommendations might have in the aftermath of comparatively serious incidents. It is highly unlikely that the individuals involved in this incident would need to be reminded of their individual shortcomings given the consequences of their 'errors'. Such objections can be addressed by drafting recommendations to 'perfect' the performance of groups rather than individual. For instance, the first recommendation in Table 12.3 might be

Cause	Individual Recommendation
The breaching team leader failed to turn in excess demo material to the ammunition supply point.	The breaching team leader should be reminded of the proper procedures for the turn-in of excess munitions.
The breaching team leader did not ensure that any excess demolition material was tied into the ring charge.	The breaching team leader should be reminded of the proper procedures for the disposal of excess munitions. The use of a 'last-shot' to dispose of excess munitions is a dangerous practice and creates the opportunity for such failures.
The breaching team leader's addition of the second charge was not planned, practiced or communicated to the other participants.	The breaching team leader and the exercise safety officer must be reminded of their responsibility to consider the consequences of and communicate necessary information about any unplanned changes to an exercise.
There was no appointed command-directed observer/controller at the breaching site.	The officer in charge of the exercise should be reminded of the need to appoint observers to intervene during potentially hazardous training operations.
Breaching team members failed to question or stop the deviated and unpracticed operation.	Breaching team members must be reminded of their duty to immediately stop any unsafe life threatening act.
Battalion S3 (operations, planning, and training officer) recognised but failed to stop the deviated and unpracticed operation.	Battalion S3 must receive additional training to ensure that they intervene if similar situations arise in future training exercises.
Marking team leader took up hide position closer than the authorised 50 meters to the breaching site.	The marking team leaders must be reminded to follow the required distance regulations specified in IAW FM 5-250.
Marking team leader was unable to distinguish between the initial (smaller) detonating cord detonation and the larger Bangalore detonation.	The marking team leader must be trained to a point where they can distinguish between such different types of detonation.

Table 12.3: 'Perfectability' Recommendations for the Bangalore Torpedo Incident.

applied to all individuals who perform similar tasks to the breaching team leader; 'all personnel must be reminded of the proper procedure for turning-in excess munitions'. This more general approach leads to further problems. For instance, some reporting systems provide participants with apparently random reminders about particular safety procedures. It can be difficult for individuals to follow the justification for these reminders if they are not kept closely informed of the incidents that motivate safety managers to reinforce these particular guidelines. Chapter 13.5 will describe techniques that can be used to address these potential problems. For now, however, it is sufficient to emphasise that a host of further problems complicate the application of the perfective approach to drafting incident recommendations. In particular, the perfective approach often relies upon demonstrating that individuals have in some way contravened regulations and procedures that they ought to have followed. This creates problems when an incident is not covered by any applicable regulation. It then becomes difficult to argue that individual operators should have intervened to mitigate a potential failure. One ad hoc solution is to continually redraft procedures in a (probably) futile attempt to codify appropriate behaviour in all possible situation. For instance, the US Army Safety Policies and Procedures for Firing Ammunition for Training, Target Practice and Combat contains a requirement that:

> "Accidents caused by firing or evidence that would indicate that the safety provisions of this regulation are inadequate will be reported by letter. The letter must give all pertinent information on the alleged inadequacy of the regulation" [796]

Further problems affect the punitive measures that are associated with the perfective approach. For example, it can be difficult to know exactly what sanctions can be applied to address particular errors and violations. These measures can be influenced by local practices within particular organisations but they are ultimately governed by legislation. Chief Justice Lamer of the Supreme Court of Canada explained in R. v. Généreux in 1992:

> "The purpose of a separate system of military tribunals is to allow the Armed Forces to deal with matters that pertain directly to the discipline, efficiency and morale of the military. The safety and well-being of Canadians depends considerably on the willingness and readiness of a force of men and women to defend against threats to the nation's security. To maintain the Armed Forces in a state of readiness, the military must be in a position to enforce internal discipline effectively and efficiently. Breaches of military discipline must be dealt with speedily and, frequently, punished more severely than would be the case if a civilian engaged in such conduct. As a result, the military has its own Code of Service Discipline to allow it to meet its particular disciplinary needs. In addition, special service tribunals, rather than the ordinary courts, have been given jurisdiction to punish breaches of the Code of Service Discipline. Recourse to the ordinary criminal courts would, as a general rule, be inadequate to serve the particular disciplinary needs of the military. There is thus a need for separate tribunals to enforce special disciplinary standards in the military." [130]

The Chief Justice refers to the importance of punishing breaches of the Code of Service Discipline in order to preserve the 'safety and well-being' of the Armed Forces. This may seem to be a relatively clear-cut decision. There are, however, situations in which there are legal barriers that prevent the application of the 'perfectability' approach even though organisations might want to impose particular sanctions. For instance, a former Sergeant in the Canadian Army found himself as a defendant in a standing court martial when he refused to receive an anthrax vaccination while deployed in Kuwait [142]. His opposition was described as 'unsafe and hazardous'. The case was, however, stopped when the defence cited the Canadian Charter of Rights and Freedoms. This is one of several similar cases in which individuals have used legal arguments to defend themselves against punitive sanctions. Such defences must be provided because there is a danger that superiors may apply 'perfective' sanctions for personal rather than professional reasons. Article 138 of the Uniform Code of Military Justice, section 938 of title 10, United States Code provides one such defence. This article enables a member of the US Armed Forces to seek redress for grievances against a commanding officer and, if redress is denied, to file a formal complaint against that officer. The Judge Advocate General of the Army will then review and take final action on such 'Article 138' complaints.

In more serious cases, sanctions cannot simply be applied by commanding officers. They must be supported by legal argumentation in court martials. Even here, however, there are checks and balances that prevent the arbitrary application of the 'perfective' approach. For example, two of the six appeals currently recorded by the Canadian Judge Advocate General relate to military personnel challenging sanctions that are imposed following safety-related incidents. Such incidents illustrate the more general, pragmatic problems that make it difficult to identify appropriate recommendations within the 'perfective' approach. Training can be ineffective if it is not supported by practical demonstrations and almost constant reminders of the importance of key safety topics. These constant reminders can alienate staff unless properly motivated by concrete, 'real-world' examples. Conversely, more punitive sanctions can be administered by organisations. These legal sanctions are bounded by the civil law and, in the context of our case study, by military law. The development of human rights legislation and of case law that stresses the importance of performance shaping factors as well as individual violations has helped to 'draw the teeth' of the perfective approach in many application domains.

There are a number of theoretical reasons why the perfective approach offers dubious support for investigators and regulators. Recommendations that are intended to perfect operator behaviour often lead to a vicious cycle in which employers become increasingly frustrated by recurring incidents. Reason terms this process the 'blame cycle'. This cycle is based on the notion that operators exercise free will in the performance of their daily tasks [702]. They are assumed to be free to choose between right and wrong, between error-free and error-prone paths of interaction. Any incidents and accidents that do occur are, therefore, partly the result of voluntary actions on the part of the operator. As we have seen, employers and regulators who adopt the 'perfectability' approach are likely to respond to such failures by reminding individuals of their responsibilities and duties. Retraining may be used to reinforce key safety information. Warnings about the consequences of violation are, typically, reiterated after particular incidents. Unfortunately, these recommendations and remedial actions may not address the underlying causes, or performance shaping factors, that created the context in which an 'error' occurred. In consequence, it is likely that there will be future incidents. When these occur, employers and regulators are increasingly likely to resort to additional sanctions and punishments for what they interpret to be willful violations of publicised procedures. Their response to recurrent incidents can be driven by the 'fundamental attribution error' that we have met several times in previous chapters [702]. This arises describes situations in which we ascribe the failure of others to personal characteristics, such as neglect or incompetence, when in similar circumstances we might justify our own mistakes by pointing to contextual factors, such as the level of automated support or time pressures. If punitive sanctions are introduced then they can have the paradoxical effect of making future incidents more likely. They may increase the level of stress in the workplace or may increase a sense of alienation between the employees and their supervisors. In either case, future incidents are likely unless the underlying causes are addressed and so the cycle continues.

To summarise, the 'perfective' approach drafts recommendations that are intended to avoid any recurrence of particular individual errors. This approach is limited because recommendations often address the causes of catalytic failures rather than the causes of more deep-seated managerial and organisational problems. Reason [702], Hollnagel [363], Perrow [677] and Leape [479] have done much to challenge previous applications of this perfective approach. They draw upon a wealth of evidence to suggest that punitive sanctions, individual retraining and constant reminders may have little long-term effect on the future safety of complex, technological systems. There is, however, a need for balance. Any consideration of the context in which an incident occurs must not obscure individual responsibility for certain adverse occurrences. For example, it is possible for risk preferring individuals to alter their behaviour when responding to particular situations in their working environment [370]. It then becomes difficult to distinguish between situations in which those individuals fail to recognise the potential danger inherent in a particular situation, for example because they did not receive adequate training, and situations in which they deliberately choose to accept higher risks in the face of adequate training. There is, therefore, a tension between the need to recognise the impact of contextual or performance shaping factors and the importance of an operator's responsibility for their actions. Many organisations have drafted guidelines that recognise this tension. For instance, the US Air Force's guidance on Safety Investigations and Reports contains the following advice about the drafting of recommendations:

> "5.10.1.5. Write recommendations that have a definitive closing action. Do not recommend sweeping or general recommendations that cannot be closed by the action agency. Vague recommendations addressing the importance of simply doing ones job properly are also inappropriate. However, recommendations to place CAUTIONS and WARNINGS in Technical Order guidance relating the adverse consequences of not doing ones job properly may be appropriate. Recommendations for specific action such as refresher training, implementing in-process inspections, etc. to ensure job duties are being properly performed may also be appropriate since they are specific, and can be closed." [795]

This reflects the tension that exists between the impact of more recent ideas about the organisational roots of many incidents and the 'perfective' notions of free will and individual responsibility. The USAF guidelines reject the 'perfective' notion that individuals should be encouraged to do their job properly. They do, however, accept that it may be necessary to warn operators about the consequences of failing to do their job properly.

12.2.2 Heuristics

Most incident reporting systems provide only a limited guidance about the techniques that investigators might use to derive conclusions for the results of a causal analysis. The NASA procedures and guidelines (NPG 8621.1) that structured the analysis in Chapter 9.3 recommend seven different causal analysis techniques. In contrast, they offer no suggestions about techniques that might be used to identify potential remedies once causes have been determined [572]. There are good reasons for this reticence. As has been mentioned, a relatively large number of techniques have been proposed to support causal analysis while only a handful have been developed to help structure the identification of recommendations. Those techniques that have been developed are not widely known and tend only to be applied within particular industries, such as chemical process engineering. This contrasts with a technique such as MORT which has been more widely applied and is known throughout many different safety-critical domains;

There are further reasons why some organisations fail to identify appropriate recommendation techniques. Many organisations have failed to propose specific techniques to support the process of identifying recommendations because there is a natural concern that such an approach might unnecessarily constrain the skill and judgement of investigators. A particularly important issue here is that considerable domain knowledge is needed when identifying appropriate remedies. Such expertise cannot easily be synthesised within recommendation techniques. This can be contrasted with causal analysis where it is possible to identify broad categories of failure that contribute to many different incidents. It is possible to challenge these diverse arguments. For instance, the lack of consistency between the recommendations of many investigators in the same industry seems to demonstrate that many do not currently share the same, necessary level of expertise. Similarly, as we shall see, some recommendation techniques have succeeded in identifying generic remedies that can be applied to particular causes in a broad range of industries.

Finally, management may lack the will or the commitment necessary to ensure that investigators follow approved methods when proposing particular recommendations. As mentioned, incident investigators tend to be highly skilled in primary and secondary investigation. Considerable expertise is required in order to direct the causal analysis of safety-critical incidents. In consequence, investigators yield considerable power and influence within investigatory and regulatory organisations. New techniques, that support either causal analysis or the identification or recommendations, can be perceived as a threat to their existing skills and expertise [687]. Many statutory bodies also fail to perform any quality control over the work of their investigators. This leads to a paradox. Investigatory and regulatory organisation do not follow the standardised working practices that they enforce on others.

Many organisations do provide high-level guidance to their investigators. For instance, the Canadian Army's safety program includes a five step guide to accident and incident investigation [131]. These steps are: visit the accident scene; conduct interviews; gather and record evidence; evaluate the evidence and draw conclusion; make recommendations. The following high-level advice is offered to support the final stage of this process:

> "Recommendations:
>
> 31. Once the cause factors have been identified, the investigator(s) recommend(s) preventive measures be taken based on the findings of the investigation. The basic aims when developing preventive measures are as follows: treat the cause and not the effect; ensure that the measures will enhance and not restrict overall operational effectiveness; ensure preventive measures eliminate or control all causes.
>
> 32. Simply recommending that the individual(s) involved by briefed contributes little. It merely indicates fault finding. If human factors (inaction or action - human error) is a

> cause, revising job procedures, training of all employees doing similar tasks and publicity of the accident, to name a few, would be more meaningful and certainly more productive.
>
> 33. If shortcomings in equipment, facilities or other resources are causes, then modifications, substitution or acquisition would be valid recommendations." [131]

This quotation illustrates the importance of eliminating or controlling all causes. Many organisations, therefore, require that investigators explicitly list the remedies that are proposed next to each cause of the incident. This enables colleagues to ensure that each cause is considered in an eventual report. A number of theoretical objections can be raised to this pragmatic objective. For example, the subjective nature of many causal analysis techniques provides few guarantees that this approach will address all of the causes that might possibly be identified in the aftermath of an incident or accident.

The previous quotation stresses the overall objective of operational efficiency. A number of caveats can also be made about this requirement. For example, the guidance does not provide a clear definition of 'operational efficiency'. In practice, therefore, staff may find particular problems in resolving the conflict that often arises between safety concerns and more efficient operational techniques. Paragraph 32 makes the important point that re-briefing soldiers should not be seen as a recommendation. Previous work has noted the tendency of many incident reporting systems to rely upon issuing dozens of similar warning messages [411]. Such 'remedies' provide cheap fixes and may neglect underlying safety issues. The following paragraphs will refer to this as the 'perfective approach' to issuing recommendations. Other organisations have issued more detailed guidance that is intended to help investigators derive particular recommendations from the findings of a causal analysis. For instance, the US Air Force's involvement in aviation incidents has led to the publication of extensive guidance on incident and accident reporting [795]. The following paragraphs use the USAF guidelines to identify a number of high-level recommendation heuristics.

Heuristic 1: Match Recommendations to Each Causal Factor

The USAF guidelines include the generic requirement that 'all mishap investigations should include recommendations to prevent future mishaps'. Like Canadian Army guidance, investigators are urged to match recommendations to each causal finding although exceptions are permitted if they are explicitly justified. Recommendations can also be made against non-causal findings. For example, an investigation may identify alternative ways in which an incident might have occurred. It is, therefore, important to draft recommendations that address both the causal chain that led to an incident as well as any other potential failures that might also have been identified.

Heuristic 2: Assign action agencies for all recommendations

Investigators must clearly identify an agency that will be responsible for ensuring that a recommendation is implemented. Safety management groups should not routinely be tasked to implement particular remedies. In contrast, investigators should identify those groups that manage the resources that are necessary to implement a recommendation. Investigators should also confirm that they have correctly identified a responsible authority providing that this does not compromise their work, for instance by fueling rumours about the potential recommendations.

Heuristic 3: Recommendations Correct Deficiencies

Rather than requiring that an agency should implement a particular solution, investigators should draft recommendations to correct deficiencies. For example, investigators might avoid proposals to 'move the right engine fire push-button to the right side of the cockpit'. In contrast, it would be better to recommend that 'changes should be made to the engine fire push-buttons to help preclude engine shutdown errors' [795]. This second approach goes beyond a simple instruction and helps to provide the rationale behind a particular recommendation. There are further justification for this heuristic. The time-pressures that affect many incident investigations can often prevent investigators from identifying all of the potential ways in which a problem might be addressed. Investigators may also lack the necessary, detailed, domain knowledge that is shared by particular system operators. They might, therefore, be able to device more optimal solutions to that recommended by an investigator in the immediate aftermath of an incident.

Heuristic 4: Recommendations Support Actions NOT Studies

Investigators should be encouraged to draft recommendations that support particular actions. If there is insufficient information upon which to base those actions then studies can be advocated but only as part of the process of implementing the higher-level recommendation. If investigators simply recommend that a study is conducted then there may be no guarantee that any actions will be based on the findings of such an enquiry. Similarly, if a recommendation refers to tests that are incomplete when the report is sent prepared then investigators must identify potential remedies that are contingent upon the outcome of such studies. These different recommendations must be explained and investigators should make explicit reference to the test. They should also explain the reasons why a report was issued before the analysis was completed.

Heuristic 5: Recommendations follow Implementation Paths

It is important that any recommendations take into account the correct procedures and paths for ensuring that corrective actions are implemented effectively. Part of this requirement can be satisfied by ensuring that the recommendation identified an appropriate implementation agency. There may also be other constraints depending on the nature of the recommendation and the organisation in which the incident occurred. For example, investigating officers who recommend changes to military documentation may be required to initiate those changes themselves. This involves the submission of revision requests by submitting the appropriate forms to the relevant office. For example, the USAF guidelines describe the use of the Technical Order System, or AF Form 847, Recommendation for Change of Publication (Flight Publications), according to AFI 11-215, Flight Manual Procedures 'as applicable' [795].

Heuristic 6: Recommendations Acknowledge Minority Opinions

In multi-party investigations, different investigators can have different degrees of influence on the drafting of recommendations. Problems arise when these 'primary' analysts disagree with the remedies proposed by their colleagues. Alternatively, investigators may hold equal influence but are divided into majority and minority opinions. In such circumstances, it is important that the dissenting opinions are voiced. Majority groups or primary investigators must justify their decision not to recommend certain courses of actions.

The USAF guidelines are unusual. They provide detailed heuristics for the identification of particular recommendations. Those heuristics are relatively informal. No explanation is provided for how they were drafted. The reader is not informed of any validation that might confirm the utility of this guidance. They do, however, reflect the pragmatic concerns that are commonly voiced by incident investigators [851]. The US Army's Army Accident Investigation and Reporting Procedures Handbook contains less detailed advice [807]. It does, however, summarise many of the points made in the equivalent USAF publication:

> "Recommendations. Each finding will be followed by recommendations having the best potential for correcting or eliminating the reasons for the error, material failure, or environmental factor that caused or contributed to the incident. Recommendations will not focus on organisational steps addressing an individuals failure in a particular case. To be effective at preventing incidents in the future, recommendations must be stated in broader terms. The board should not allow the recommendation to be overly influenced by existing budgetary, material, or personnel restrictions. In developing the recommendations, the board should view each recommendation in terms of its potential effectiveness. Each recommendation will be directed at the level of command / leadership having proponency for and is best capable of implementing the actions contained in the recommendation." [807]

As can be seen, there are also similarities between these guidelines and those issued by the Canadian Army. Both emphasise the 'effectiveness' of any recommendations. There are also differences. For instance, the US Army explicitly states that investigators need not be 'overly influenced' by existing budgetary constraints. All three of the organisational guidelines in this section emphasise the importance of directing recommendations at a responsible authority. However, the previous quotation not only stresses the need to identify an appropriate agency, it also stresses the need to specify an appropriate level of command within that organisation.

These guidelines are informal. They gather together ad hoc requirements that are intended to improve the quality of recommendations that are produced in the aftermath of safety-critical incidents. They are 'ad hoc' because they have not been integrated into a systematic method or process. Investigators must endeavour to ensure that they obey these guidelines as they develop individual recommendation. It is important to emphasise, however, that these comments should not be interpreted as overt criticisms. Informal guidelines provide important pragmatic advice that is essential given the relative lack of well-developed methods in this area.

Table 12.4 shows how the US Army Technical Centre for Explosive Safety's recommendations from our case study incident can be mapped onto the causal factors that were identified in Table 12.4. As can be seen, this summary explicitly identifies the responsible agency that was charged with implementing the recommendation. The tabular form also illustrates the relationship between recommendations and causal factors. As can be seen, some causal factors are not explicitly addressed. Similarly, some recommendations are not associated with an implementation agency. Table 12.5 also records a recommendation that was made in the incident report but which cannot easily be associated with any of the particular causal factors that were identified from this incident.

This analysis shows how a simple tabular form can be used, together with Army guidelines, as a form of quality control for the recommendations that are made in incident reports. Investigators might be asked to ensure that a recommendation is associated with each of the causal factors. For example, Table 12.5 does not explicitly denote any recommendation that might have helped to avoid situations in which excess demolition material is not tied into a ring charge. It can be argued that this cause is addressed by the previous entry describing how excess material must be turned in. If this analysis were accepted then Table 12.5 should be revised to explicitly associate this recommendation with both causes. Alternatively, it can be argued that this approach would not provide any 'defence in depth'. If excess munitions were not handed in then there is still a danger that the independent firing of charges might cause the same confusion that led to this incident. Under such circumstances, Table 12.5 should be revised by introducing an additional recommendation specifically addressing the detonation of excess material as part of another charge.

As mentioned, the case study incident report does not identify recommendations for each cause nor does it identify responsible authorities for the implementation and monitoring of each recommendation. It is not surprising that our case study does not conform to the US Army guidelines [807]. The recommendations that are cited in Tables 12.4 and 12.5 were derived from material that was used to publicise the remedies that were advocated in the main report. They were not directly taken from the report itself. The example does, however, illustrate the application of these informal guidelines to assess the recommendations that were publicised in the US Army Technical Centre for Explosive Safety's account of the incident. It can also be argued that many of the principles that are proposed in the army guidelines ought to have been carried forward into the accounts that are used to disseminate information about this failure to other engineers throughout that organisation.

12.2.3 Enumerations and Recommendation Matrices

The heuristics that were introduced in the previous section leave considerable scope for individual investigators. They provide guidance about the general form of particular recommendations, for instance by stressing the importance of identifying appropriate implementation paths. They do not directly help investigators to identify appropriate remedies for particular causal factors. In contrast, enumerated approaches list the possible recommendations that might be made in response to particular incidents. For example, the incident involving the Bangalore Torpedoe was analysed according to the US Army's Accident Investigation and Reporting pamphlet PAM-385-40. This

Cause	Recommendation	Agency
The breaching team leader failed to turn in excess demo material to the ammunition supply point.	Training and safety briefings must present and stress proper procedures for disposal/turn-in of excess munitions and/or explosives. Introduction of left over demolition materials into the last shot has been a longstanding accepted procedure. Such action violates the requirement to turn in all excess explosives.	Training and briefing officers
Excess demolition material was not tied into the ring charge.		
Addition of the second charge was not planned, practiced or communicated to the other participants.		
There was no appointed command-directed observer/controller at the breaching site.		
Breaching team members failed to question or stop the deviated and unpracticed operation.	All personnel must have confidence in their authority to immediately stop any unsafe life threatening act and exercise it accordingly.	All personnel
Battalion S3 (operations, planning, and training officer) recognised but failed to stop the deviated and unpracticed operation.	All personnel must have confidence in their authority to immediately stop any unsafe life threatening act and exercise it accordingly.	All personnel
Marking team leader took up hide position closer than the authorised 50 meters to the breaching site.	Inadequate personnel hide distance approximately 25 meters: Required distance (according to IAW FM 5-250) would have been 100 meters for a missile-proof shelter, 200 meters for a defilade position with overhead cover, 50 meters for Command waiver authorised defilade position.	Unspecified
Marking team leader unable to distinguish between the initial (smaller) detonating cord detonation and the larger Bangalore detonation.		

Table 12.4: Guideline Recommendations for Bangalore Torpedo Incident.

Cause	Recommendation	Agency
	The Phase 1 and Phase 2 walk through exercise, prior to live fire operation, is specifically designed to validate the safe execution for all elements of the live fire exercise. A thorough detailed review of all aspects of the operations should have identified the violation of the 50-meter safe hide distance. Had the marking team and security members been properly distanced from the breaching site, their survivability from injury would have been greatly increased.	All personnel, to include command-directed observer/controllers and safety representative, failed to identify violation of the waiver authorised minimum safe hide separation distance during walk through and dry fire iterations.

Table 12.5: Additional Recommendation for Bangalore Torpedo Incident.

enumerates potential root causes. It also provides a list of recommendations that must be considered when drafting the findings from any investigation:

"**Code: 01, Key Word/Explanation: Improve school training.**
The improvement recommended should be directed toward the content or amount of school training needed to correct the accident causing error. For example: a. Provide school training for the person who made the error due to not being school trained. b. Improve the content of a school training program to better cover the task in which the error was made. c. Expand the amount of school training given on the task in which the error was made.
Code: 02, Key Word/Explanation: Improve unit training.
The improvement recommended should be directed toward the content or amount of unit training needed to correct the accident causing error. For example: a. Provide unit training for the person who made the error due to not being unit trained. b. Improve the content of unit training to better cover the task in which the error was made. c. Expand the amount of unit training given on the task in which the error was made.
Code: 03, Key Word/Explanation: Revise procedures for operation under normal or abnormal/emergency conditions.
The changes recommended should be directed toward changing existing procedures or including new ones. If the change is to an AR, TM, FM, Soldiers Manual, or other Army publication, tell the date when Department of the Army Form 2028 was submitted.
Code: 04, Key Word/Explanation: Ensure personnel are ready to perform.
The purpose of this recommendation is to encourage supervisors to make sure that their people are capable of performing a job before making an assignment. They should consider training, experience, physical condition, and psychophysiological state (e.g., fatigue, haste, excessive motivation, overconfidence, effects of alcohol/drugs).
Code: 05, Key Word/Explanation: Inform personnel of problems and remedies.
This recommendation should be used when it is necessary to relay accident related information to people at unit, installation, major Army Command, or Department of the Army levels.
Code: 06, Key Word/Explanation: Positive command action.
The purpose of this corrective action is to recommend that the supervisor take action to encourage proper performance and discourage improper performance by his people.
Code: 07, Key Word/Explanation: Provide personnel resources required for the job.
This recommendation is intended to prevent an accident caused by not enough qualified people being assigned to perform the job safely.
Code: 08, Key Word/Explanation: Redesign (or provide) equipment or ma-

> **teriel.**
> This recommendation is made when equipment or materiel caused or contributed to an accident because: a. The required equipment or materiel was not available. b. The equipment or materiel used was not properly designed.
> **Code: 09, Key Word/Explanation: Improve (or provide) facilities or services.**
> This recommendation is made when facilities or services lead to an accident because a. The required facilities or services were not available. b. The facilities or services used were inadequate.
> **Code: 10, Key Word/Explanation: Improve quality control.**
> This recommendation is directed primarily toward the improvement of training, manufacturing, and maintenance operations where poor quality products (personnel or materiel) have led to accidents.
> **Code: 11, Key Word/Explanation: Perform studies to get solution to root cause.**
> This recommendation should be made when corrective actions cannot be determined without special study. Such studies can range from informal efforts at unit level to highly technical research projects performed by Department of the Army level agencies." [797]

This enumeration illustrates some of the problems that arise when attempting to guide the drafting of recommendations in the aftermath of accidents and incidents. As we have seen, the US Air Force guidelines specifically urge investigators not to draft recommendations that involve additional studies. Heuristic 4 in the previous section was that 'recommendations support actions not studies' [795]. In contrast, the US Army guidance includes code 11 that explicitly covers recommendations to perform studies which can identify solutions to 'root causes'. Such inconsistencies are unsurprising given that very few studies have addressed the problems of deriving appropriate recommendations from the outcome of causal analysis techniques.

Table 12.6 illustrates the way in which the PAM 385-40 guidelines can be applied to the Bangalore Torpedoe case study. As can be seen, each causal factor is addressed by one or more of the recommendations proposed by the army guidance material. PAM 385-40 does not specify the way in which an investigator might identify a particular recommendation for any particular causal factors. This is left to the skill and expertise of the analyst. The specific entries in Table 12.6 must, therefore, be validated by peer review. For this reason, it might also be appropriate to introduce an additional column that explains the reason why a recommendation code was associated with each causal factor. For example, a positive command action might address the unplanned addition of the second change because the "supervisor (would) take action to encourage proper performance and discourage improper performance by his people". This example illustrates the pervasive nature of the 'perfective' approach to incident reporting. The US Army guidelines contain several recommendations that reflect this corrective attitude towards operator involvement in accidents and incidents: 01 (improve school training); 02 (improve unit training); 03 (revise procedures...); 04 (ensure personnel are ready to perform); 05 (inform personnel of problems and remedies) and 06 (positive command action). None of the proposed recommendations addresses the organisational and managerial problems that have been stressed by recent research into the causes of accidents and incidents. Similarly, the proposed recommendations only capture a limited subset of the performance shaping factors that have been considered in previous chapters. These are partially covered by recommendation 04 that encourages supervisors to ensure that their teams are properly trained and in an adequate 'psycho-physiological state'.

Such objections can be addressed by extending the list of proposed recommendations. Additional codes can direct investigator towards recommendations that improve communications between different levels in an organisation or between regulators and line management. Unfortunately, the piecemeal introduction of new recommendation codes raises a number of further questions. For example, previous chapters have argued that the nature of incidents will change over time as new equipment and methods of operation are introduced into complex working environments. This argument has been used to stress the problems of identifying the generic causal factors that drive checklist approaches such as MORT, see Chapter 10.4. Similar problems arise when investigators

Cause	PAM 385-40 Recommendation
The breaching team leader failed to turn in excess demo material to the ammunition supply point.	Code 01 - improve school training. Code 06 - positive command action.
Excess demolition material was not tied into the ring charge.	Code 06 - positive command action. Code 10 - improve quality control.
Addition of the second charge was not planned, practiced or communicated to the other participants.	Code 02 - improve unit training. Code 06 - positive command action.
There was no appointed command-directed observer/controller at the breaching site.	Code 07 - provide personnel resources required for the job.
Breaching team members failed to question or stop the deviated and unpracticed operation.	Code 01 - improve school training. Code 02 - improve unit training.
Battalion S3 (operations, planning, and training officer) recognised but failed to stop the deviated and unpracticed operation.	Code 01 - improve school training. Code 06 - positive command action.
Marking team leader took up hide position closer than the authorised 50 meters to the breaching site.	Code 01 - improve school training. Code 06 - positive command action.
Marking team leader unable to distinguish between the initial (smaller) detonating cord detonation and the larger Bangalore detonation.	Code 01 - improve school training. Code 04 - ensure personnel are ready to perform.

Table 12.6: PAM 385-40 Recommendations for the Bangalore Torpedo Incident.

attempt to enumerate the recommendations that might be used to address these causal factors. It can be difficult to identify appropriate responses to future incidents. If thee could be predicted with any confidence then safety managers would deploy such remedies pre hoc in order to prevent incidents from occurring in the first place!

A number of further problems complicate the use of enumerations. Lists of approved recommendations can guide investigators towards effective remedies. There is equally a danger that they may bias analysts towards ineffective or even dangerous interventions. Chapter 14.5 will introduce a number of monitoring techniques that can be used to identify such potential problems. It is important to emphasise, however, that the elements in an enumeration must be carefully validated if they are not to advocate ineffective solutions. These problems are exacerbated by the delays that can arise before the publication of revised recommendation lists. In more ad hoc approaches, individual investigators can tailor their interventions to reflect local conditions and personal observations about effective remedies for particular root causes. Such practices can be constrained when analysts must select recommendations from an enumerated list of approved interventions.

PAM 385-40 enumerates the recommendations that US Army investigators must consider when drafting their reports. As mentioned previously, it does not prescribe which particular remedies should be proposed for particular causal factors. This is both a strength and a weakness of this application of a checklist or enumerated approach. This technique relies upon the skill and insight of the investigator to determine whether or not any of the eleven recommendations can be applied. This provides a degree of flexibility that can be important for organisations that are faced with diverse failures in many different geographical and functional areas. This flexibility creates problems. As we have seen, subjective factors and individual biases might affect an investigator's decision to propose one of these recommendations. Any potential inconsistency is reduced by selecting a remedy from the enumeration. There are, however, no guarantees that any two investigators will agree on the same recommendations from that list for any particular incident. Checklist approaches address these potential problems by providing guidance on which recommendations can be best used to address particular causal factors.

It is important to distinguish between recommendation techniques that simply list proposed remedies and those that provide more direct guidance about when to apply particular remedies. The previous section has illustrated the US Army's use of simple enumerations in PAM 385-40. In contrast, Chapter 10.4 has introduced the use of more directed approaches. For instance, Table 12.7 reproduces the Classification/Action matrices that from part of the PRISMA causal analysis technique. As can be seen, incidents that involve a failure in knowledge transfer within an organisation might result in recommendations to revise training and coaching practices. Failures that stem from operating procedures are addressed by revising procedures and protocols.

	Organisational Factors				
	External Factors (O-EX)	Knowledge Transfer (OK)	Operating procedures (OP)	Manag. priorities (OM)	Culture (OC)
Inter-departmental communication	X				
Training and coaching		X			
Procedures and protocols			X		
Bottom-up communication				X	
Maximise reflexivity					X

Table 12.7: Example PRISMA Classification/Action Matrix (2) [845]

The approach is more 'directed' than the enumeration presented in the previous section because investigators can identify appropriate recommendations by reading down the column that is associated with each causal factor. Conversely, if other participants in the investigatory process propose a particular recommendation then analysts can read along the rows of the Classification/Action matrix to determine whether this would be consistent with previous findings. Table 12.7 only associated a single recommended action with each causal factors. It is important to stress that this need not be the case in all application domains. For instance, problems involving knowledge transfer might be addressed by revised training procedures and by changes in protocols and procedures. Conversely, there may be situations in which 'cultural factors', such as deliberate violations of procedures, cannot simply be addressed by the 'maximise reflexivity' recommendation proposed in Van Vuuren's Classification/Action matrix. In such circumstance, investigators may not be able to directly read off an appropriate recommendation from such a table. Most of the proponents of this approach confirm this analysis by arguing that these matrices are intended as guidelines that can be broken after careful deliberation rather than rules that should be followed in all circumstances. In consequence, these matrices can only be relied upon to increase the consistency of the recommendations made by investigators. They are unlikely to ensure absolute agreement.

Table 12.7 was originally developed by Van Vuuren to help identify recommendations within Healthcare applications [845]. The precise nature of recommendation tables is determined by the context in which they are applied. For example, the causal factors that are represented as columns in the table must reflect the causal factors that are likely to be identified within a particular application domain. Conversely, the recommendations that form each row of the matrix must capture appropriate remedies for those causes. In terms of our case study, the rows of the matrix can be directly derived from the enumeration provided by PAM 385-40 [797]. Fortunately, the same document also provides an enumeration of potential causal factors. For instance, Table B5 lists 'System inadequacies/readiness shortcomings/root causes'. These can be incorporated into the matrix in a similar fashion to the recommendations that were enumerated in the previous section.

Tables 12.8, 12.9, 12.10 and 12.11 are directly derived from the causal codes and recommendation codes that are given in the US Army's guidance on incident and accident investigation [797]. The crosses represent the only additional information that has been introduced into the matrices. These are used to denote those recommendations that might be made given that particular causal factors have been diagnosed. For example, Table 12.8 shows that if an incident had been caused by inadequate supervision by higher command, investigators might consider recommendations that are intended to ensure that personnel were adequately prepared for the tasks that they were presented with (recommendation code 04). Additional recommendations might be drafted to increase the personnel available in an operation (07), to improve facilities (09) or to improve quality control on maintenance and support services (10). Conversely, Table 12.9 can be used to deduce that recommendations to perform more studies (recommendation code 11) might be proposed if there is evidence of inadequate school training (cause code 05) or inadequate unit training (cause code 06).

Not only can the drafting of recommendation matrices help investigators to move from a causal analysis to the findings of an incident report, they can also help to identify potential flaws in the guidance that is provided to investigators. For instance, Table 12.9 lists the causes that PAM385-40 associated with training failures. These include 'habit interference' (cause code 08). This occurs when 'a person makes an accident causing error because task performance was interfered with either in the way he usually performs similar tasks or the way he performs the same tasks under different operating conditions or with different equipment' [797]. As can be seen from the recommendation matrix, it is difficult to identify one of the approved recommendation codes that might be associated with this potential cause. Improved training, possibly following the principles of Crew Resource Management programmes, might address this problem. There is, however, considerable controversy about the effectiveness of such recommendations [412].

The recommendation matrices that we have derived from the PAM 385-40 codes can be applied to the Bangalore Torpedoe incident. For example, previous sections have argued that the Battalion S3 recognised but failed to question or stop the unrehearsed detonation of the excess munitions. This could have been caused by several factors. For instance, it might be argued that this stemmed from environmental factors such as the timescale available to complete the operation or the difficulty of communicating effectively with personnel during a night-time exercise (cause code 21). In such circumstance, investigators might use Table 12.11 to guide their analysis towards particular recommendations. For instance, investigators might advocate that additional measures be taken to ensure that S3's are prepared, in terms of individual training and safety briefings, to ensure that such departures are prevented from occurring (recommendation code 04). Alternatively, investigators might stress the importance of positive command actions on the part of S3's in similar circumstances (recommendation code 06). It is important to recognise, however, that analysts must continue to exercise their skill and judgement in the application of recommendation matrices. For example, Table 12.11 advocates recommendation to improve facilities (recommendation code 09) and to perform more studies (recommendation code 11) in response to the environmental causes (cause code 21), mentioned above. It is difficult to identify ways in which such measures might help to avoid the recurrence of our case study. Investigators might, therefore, argue that they need not draft recommendations to cover all of the potential remedies that are identified in these matrices. The sufficiency of the proposed solutions can be judged by peer review with other investigators. The proposed remedies will, in most cases, also be assessed by regulators and safety managers when they eventually receive the investigators' report.

It might also be argued that 'failure' was caused by a variant of habit interference. The S3 had become habituated to personnel following the approved plan and so failed to identify that the use of excess munitions departed from the approved procedure. Conversely, departures from approved plans might have become so commonplace that the S3 did not interpret the use of the excess munitions as anything 'out of the ordinary'. This analysis raises a number of problems for our application of the recommendation matrices. The causal taxonomy afforded by PAM 385-40 does not distinguish between these very different causes. In consequence, it can be difficult to identify

LEADER FAILURE				
	Cause 01: Inadequate supervision by higher command.	Cause 02: Inadequate supervision by staff officer.	Cause 03: Inadequate supervision by unit command.	Cause 04: Inadequate supervision by direct supervisor, NCO, platoon leader or instructor.
Recommend. 01: Improve school training				
Recommend. 02: Improve unit training				
Recommend. 03: Revise procedures				
Recommend. 04: Ensure personnel ready	X	X	X	X
Recommend. 05: Inform personnel of problems, remedies				
Recommend. 06: Positive command action			X	X
Recommend. 07: Provide more personnel	X			
Recommend. 08: Improve equipment				
Recommend. 09: Improve facilities	X	X		
Recommend. 10: Improve quality control	X			
Recommend. 11: Perform more studies				

Table 12.8: Recommendation Matrix for Leadership Failures

TRAINING FAILURE

	Cause 05: Inadequate school training.	Cause 06: Inadequate unit/on the job training.	Cause 07: Inadequate experience.	Cause 08: Habit interference
Recommend. 01: Improve school training	X			
Recommend. 02: Improve unit training		X		
Recommend. 03: Revise procedures	X	X	X	
Recommend. 04: Ensure personnel ready				
Recommend. 05: Inform personnel of problems/remedies				
Recommend. 06: Positive command action				
Recommend. 07: Provide more personnel				
Recommend. 08: Improve equipment				
Recommend. 09: Improve facilities				
Recommend. 10: Improve quality control				
Recommend. 11: Perform more studies	X	X		

Table 12.9: Recommendation Matrix for Training Failures

STANDARDS FAILURE						
	Cause 09: Inadequate written procedures.	Cause 10: Inadequate facilities.	Cause 11: Inadequate equipment.	Cause 12: Insufficient personnel.	Cause 13: Inadequate quality control.	Cause 14: Inadequate maintenance.
Recommend. 01: Improve school training						
Recommend. 02: Improve unit training						
Recommend. 03: Revise procedures	X					
Recommend. 04: Ensure personnel ready						
Recommend. 05: Inform personnel of problems, remedies	X					
Recommend. 06: Positive command action						
Recommend. 07: Provide more personnel				X		
Recommend. 08: Improve equipment			X			
Recommend. 09: Improve facilities		X				
Recommend. 10: Improve quality control					X	X
Recommend. 11: Perform more studies	X	X				

Table 12.10: Recommendation Matrix for Standards Failures

INDIVIDUAL FAILURE							
	Cause 15: Fear, Anger	Cause 16: Complacency	Cause 17: Lack of confidence	Cause 18: Haste, Attitude	Cause 19: Fatigue (self-induced)	Cause 20: Alcohol, drugs, illness	Cause 21: Environment
Recom. 01: Improve school training	X	X	X	X	X	X	
Recom. 02: Improve unit training	X	X	X	X	X	X	
Recom. 03: Revise procedures							
Recom. 04: Ensure personnel ready	X	X	X	X	X	X	X
Recom. 05: Inform personnel of problems, remedies							
Recom. 06: Positive command action	X	X	X	X	X	X	X
Recom. 07: Provide more personnel							
Recom. 08: Improve equipment							
Recom. 09: Improve facilities							
Recom. 10: Improve quality control							X
Recom. 11: Perform more studies							X

Table 12.11: Recommendation Matrix for Individual Failures

recommendations that might be used to combat these problems. Further problems arise because even if we could unambiguously ascribe the S3's actions to an habituation error there are no specific recommendations associated with this causal factor. In consequence, investigators are free to identify any remedy that is considered appropriate for such an error.

The allocation of recommendations to causal factors in Tables 12.8, 12.9, 12.10 and 12.11 is arbitrary in the sense that it is based on an initial analysis of PAM 385-40. In practice, additional validation would be required before investigators could use such matrices. As we have mentioned, there can be profound consequences if safety managers propose inappropriate or ineffective remedies for the particular causes of adverse incidents. A particular concern is that we have derived these tables from the US Army's published procedures and guidance documents. There are strong differences between these sources and similar publications that guide civilian forms of incident reporting. For instance, the influence of the 'perfective' approach is arguably greater in systems where military discipline and the chain of command are guiding principles. Having raised this caveat, it is important to acknowledge that the recommendation matrices in Tables 12.8, 12.9, 12.10 and 12.11 are still vulnerable to the criticisms raised by Leape [479] and Reason [702]. The focus on individual error and leadership failures obscures the organisational and managerial factors that have been identified in many previous accidents.

A number of problems complicate the use of navigational techniques that are intended to guide investigators towards particular recommendations from lists of approved interventions. For instance, it can be difficult to predetermine a range of appropriate remedies for incidents that have not yet occurred. In consequence, it is unlikely that investigators will be able to identify potential recommendations for all of the incidents that they might encounter. Similarly, the complex nature of many failures can make it difficult to ensure that approved recommendations address all of the detailed causes of particular incident.

Further problems can arise when approved recommendations do not provide sufficient details for investigators to implement them in the aftermath of a particular incident. For instance, the previous analysis of the Bangalore torpedoe case study identified the following causal factor 'Battalion S3 (operations, planning and training officer) recognised but failed to stop the deviated and unpractice operation'. PAM 385-40 codes can be used to classify this cause. For example, Table 12.11 identifies range of individual categories that might be used. These include a lack of confidence (code 17), undue haste (code 18) or problems with fatigue (code 19). As can be seen, however, these are at a more detailed level than the observation that was derived from the US Army's causal analysis. Investigators must, therefore, extend the initial investigation to ease the mapping between the products of the investigation and the classification provided by PAM 385-40. The same problem occurs in reverse when when the matrix approach is extended to identify 'recommended' intervention techniques. Table 12.11 proposes improved school (code 01) or unit training (code 02). Investigators are also encouraged to draft recommendations that ensure a more positive command action (code 06) or that personnel are ready (code 04). At first sight, this might seem to encourage the consistency that has been advocated in previous sections. Such an impression can be misleading. Even if investigators can agree upon a common recommendation code for a causal classification, there is no guarantee that a high-level remedy such as 'improve unit training' will result in similar interventions at an operational level. There are many different ways in which training might be 'improved' the efficacy of such interventions depends entirely upon which techniques are recommended and whether or not they are successfully implemented at the unit level.

12.2.4 Generic Accident Prevention Models

A number of alternate recommendation techniques explicitly acknowledge the problems in classifying causes and then uses such a classification to identify recommended interventions. These techniques exploit a higher level of abstraction than that embodied within the guidance of PAM 385-40. Investigators are then encouraged to introduce additional 'contextual' details into these abstractions. They are expected to exploit their skill and experience to identify the more detailed interventions that are intended to combat future failures. For instance, Haddon identified ten strategies for accident or incident prevention [301]. These strategies are associated either with the source of the energy that is transferred during an incident or with the barriers that protect the system or with the target that is potentially exposed to the energy release. They, therefore, have close links to the from of barrier analysis that was introduced in Chapter 9.3 that was developed in Haddon's earlier work [300]. These strategies are mentioned now because they have also been proposed as a high-level framework for the identification of recommendations in incident reports [444].

Energy source.
1. Prevent the buildup of energy, this will help to ensure that the conditions for an unwanted release do not slowly accumulate over time.
2. Modify the qualities of the energy, this will help to ensure that appropriate control measures are identified to help prevent any unwarranted releases.
3. Limit the amount of energy, this will minimise the consequences of any uncontrolled release and may make that release easier to control.
4. Prevent the uncontrolled release of energy.
5. Modify the rate and distribution of released energy, this will help to ensure that any unwanted release is stopped at source as soon as possible.

Barriers.
6. Separate the energy source from the target either in time or space, this helps to mitigate the consequences of any energy release.
7. Use physical barriers to separate the energy source and the target.

Target.
8. Increase the resistance of the target to any potential energy flows.
9. Limit any knock-on or consequent damage following any initial energy loss.
10. Stabilise the situation and initiate repairs as soon as possible in case of compound failures.

As mentioned, the components of Haddon's model have been used to provide a high-level framework that is designed to help investigators identify potential recommendations in the aftermath of incidents and accidents [444]. The particular nature of those recommendations will vary from industry to industry and even from incident to incident. The intention is, therefore, not to explicitly provide an enumeration of potential remedies. In contrast, the components of the model are intended to provide an abstract model of those areas in which an investigator might focus any remedial actions.

Table 12.12 shows how Kjellén's [444] application of Haddon's high-level strategies can be used to structure the identification of recommendations. In this case, we have applied Kjellén's approach to identify potential interventions following the Bangalore Torpedoe incident. This example illustrates both the strengths and the weaknesses of the general approach. Haddon's more general model of accident prevention strategies provides a number of high-level prompts that can guide an initial consideration of potential recommendations. The model is based on the notions of barrier analysis, introduced in Chapter 9.3, and so it avoids some of the myopia associated with 'perfective' approaches. The focus both on causal factors, such as the build-up of energy, and on mitigating factors, such as the resilience of the target, ensure that investigators do not simply focus on the products of a causal analysis when considering the recommendations for an incident report.

Table 12.12 also illustrates some of the potential problems that can complicate Kejellén's application of Haddon's strategies. Although this approach provides important general guidance, it can be difficult to determine what high-level concepts such as 'prevent the build-up of energy' actually mean in the context of a particular incident. Further problems arise when there are clear conflicts between the potential recommendations that might be derived from Haddon's strategy and the operational objectives that govern particular application domains. For instance, Table 12.12 suggests that the rate and distribution of the energy hazard might be altered by possibly increasing the size of breach that the explosives were used against. This would potentially distribute the forces acting on any particular individual who might be caught in a blast during a training exercise. Any intended reduction in the severity of an incident would, however, have to be offset against the potential tactical problems of alerting the enemy to a failed attempt on their position. It is also important to

Type of Strategy	Case Study Recommendation
	Hazard/Energy Source
1. Prevent build-up	Avoid use of explosives in night-time exercises.
2. Modify quantities	Limit the power of explosives used in night-time exercises.
3. Limit the amount	Limit the quantity of explosives issued to all personnel in a night-time exercise.
4. Prevent release	Limit the number of detonation devices issued in night-time exercises and have procedures for approving release of additional devices only when needed.
5. Modify rate and distribution	Not applicable - possibly increase size of breach area to distribute force?
	Barriers
6. Separate Source and Target	Ensure marking do not proceed until permission to proceed received from the breaching team.
7. Physical barriers	Prevent any detonation without explicit confirmation from a member of the marking team.
	Vulnerable Target
8. Increase resilience	Ensure marking team carry additional protective equipment.
9. Limit damage	Paramedic teams in immediate vicinity.
10. Rehabilitation/initiate repairs	Depends on type of injury.

Table 12.12: Applying Haddon's Ten Strategies to the Bangalore Torpedoe Case Study

remember that mission objectives should not be seen narrowly in terms of the short-term outcome from a particular training exercise:

> "Regardless of the training situation, leaders and soldiers must also understand that training exercises are just that training. Under no circumstances should safety be overlooked to achieve a training objective. It is the safety-oriented process that will assist the unit in achieving the mission successfully. Another accident demonstrates the importance of maintaining focus on the objective safely. The unit was engaged in a challenging river crossing operation when the decision was made to float downstream. Even though current readings had not taken place, a safety boat was not on standby, and an exercise participant was not wearing a flotation device, the squad decided to proceed with the mission anyway. Unfortunately, the rivers current was strong enough that it pulled all the team s elements under an anchored barge. Some of the team members survived, but two of them did not. Again, the mission was part of a training exercise. Now we can look back and think of all actions we could have taken to prevent this unfortunate accident; however, now it is too late for the unfortunate participants. Again, leaders must re-emphasise that when encountering an unsafe situation, the mission must now become safety." [808]

Such complex trade-offs between safety and mission objectives should not be surprising. The opening sections of this chapter argued that they are inevitable given that investigators may recommend changes in current operating practices. The key point is, however, that any potential recommendations that appear to fit well with Haddon's accident prevent strategies must also be carefully validated to ensure that they do not result in unintended consequences that might ultimately increase the likelihood of other incidents.

As mentioned, Haddon's strategies provide a high-level framework that Kjellén has used to guide the identification of potential recommendations following incidents and accidents. Some elements of this approach have been developed more than others. For example, barrier analysis is based around strategies 6 and 7 in Table 12.12. Chapter 9.3 has already referred to its widespread application as part of many causal analysis techniques. Not only can barrier analysis be used to help identify the failure of protection mechanisms, it can also used to identify potential interventions that might avoid future failures. Before providing an example of barrier analysis as a recommendation technique, it is important to emphasise a number of underlying differences between this approach and the others that have been introduced in previous sections. As we have seen, perfective approaches place sanctions on those individuals and groups who are deemed to be responsible for particular failures. The enumeration and matrix approaches that we have analysed typically focus on identify corrective actions for the causes of incidents and accidents. In contrast, barrier analysis typically helps to identify interventions in the accident 'process' that are intended to eliminate or reduce harmful outcomes. It is possible to object that this approach does not address the root causes that provide the 'starting point' for any failure. On the other hand, barrier analysis is supported by the analysis of causal asymmetry that was introduced in Chapter 10.4. As we have seen, Hausman has argued that it is infeasible to perform 'backwards reasoning' as a reliable means of identifying particular causes from a set of effects [315]. Perrow confirms this when he argues that it is impossible to anticipate the many different causes of technological failure [677]. It, therefore, makes great sense to attempt to control or mitigate those failures that do occur rather than try to eliminate them entirely.

It is possible to identify a vast range of different barriers that might be recommended in the aftermath of an incident. Physical barriers restrict access to hazardous areas, they constrain the flow of energy from a source towards the target. Organisational barriers, such as permit to work schemes, rely upon procedural mechanisms and surveillance activities to achieve similar ends. Barriers may also be active, in other words they are dependent on the actions of operators or systems, or they may be passive. Passive barriers are inherent within a design and are independent of any initiating actions once they are deployed. They must, however, be monitored in case operational demands erode the protection that they afford to the user. For example, the doors of safety cages can be damaged in order to provide greater access to a working area. Kjellén also argues that barriers can be classified as either technical, organisational or social/individual in nature [444]. He provides a detailed list of such barriers that can provide the basis of a checklist approach to the identification of particular recommendations. Unlike some of the previous enumerations, the intention is not to provide a detailed, exhaustive domain specific list. In contrast, these high-level barriers are domain independent and analysts must again apply their skill and experience to interpret them within the context of a particular incident. For example, the following list builds upon what Kjellén calls social and individual barriers. These are intended to prevent future incidents by changing the 'safety culture' in a working environment:

- 1. education, training and experience of personnel;
- 2. feedback on causes and consequences of previous incidents;
- 3. motivational campaigns, safety meetings and awareness raising initiatives;
- 4. feedback rewards for 'safe' performance and punishments for some violations;
- 5. use of automated and peer monitoring systems to assess safety performance.

As with Haddon's original strategies, investigators must translate these high-level barriers into the specific measures that are recommended in the aftermath of an incident. It is entirely possible that this process of interpretation might result in ineffective or even dangerous proposals. For example, there is no guarantee that a motivational campaign will have any effect upon individual behaviour. Similarly, reward and punishment systems can have negative effects if they alienate staff and create workplace conflict [702]. In consequence, it is also important that investigators consider means of validating the implementation of their recommendations. This is addressed in greater detail in Chapter 14.5. In contrast, the following list extends the previous analysis to summarise a range of organisational barriers to future incidents [444]. As can be seen, these relate to the procedural mechanisms that are intended to promote the safe operation of application processes:

- 6. ensure sufficient numbers of staff;

- 7. monitor implementation and efficacy of all barriers.
- 8. ensure correct levels of expertise and training;
- 9. provide adequate reference documentation to support training;
- 10. provide adequate documentation for emergency procedures;
- 11. rehearse emergency procedures;
- 12. ensure maintenance is effective and timely;
- 13. exploit a 'permit to work' system if maintenance is itself dangerous;
- 14. ensure adequate exchange of information and staff briefings.

It is possible to identify a number of common features between the elements of this barrier analysis and previous recommendation techniques. For instance, '8. ensure correct levels of expertise and training' is similar to recommendation code 01 'improve school training' and 02 'improve unit training' in PAM 385-40. Similarly, '6. ensure sufficient numbers of staff' is similar to recommendation code 07 'provide personnel resources required for job'. Other organisational barriers have not been proposed by more ad hoc approaches to the enumeration of recommendations. For example, the army schemes that were described in previous sections have had relatively little to say about the maintenance activities addressed by items 12 and 13 in the previous list. The following list again extends Kjellén's application of barrier analysis to summarises a number of technical barriers that might prevent the recurrence of previous incidents. As before, these are intended to provide generic recommendations that might be proposed in the aftermath of many different incidents:

- 15. eliminate or reduce hazards in the design of equipment;
- 16. introduce physical barriers to minimise personnel's exposure to hazard s;
- 17. ensure that personnel wear protective equipment whenever necessary;
- 18. ensure that emergency and first aid equipment is provided;
- 19. design workplace to support operators (noise, ventilation etc);
- 20. minimise the use, transportation and handling of hazardous materials.

As with social and organisational barriers, each of these barriers can satisfy a dual role. They can be used to guide the initial design of a safety critical application. For example, an injunction to 'introduce physical barriers to minimise personnels' exposure to hazards' can be used to guide the development of a design. The products of barrier analysis can also be used to identify recommendations in the aftermath of incidents and accidents. For instance, the same injunction might be proposed as a potential remedy in the aftermath of an incident or accident. Table 12.13 builds on this analysis and uses our extended version Kjellén's barriers to identify potential recommendations from the Bangalore Torpedoe case study.

As can be seen, our application of Barrier Analysis identifies a number of potential recommendations that might be used to inform the drafting of an incident report following the Bangalore Torpedoe case study. Potential remedies are again described at a high level of abstraction and must be refined to include the domain details that characterise this particular incident. For example, a requirement to 'ensure effective use of automated and peer monitoring systems' must be translated into particular procedures that can be implemented within the army's command structure. Further validation would then be required to ensure that the particular steps which were taken in the aftermath of an incident actually satisfied this high-level recommendation. These observations are similar to those that were made about the application of more general models of accident prevention, illustrated by Table 12.12. This should not be surprising as both approaches share a common root in Haddon's work on incident causation [300, 301].

Cause	Barrier
The breaching team leader failed to turn in excess demo material to the ammunition supply point.	1. Education, training and experience of personnel. 2. Feedback on causes and consequences of previous incidents.
Excess demolition material was not tied into the ring charge.	15. Eliminate or reduce hazards in the design of equipment.
Addition of the second charge was not planned, practiced or communicated to the other participants.	14. Ensure adequate exchange of information and staff briefings.
There was no appointed command-directed observer/controller at the breaching site.	6. Ensure sufficient numbers of staff. 8. Ensure correct levels of expertise and training;
Breaching team members failed to question or stop the deviated and unpracticed operation.	14. Ensure adequate exchange of information and staff briefings 5. Ensure effective use of automated and peer monitoring systems.
Battalion S3 (operations, planning, and training officer) recognised but failed to stop the deviated and unpracticed operation.	5. Ensure effective use of automated and peer monitoring systems. 14. Ensure adequate exchange of information and staff briefings.
Marking team leader took up hide position closer than the authorised 50 meters to the breaching site.	2. Feedback on causes and consequences of previous incidents. 4. Feedback rewards for 'safe' performance and punishments for some violations.
Marking team leader unable to distinguish between the initial (smaller) detonating cord detonation and the larger Bangalore detonation.	1. Education, training and experience of personnel. 8. Ensure correct levels of expertise and training.

Table 12.13: Barrier Analysis of Recommendations from Bangalore Torpedo Incident.

There are also more worrying similarities. For example, the recommendations identified in Table 12.13 are similar to many of the interventions that were identified using ad hoc heuristics and enumerations, such as those illustrated in Table 12.6. It can be argued that these similarities perhaps reflect particular properties of our case study. The Bangalore Torpedoe incident does not provide a suitable example to demonstrate the differences between these contrasting recommendation techniques. Alternatively, it can be argued that there are very few differences between the application of accident prevention models and more ad hoc techniques. There is, however, a third explanation. Table 12.13 illustrates some of the problems that can arise when recommendation technique are driven directly by causal analysis. For instance, previous sections have argued that investigators must not only focus on the causes of an incident but also on those barriers and controls that help to mitigate its consequences. Unfortunately, Table 12.13 focuses only on remedies for the causes of the incident. It does not consider the performance of triage and evacuation procedures in the aftermath of the incident. This reflects the balance of detail that was provided in the initial US Army report [819]. In consequence, our analysis does not consider certain recommendations: '10. provide adequate documentation for emergency procedures'; '11. rehearse emergency procedures' or '18. ensure that emergency and first aid equipment is provided'. If the initial causal analysis of the incident had also been extended to include mitigating factors, as was done in Chapter 9.3 then this would have exposed important differences between the recommendations identified in Table 12.6 and those proposed in Table 12.13.

12.2.5 Risk Assessment Techniques

This section began by describing perfective techniques. These approaches focus almost exclusive on exhortations for operators to 'do better' in order to avoid previous failures. Subsequent sections identified a range of techniques that broadened the scope of this analysis. For example, US Army and Air Force heuristics urge investigators to identify recommendations that address each of the causal factors identified during previous stages in an investigation [795, 797]. This more general approach has become embodied within recommendation matrices. Accident prevention models further broaden the scope of any recommendations that are identified in the aftermath of an incident. Not only do they address individual causal factors, they have also been extended to identify recommendations that are intended to strengthen system defences. These including the mitigating factors that can help to control the adverse consequences of particular failures.

The broadening scope of recommendations is appropriate because it reflects a growing recognition that most incidents involve complex interactions between people, systems and the environment in which they interact [677]. It does, however, create a host of practical problems. In particular, it can be difficult for the recipients of an incident report to determine how best to allocate finite resources to support the implementation of all of the diverse recommendations that might be made by investigators. The Canadian report into Operation Assurance illustrates the scale of this problem [128]. This summarised approximately fifty-one recommendations that were made as a result of incidents that occurred during relief efforts in Rwanda. These recommendations included specific measure to improve training at the highest level within the joint forces:

> "Canadian Forces must 'educate leaders and staffs at the most senior levels in both strategic and operational level doctrine processes'. This should be done as a teaching seminar either prior to or in concert with a major command post or computer assisted exercise. The objectives of the exercise should include education and validation with regards to joint doctrine and validation of Joint Forces Headquarters. Thereafter, education/review must be conducted on a routine basis." [128]

It also included more detailed recommendations, for example about the amount of notice that personnel should be given prior to being deployed in remote locations. Similar observations can be made about detailed investigations into single incidents. Apparently simple incident, such as the misuse of commercial heaters in tents, can generate tens of recommendations that range from improved training of personnel through to changes in the monitoring of standards throughout the chain of command [816].

The diverse nature of many recommendations and the sheer volume of remedial actions that can be proposed in the aftermath of an incident can create considerable problems from the recipients of these reports. Risk assessment techniques provide investigators, regulators and end-users with means of prioritising the recommendations that are are made in the aftermath of an adverse occurrence. Previous sections have noted that the particular details of who performs this prioritisation vary between different industries. For instance, in the Air Traffic Management domain there are well specified procedures that govern the reporting of recommendations by investigators back to safety managers who then prioritise their findings [423]. In local incident reporting systems, for example with UK hospitals, the same individuals may identify and prioritise potential recommendations [119]. This informal process is intended to be highly cost-effective in terms of the resources required to perform the analysis. Although it can be carefully tuned to the local working conditions of the units that operate the incident reporting system, this approach is also open to the many subjective biases that can distort risk assessments [2].

A number of organisations have recognised the key relationship between incident reporting and risk analysis. For example, the US Army Safety Program recently devoted an issue of their Countermeasure magazine to 'Accident Investigation: The Other Side of Risk Management' [808]. Of course, this relationship is more complex than the prioritisation of recommendations. For example, the US Army identifies five stages in a risk management process [806, 799]. These can be summarised as follows:

1. Identify hazards.
   Incident reporting provides important guidance in this initial stage of any risk assessment because it provides information about previous failures. Data can be collated from other operational units both within the same organisation and from national and internation groups operating similar processes. There is, however, no guarantee that previous incidents will provide good information about future failures involving novel production techniques.

2. Assess hazards.
   This second stage of risk management is intended to assess the impact of each hazard in terms of potential loss and cost based on probability and severity. More will be said about this in the following paragraphs. However, for now it is sufficient to observe that incident reporting systems not only provide information about previous types of hazard, they can also be used to identify the likely consequences of future failures based upon previous outcomes.

3. Develop controls and make risk decision.
   As control measures are developed, risks must be re-evaluated until they are reduced to a level that is 'as low as reasonably practicable'. This ALARP principle is controversial because it implies that it is possible to identify situations in which the perceived benefits of reducing the risk of a particular failure any further are outweighed by the potential costs of implementing such a risk reduction. Chapter 14.5 will describe how incident reporting systems can be used to support this aspect of risk management. In theory, it should be possible to demonstrate the effectiveness of particular recommendations by monitoring falls in the frequency and severity of future incidents. This is not always possible given the problems of ensuring the uniform implementation of recommendations and the relatively low frequency of many safety-critical incidents.

4. Implement controls.
   The fourth stage in any risk management program is to implement the controls that are intended to achieve the intended risk reduction. Again incident reporting systems provide an important source of information on the potential benefits of particular forms of control or barrier. Data from other plants can be sued to determine whether the introduction of these measures can create the opportunity for further types of incident, for instance during the installation and 'burn-in' of new equipment.

5. Supervise and evaluate.
   Finally, it may be necessary to monitor not simply the performance of any recommended controls but also to ensure that personnel continue to follow recommended practices. Similarly,

it is important to ensure that recommended safety equipment is maintained and operated in a manner that is intended to ensure that it is availability on demand. It is important to remember the problems associated with gathering reliable evidence for violations from incident reporting systems. It can be difficult to obtain evidence about conformance to recommendations, especially if they have been implemented following previous incidents.

As can be seen, several dependencies exist between risk management and the identification of recommendations in the aftermath of an incident. Risk management techniques can be used to determine the relative priority of particular recommendations. If a particular hazard is thought to be very unlikely or if it implies only marginal consequences for the safe operation of an application then the recommendation may be assigned a relatively low level of priority. Conversely, if an associated hazard is predicted to have a high frequency or a relatively large impact on safe and successful production then recommendations to address that hazard will be assigned a high-level of priority. Incident reporting systems can then be used to assess the efficacy of those recommendations that are rated particularly highly using such risk management techniques. If similar incidents continue to occur then the effectiveness of a recommendation may be questioned. Conversely, if incidents occur from hazards that were assigned a low relative priority then the effectiveness of the risk management system can be questioned.

In order to understand the role of risk management techniques in the identification and prioritisation of recommendations it is first necessary to describe the underlying components of a risk management system in greater detail. The fundamental concept behind this approach to the development of safety-critical systems is that:

$$Risk \ = \ Frequency \ \times \ Cost$$

This formula provides a means of assessing the potential effectiveness of any recommendation in terms of reductions in the costs or consequences of an incident. It can also be used to prioritise recommendations in the aftermath of an incident. As mentioned in previous sections, US Army [797] and Air Force [795] guidelines argue that each recommendation must be clearly associated with the results of a causal analysis. The US Army defines a hazard to be 'any real or potential condition that can cause injury, illness, or death of personnel or damage to or loss of equipment, property or mission degradation' [806]. In consequence, the same frequency and consequence that are associated with a hazard can also be associated with the causes of an incident or accident. This can inform the identification of recommendations in one of two ways:

1. if recommendations have already been identified using one of the techniques described in previous sections then risk assessment techniques can be used to identify the priority of each proposed remedy in terms of the risk associated with the cause that it is intended to address;

2. if recommendations have not already been identified then a risk assessment can be performed for each cause. The results of this analysis help to establish a partial ordering that can be usd to allocate finite investigatory resources. Greatest attention should be paid to finding appropriate recommendations for those causes that are assumed to pose the greatest continuing threat to a system.

Unfortunately, a number of factors complicate the application of the previous formula to guide the prioritisation of recommendations. The previous formula is a simplification. Subsequent paragraphs will introduce concepts such as risk exposure that must also be considered when attempting to assess the priority of particular recommendations. If such factors are not taken into account then it is possible to assign relatively low priorities to recommendations that could have a relatively large impact upon the risk of future incidents because investigators fail to accurately assess the potential frequency of a particular causal factor or hazard. It can be argued from the previous formula that the risk associated with a hazard will fall if either its frequency is reduced or the costs associated with that hazard fall. This, of course, assumes that such reductions are not offset by a corresponding fall in the other component of the equation. For instance, Bainbridge has argued that the implementation of many safety recommendations reduces the frequency of a particular cause but can also increase the consequences of those hazards when they do occur [65]. This one of several 'ironies of automation'; the relatively low frequency of certain failures can leave operators unprepared to intervene in adverse incidents.

Further problems stem from attempts to derive numerical estimates for the consequent cost of a particular hazard. The amount of money that must be spent in the aftermath of previous incidents can prove to be an extremely poor indication of what might have to be paid in the future. The increasing use of litigation within certain Healthcare systems has resulted in massive changes in the scale of compensation that must now be paid following many adverse incidents [453, 635]. There are well established mechanisms for calculating the potential liability associated with fatalities and personal injuries. It can, however, be difficult to predict the potential scale of such injuries that might result from future incidents. The costs associated with air collisions can vary greatly depending on the numbers of ground fatalities that are factored into any calculation. It is also difficult to predict the punitive elements that can be introduced during the settlement of claims within some legal systems In consequence, most organisations avoid precise numerical assessments for the potential costs associated with particular hazards. In contrast, they rely upon subjective bands that are described using keywords. This is an approach that complements the use of such terms within HAZOPS [27]. For instance, the US Army encourages risk managers to consider a number of basic categories that can be used to describe the consequences associated with a particular hazard [806]. The costs of an incident are assessed in terms of the expected degree of injury, property damage or other 'mission-impairing' factors:

1. Catastrophic: death or permanent total disability, system loss, major damage, significant property damage, mission failure.
2. Critical: permanent partial disability, temporary total disability in excess of 3 months, major system damage, significant property damage, significant mission degradation.
3. Marginal: minor injury, lost workday accident, minor system damage, minor property damage, some mission degradation.
4. Negligible: first aid or minor medical treatment, minor system impairment, little/no impact on mission accomplishment.

A number of caveats can be raised about the interpretation of these different categories. The relatively low costs associated with near-miss incidents can persuade organisations to underestimate the consequences of a potential accident. It is for this reason that some organisations have argued that the cost component of the risk management equation, given above, should only be calculated in terms of the *worst plausible outcome* of an incident. If pilots were able to narrowly avert a collision then safety managers might assess the costs of such an occurrence in terms of the potential loss of both aircraft. This appears to be a rationale and well considered approach. Problems arise, however, when investigators must determine what 'worst plausible outcome' actually means for specific incidents. This issue was addressed in more detail in Chapter 3.7.

Chapter 10.4 notes the difficulty of obtaining quantitative data about incident frequencies. Data from bench trials and experimental observations often cannot be replicated in complex, working environments. Conversely, observational data and information from automated logging systems can be difficult to calibrate and interpret. Incident reporting systems provide a partial solution to these problems. They provide information about 'actual' incidents in 'real' working environments. Forms can be designed to elicit the information that is necessary to interpret observations about adverse events. In confidential systems it is possible to gather additional information about the context in which failures occur. As we have seen, however, participation bias and relatively low submission rates create significant problems for the use of incident reporting data as a 'raw' source for risk management. The US Army [806], therefore, also provides guide-words that describe the frequency of a potential hazard:

1. Occurs often, continuously experienced.
2. Occurs several times.

3. Occurs sporadically.

4. Unlikely, but could occur at some time.

5. Can assume it will not occur.

A number of further problems complicate the application of this approach to risk management. Previous paragraphs briefly mentioned that the risk associated with a particular hazard is partially determined by the length of exposure to that hazard. This must take into account both the cumulative duration of any exposure but also the summative effect of individual exposures across different operational units. These issues were not considered in previous formulae. One means of addressing this omission is to refine the subjective categories that are used to describe the potential frequency of a hazard. This is the approach that is advocated by the US Army's guidance on Risk Management, illustrated in Table 12.14 [799]. One consequence of adopting this approach is that it can introduce additional complexity into the superficial simplicity which is an important strength of the initial frequency definitions.

As mentioned, the previous risk assessment formula can be applied together with the previous definitions of consequence and frequency to estimate the risk that is associated with particular hazards. In practical terms this is accomplished using a risk assessment matrix similar to that presented in Table 12.15. The use of such matrices has important consequences for the use of risk analysis to drive the prioritisation of incident recommendations. As can be seen, Table 12.15 supports the high level classifications of hazards into Extremely high, High, Moderate and Low risks. Such distinctions are unlikely to provide a total ordering over the many different recommendations that are made in the aftermath of safety-related incidents. In consequence, even if analysts do resort to the use of risk assessment techniques to supplement an incident investigation they will still have to exploit a range of additional techniques to rank individual recommendations within these gross categories.

Table 12.15 can be used in conjunction with the US Army guidance on frequency and consequence assessment to prioritise the recommendations that were identified by the investigation into the Bangalore Torpedoe case study. This process begins by performing a risk assessment of the causal factors that were identified in the aftermath of this incident. This approach is justified by the Army guidance that points to the close relationship between the hazards that are considered in any risk assessment and the causes of previous accidents [806]. Table 12.16 illustrates the results of such an analysis. As can be seen, a frequency and criticality level are associated with each of the causal factors. The subjective nature of these assessments makes it important that investigators also document the justification for the allocation of particular levels to each of the causal factors. For instance, the breaching team leader's failure to turn in excess demo material was classified as a likely occurrence on the basis of comments made by the investigating officer: "Introduction of left over demolition materials into the last shot has been a longstanding accepted procedure. Such action violates the requirement to turn in all excess explosives..." [819]. Similarly, the breaching team members' failure to question or stop the deviated and unpracticed operation was assessed as being unlikely. This was based on an analysis of previous exercises in which phase one and phase two walkthroughs established the pattern for an operation and helped personnel to question deviations from the planned actions. Such justifications might be explicitly included within risk assessment documents such as Table 12.16.

Previous paragraphs have briefly described the problems of assessing the likely consequence of a particular hazard in the aftermath of an adverse occurrence. It might be argued that there were no consequences from any of the particular causes of a 'near-miss' incident. In contrast, if we apply the 'worst plausible outcome' assumption then almost every cause can have potentially catastrophic outcomes. This dilemma can be illustrated by assigning a criticality level to the observation that there was 'no appointed command-directed observer/controller at the breaching site'. It is difficult to argue that the lack of an observer led to mission failure, 'death or permanent total disability' unless we know the context in which this hazard occurred. If excess material was being used in an unscheduled procedure then the lack of an observer can have catastrophic consequences. In other contexts the consequences are much less severe. This illustrates the need to provide additional

FREQUENT (A) Occurs very often, continuously experienced

Single item	Occurs very often in service life. Expected to occur several times over duration of a specific mission or operation. Always occurs.
Fleet or inventory of items	Occurs continuously during a specific mission or operation, or over a service life.
Individual soldier	Occurs very often in career. Expected to occur several times during mission or operation. Always occurs.
All soldiers exposed	Occurs continuously during a specific mission or operation.

LIKELY (B) Occurs several times.

Single item	Occurs several times in service life. Expected to occur during a specific mission or operation.
Fleet or inventory of items	Occurs at a high rate, but experienced intermittently (regular intervals, generally often,).
Individual soldier	Occurs several times in career. Expected to occur during a specific mission or operation.
All soldiers exposed	Occurs at a high rate, but experienced intermittently.

OCCASIONAL (C) Occurs sporadically.

Single item	Occurs some time in service life. May occur about as often as not during a specific mission or operation.
Fleet or inventory of items	Occurs several times in service life.
Individual soldier	Occurs some time in career. May occur during a specific mission or operation, but not often.
All soldiers exposed	Occurs sporadically (irregularly, sparsely, or sometimes).

SELDOM (D) Remotely possible; could occur at some time.

Single item	Occurs in service life, but only remotely possible. Not expected to occur during a specific mission or operation.
Fleet or inventory of items	Occurs as isolated incidents. Possible to occur some time in service life, but rarely. Usually does not occur.
Individual soldier	Occurs as isolated incident during a career. Remotely possible, but not expected to occur during a specific mission or operation.
All soldiers exposed	Occurs rarely within exposed population as isolated incidents.

UNLIKELY (E) Can assume will not occur, but not impossible.

Single item	Occurrence not impossible, but can assume will almost never occur in service life. Can assume will not occur during a specific mission or operation.
Fleet or inventory of items	Occurs very rarely (almost never or improbable). Incidents may occur over service life.
Individual soldier	Occurrence not impossible, but may assume will not occur in career or during a specific mission or operation.
All soldiers exposed	Occurs very rarely, but not impossible.

Table 12.14: US Army Guidance on Hazard Probability [799].

	A. Frequent	B. Likely	C. Occasional	D. Seldom	E. Unlikely
1. Catastrophic	Extremely high	Extremely high	High	High	Moderate
2. Critical	Extremely high	High	High	Moderate	Low
3. Marginal	High	Moderate	Moderate	Low	Low
4. Negligible	Moderate	Low	Low	Low	Low

Table 12.15: Risk Assessment Matrix.

Cause	Frequency	Consequence	Risk Assessment
The breaching team leader failed to turn in excess demo material to the ammunition supply point.	B. Likely	1. Catastrophic	Extremely high
Excess demolition material was not tied into the ring charge.	D. Seldom	4. Negligible	Low
Addition of the second charge was not planned, practiced or communicated to the other participants.	D. Seldom	1. Catastrophic	High
There was no appointed command-directed observer/controller at the breaching site.	B. Likely	1. Catastrophic	Extremely high
Breaching team members failed to question or stop the deviated and unpracticed operation.	E. Unlikely	4. Negligible	Low
Battalion S3 (operations, planning, and training officer) recognised but failed to stop the deviated and unpracticed operation.	E. Unlikely	1. Catastrophic	Moderate
Marking team leader took up hide position closer than the authorised 50 meters to the breaching site.	B. Likely	2. Critical	High
Marking team leader unable to distinguish between the initial (smaller) detonating cord detonation and the larger Bangalore detonation.	D. Seldom	4. Negligible	Low

Table 12.16: Risk Analysis for Bangalore Torpedo Incident.

guidance for investigators who must determine the potential future consequences of such causal factors in a variety of different contexts. Ideally, we would like a rule or form of argument that plays a similar role to counterfactual reasoning in many causal analysis techniques [470]. Without such a decision procedure, investigators must continue to rely upon their expertise and judgement when determining the consequence of future hazards. As before, it is important that others can follow the justifications that support such judgements. For example, Table 12.16 assigns negligible consequences to the 'breaching team members failed to question or stop the deviated and unpracticed operation' because this last line of defence should not be relied upon given the stress levels and distractions associated with nighttime operations. Of course, other investigators might argue that the consequences of breaching such a final barrier are critical or catastrophic. The key point here is that by documenting the justifications for such an allocation, it is then possible for other analysts to validate the reasons for prioritising the recommendations that are intended to address particular causes of an incident.

We have argued that the priority of a recommendation can be determined by assessing the risk of the causes that it is intended to address. This depends upon the recognition that the causes of incidents provide valuable information about the hazards that threaten the future operation of safety-critical systems [806]. It is important to emphasise, however, that although all causes can be though of as hazards, it is not the case that all hazards are causes. In particular, there may be potential failures that have not yet contributed to particular incidents. Investigators must consider this issue when assessing the priority of a recommendation. For example, our case study did not involve a friendly fire incident. The introduction of a controller/observer at key positions during a night exercise might also help to reduce the risks associated with this other form of hazard. Hence it can be argued that the priority of this recommendation ought to be increased to reflect the additional perceived benefit to be derived from such an intervention. It is also important to reiterate the argument that was made in the closing sections of Chapter 10.4. Causal asymmetries imply that there may be a number of different alternative causes for any particular incident. In consequence, investigators must consider the relative important of recommendations that will not simply address the causes of a particular incidents. They must also prioritise recommendations that address alternative causes that might have resulted in the same or similar failures. For instance, there are numerous ways in which the marking party might have suffered similar injuries given that they were too close to the site of the breach when the Bangalore Torpedoes were deployed. A comprehensive risk analysis would, therefore, consider these different causal paths when determining the relative priority of recommendations that might ensure conformance to the distance requirements in the FM 5-250 [819].

The US Army promotes a five stage process of risk analysis: identify hazards; assess hazards; develop controls and make risk decisions; implement controls; supervise and evaluate [799]. Previous paragraphs have described how, in the context of incident reporting, causal analysis techniques can be used to identify the particular hazards that lead to an incident or accident. Hazard assessment techniques can then be used to derive a partial ordering that prioritises those causes. The third step in the process is to identify 'controls and make risk decisions'. This stage can be implemented using the recommendation techniques that have been introduced in this chapter. For example, the US Army's FM 100-14 advocates an approach that has much in common with barrier analysis:

> "After assessing each hazard, leaders develop one or more controls that either eliminate the hazard or reduce the risk (probability and/or severity) of a hazardous incident. When developing controls, they consider the reason for the hazard not just the hazard itself. Controls can take many forms, but fall into three basic categories educational controls, physical controls, and avoidance. Educational controls are based on the knowledge and skills of the units and individuals. Effective control is implemented through individual and collective training that ensures performance to standard. Physical controls take the form of barriers and guards or signs to warn individuals and units that a hazard exists. Additionally, special controller or oversight personnel responsible for locating specific hazards fall into this category. Avoidance controls are applied when leaders take positive action to prevent contact with an identified hazard." [799]

To summarise, there are two ways in which risk assessment techniques can be used to prioritise the recommendations from incident reports. Firstly, they can be used to rank the causes of an incident. Resources can then be deployed to focus on the generation of recommendations that address those causes with that pose the highest risk to the continued safety of an application. Secondly, recommendations might be identified for all causes without predetermining the relative importance of particular causes. Once those recommendations have been identified investigators can rank them by performing a post hoc risk analysis on the causes that are associated with those recommendations. This has the advantage of enabling investigators to increase the importance of recommendations that are perceived to address more than once cause. In our case study, Table 12.4 showed how the recommendation that 'All personnel must have confidence in their authority to immediately stop any unsafe life threatening act and exercise it accordingly' was proposed by the Army investigation to address both the Battalion S3 and the breaching team members' failure to stop the 'deviated and unpracticed' operation. Post hoc risk assessments can take this into account. This is arguably less likely if recommendations are only identified after a risk assessment has been performed on the causes of an incident.

A number of further problems complicate the use of risk assessment techniques to prioritise recommendations. The US Army [797] and Air Force [795] guidelines argue that recommendations should be associated with individual causal factors. The US Army's FM 100-14 goes on to argue that the causal factors in accidents and incidents help to identify the hazards that drive risk assessments.

We have extended this argument by using these risk assessment techniques to derive priorities for the recommendations that are associated with particular causal factor. This creates problems because incidents are not, typically, the result of individual causal factors. They are, instead, the result of complex conjugations of causes. This is emphasised by the differences between the previous formula $Risk = Frequency \times Consequence$ and the more complex formulations of the partition models that were introduced in Chapter 10.4. The observation that incidents stem from causal complexes rather than individual causal factors has important implications for the use of risk assessment techniques to prioritise proposed interventions. If recommendation techniques focus on singular, particular causes rather than combinations of causes then investigators may fail to address systemic issues. For instance, Table 12.3 summarises several recommendations that advocate improved training as a potential remedy for the Bangalore Torpedoe incident. The combined effect of such individual recommendations might encourage investigators to consider a more systematic reappraisal of training procedures. Similarly, proposals to improve the 'safety culture' within an organisation have the potential to address many different hazards [344].

We have argued that the priority of a recommendation is determined by the risk associated with the cause or hazard that it is intended to address. This creates problems if the proposed recommendation only has a negligible effect upon a high-risk hazard. From this it follows that *the priority of a recommendation is determined by the reduction that it causes on the risk of an associated hazard or hazards.* There are, however, considerable practical difficulties involved in assessing the likely impact of a particular recommendation. This is acknowledged within the US Army guidance; "risk management is the recognition that decision making occurs under conditions of uncertainty" [799]. Uncertainty stems from several layers of subjunctive reasoning. The investigator must assess the likely probability of a hazard recurring then they must assess the likely consequences of that hazard. Finally, they must assess the potential impact that any recommendation will have on their predictions about the frequency and consequence of future incidents!

A number of important consequences stem from the notion that the priority of a recommendation can be determined by the expected reduction in the risk of a particular hazard. In particular, investigators may have to accept that the residual risk after any recommendations have been implemented remains so high that an operation or task should not be permitted to continue. For example, incident data was used to justify permanently suspending the use of the 1370-L956, flash artillery simulator, M110, during any training activity in the US Army. The 1370-L956 was "identified as contributing to numerous serious injuries of our military members during training activities and was permanently suspended from future use with units directed to turn in all unused assets" [818]. As might be expected, the overall residual risk associated with a system is determined by the maximum risk associated with a particular hazard and not the average of those risks:

> "If one hazard has high risk, the overall residual risk of the mission is high, no matter how many moderate or low risk hazards are present... The commander must compare and balance the risk against mission expectations. He alone decides if controls are sufficient and acceptable and whether to accept the resulting residual risk. If he determines the risk level is too high, he directs the development of additional controls or alternate controls..." [799].

Previous paragraphs have introduced the US Army's five stage process of risk analysis: identify hazards; assess hazards; develop controls and make risk decision; implement controls; supervise and evaluate. Previous paragraphs have described how the first three stages can be used to prioritise recommendations in terms of the difference between an initial risk assessment and the residual risk associated with both the particular causes of an incident and the more general hazards that an incident helps to identify. Of course, the residual risk that motivates the promotion of a particular recommendation will only be achieved if the remedial actions are effectively implemented. The incidents that have been described in previous chapters of this book provide some idea of how difficult it can be to ensure such conformance.

The problems of implementing recommendations can be exacerbated by the organisational and institutional boundaries that exist between investigatory and regulatory authorities. As mentioned in Chapter 3.7, these distinctions help to preserve the investigators' independence from those who are partly responsible for promoting an industry. One consequence of this is that the powers to ensure compliance, typically, rest with the regulators rather than the investigatory agencies. There have been notable instances in which this has resulted in recommendations not being policed or enforced in the aftermath of previous incidents [194]. Such situations have been rectified by creating a clear distinction between the roles of economic regulation and the policing of safety requirements. The follow section builds on this analysis by investigating the processes that support the implementation of particular recommendations.

12.3 Process Issues

The previous section investigated a number of recommendation techniques including the 'perfectability' approach, high level heuristics, navigation techniques including enumerations and recommendation matrices, generic accident prevention or barrier models and risk assessment techniques. These approaches are intended to help investigators identify interventions that will either mitigate the consequences of failure or will reduce the likelihood of similar incidents occurring in the future. It is important to recognise, however, that such a list of recommendations is not an end in itself. They must be validated and then presented to regulatory bodies and safety managers. They may challenge the utility of particular recommendations. The following paragraphs, therefore, analyse these additional stages that must be passed before a proposed intervention is adopted and then implemented.

12.3.1 Documentation

It is important that investigators document the recommendations that are intended to address potential problems in existing systems. This is essential if others are to implement any proposed interventions. This does not simply involve drafting guidelines to describe the proposed recommendation. In most reporting systems, investigators must also document the reasons that motivate particular findings. This is important if regulators, safety managers and other personnel are to understand the motivation for intervening in existing working practices. It is possible to identify a range of additional information that must be provided to support particular recommendations:

- *what causes or hazards does the recommendation address?*
  The opening sections of this chapter cited army and air force guidelines which require that recommendations are closely tied to particular causal factors. This is intended to ensure that as much as possible is learned from an incident; every cause should be addressed by at least one recommendation. Later sections have extended this argument by identifying recommendations, such as improvements in 'safety culture' or in training practices, that may address many different causes of a particular incident. Finally, it has been argued that incident investigations can uncover potential hazards that were not involved in a previous incident but which have the potential to jeopardise future safety. It is important for each of these cases that investigators explicitly identify the hazard that a recommendation is intended to address. Without such information it will be difficult for others to assess whether or not a proposed intervention provides sufficient protection against future failures.

- *what is the significance of the cause or hazard that a recommendation addresses?*
  As we shall see, recommendations are often passed to regulators or safety managers who must then guide the allocation of finite resources to ensure that they are implemented. From this it follows that investigators must help others to determine how to maximise their use of these resources. Risk assessment techniques have been proposed as a potential means of assessing the importance of a recommendation [799]. This can be derived from the risk associated with the hazard that a proposed intervention is intended to address. Unfortunately, a number of problems complicate the application of this technique in 'real world' systems. In consequence, a great deal of subjective judgement, of skill and expertise is required in order to assess the significance of a particular recommendation. Unless such judgements are documented, however,

there are few guarantees that resources will not be diverted towards relatively trivial changes whilst more significant recommendations are neglected.

- *what are the intended consequences of the recommendation?*
  Ideally, we would like to document measures that can determine whether or not a recommendation has been successfully implemented. This is easier with some recommendations than others. For instance, it is relatively straightforward to initiate plant inspections as a means of determining whether or not process components have been replaced. It can be more difficult for investigators to schedule inspections that might be necessary to determine whether a particular change has been made in a training regime. This often involves complex scheduling of site visits that can alert operators to a forthcoming inspection. There are further problems. It is generally much easier to determine whether or not a change has been made in an application process. It can be far more difficult to demonstrate that any change has had an anticipated impact upon the overall safety of a system. As we have seen, poor submission rates and reporting bias can prevent reliable conclusions being drawn from raw incident data. Investigators should, therefore, consider how to demonstrate the effectiveness of any funds that are invested in the implementation of particular recommendations.

- *who will implement and monitor each recommendation?*
  The US Army and Air Force heuristics urge investigators to identify the individuals or groups who are responsible for implementing particular recommendations [795, 797]. Investigators must not to specify *how* to implement a recommendation. This is important because investigators may lack the local expertise that is necessary to determine how best to implement a particular improvement. Similarly, the design and coordination of any changes might take far longer than the period of time that can be devoted to a particular investigation. Instead, incident reports must document *what* a recommendation is intended to achieve and *why* that objective is important. It is clear important, however, to determine *who* is responsible for implementing any proposed intervention. This individual must determine *how* to realise a recommendation from the investigators' description of *what* a recommendation must achieve and *why* it must achieve it. If they confuse the investigators' intentions or if they lack the resources to implement necessary changes then there is a danger that past failures will recur as future incidents.

- *establish the time-frame for any recommendation*
  The implementation of recommendations can be delayed by resource limitations, lack of managerial guidance, deliberate obstruction and so on. Ultimately, this can leave any system exposed to repeat failures if proposed changes are not introduced in time. In consequence, it is important that investigators specify *when* a recommendation should be implemented. There is a danger that this maximum time period will be seen as a target and not as an upper boundary for any remedial actions. Many investigators, therefore, provide detailed guidance on the phased introduction of particular recommendations. It is also important to monitor the implementation of key changes beyond the immediate aftermath of an incident. If this is not done then there is a danger that organisations will gradually forget previous lessons. In consequence, it is also important to consider how the monitoring of a particular recommendation might be incorporated into more routine activities.

The US Army's Accident Investigation Handbook illustrates the way in which organisations can provide detailed guidance on the approved format for the presentation of recommendations [804]. This handbook separates its advice into three causal categories: human error; material failure or malfunction and environmental factors. There are small differences in the information that is to be recorded for recommendations that address hazards in each of these different sections. For example, the handbook requires that investigators document a range of information describing human 'errors'. This includes a single sentence about what happened. This is then followed by a brief description of the context in which the incident occurred, for example "while conducting night convoy operations using blackout drive lights". Investigators must also identify the individual involved in the 'error' by describing their duty position, such as the OH-58D pilot-in-command or the driver of the M998, High Mobility Multipurpose Wheel Vehicle. As can be seen, such a requirement affords a degree of anonymity. Investigators must then identify the task error of omission or commission that motivates particular recommendations. These are classified according to Army standards. In particular, the accident investigation handbook recommends the error codes that are presented in PAM 385-40 [797]. These codes were used in recommendation matrices, such as Tables 12.8, 12.9, 12.10 and 12.11, that were presented earlier in this chapter. The example cited in the accident handbook is that the operator "exceeded the posted speed limit of 40 MPH by attempting to drive at 60 MPH in violation of Camp Swampy Reg 190-5 (Code 40)" [804]. This discussion of what happened then motivates an explanation of the consequences of the error. It may directly or indirectly result in damaged equipment or injury. For example, a road traffic accident may involve substantial damage to a vehicle and its driver. It can also involve injury to third parties, such as pedestrians and other drivers, as well as damage to other vehicles or objects in the vicinity of the incident. After having described the context in which an error occurred and having explained the consequences of that failure, investigators must document the reasons why it happened. In other words, they must record the findings of any causal analysis. As before, these causes must refer to the predefined lists that are provided in PAM 385-40 [797]. These are supported by a free-text description of the reasons why an error occurred: "the driver's actions were a result of a lack of self-discipline and improper supervision by the senior occupant... the driver had a history of speeding [804].

The documented 'causes' of an error help to motivate the subsequent section of the report that details the particular recommendations which are made in the aftermath of the incident. These are intended to answer the question, 'What to do about it?'. Previous sections have already described how the US Army relies upon an enumerate list of recommendations that are published in PAM 385-40. The Accident Investigation Handbook, therefore, suggests that investigators consult this document before drafting their recommendations. It is important to note, however, that recommendations should not be addressed at the task error itself but at the system deficiencies that led to the error. This approach is advocated in the handbook and explicitly encouraged in PAM 385-40 by including relatively few recommendation codes that might support a 'perfectability' approach. Recommendations must be addressed to unit level (company, troop, battalion), higher level (brigade, division, corps) or to Army level. The following format is recommended:

"RECOMMENDATION (1, 2, 3, etc.):

- a. Unit Level Action: Commander, ____ (unit): Brief all unit personnel on the facts and circumstances surrounding this accident. Emphasis should be placed on how human limitations combined with less than optimum systems and high task loading allow situations that contribute to undetected hover drifts.
- b. Higher Level Action: None.
- c. Army Level Action:
  - (1) Commander, U.S. Army Training and Doctrine Command:
    - (a) Validate requirements for automatic hover systems for all aircraft to assist in reducing task overloading.
    - (b) Validate OH-58D crew coordination requirements, especially in Tasks 10 67, 1114, 1140, 1147, and 1148 in TC 1-209, to ensure safe compliance with the requirement for both crew-members to simultaneously direct their attention inside the aircraft, especially in aircraft without automatic hover systems.
    - (c) Validate requirements for night vision systems with greater fields of view and resolution.
    - (d) Increase, within the flight-training program, emphasis on situational awareness and spatial disorientation.
  - (2) Program Executive Officer, Aviation, field upgrades to OH-58D aircraft which allow the use of the hover bob-up mode symbology in the LCD unit, even with weapons displayed in the LCD unit, and allow for adjusting the ODA intensity during low light ambient conditions.

- (3) Commander, U.S. Army Safety Center, disseminate/publish the facts and circumstances surrounding this accident as appropriate." [804]

As mentioned, the US Army guidelines provide similar advice on how to document recommendations for other categories of failure, including equipment problems and environmental issues. In the case of material failures or malfunctions, investigators must explain what happened in a similar fashion to that described for human error. Such failures are defined to occur when a piece of equipment "did not operate as intended or designed which contributed or caused the incident". Investigators are encouraged to search for human errors or mistakes, such as a failure to follow Army standards/procedures, design criteria or manufacturing process, that may have caused the material failure. As before, it is important to document the results of any causal analysis. This is again used to identify appropriate recommendations using PAM 385-40.

Environmental recommendations follow a similar format. They are presented at the end of an analysis of the failure that describes what happened and why it happened in the manner that it did. The US Army guidelines also suggest that investigators can determine if an environmental factor should be assessed by asking 'did this factor adversely influence human and/or equipment performance; was the environmental element unknown or unavoidable at the time of the accident/injury/occupational illness?'. The explanation of why an environmental factor affected safe and successful operation often draws upon a range of disciplines. Microbursts provide an example of such a factor. They have been cited as causal factors in several recent incidents involving military aircraft. These environmental events cannot be predicted with present meteorological equipment. They are also invisible to aircraft crew-members. Such incidents show how investigators are constrained in the range of recommendations that might counter the adverse effects of many environmental factors. For example, the US Army's investigation handbook includes the following example of an Army level recommendation to deal with microburst incidents: 'Commander, U. S. Army Safety Center, disseminate/publish the facts and circumstances surrounding this accident as appropriate'. In contrast, more detailed proposals are directed at unit Commanders:

- "(a) Coordinate through the Commander, U.S. Air force, 1st Weather Group, Fort McPherson, Georgia, to establish a pro-active interface with several groups sponsoring research into the area of windshear. These groups include NASA, the National Technical Information Service (NTIS), the Federal Aviation Administration (FAA), the American Meteorological Society, the Langley Research Center, and the National Center for Atmospheric Research.
- (b) Inform all aviation personnel assigned to Fort Rucker, Alabama, that severe weather in the form of microbursts can occur from isolated thunderstorms or rainshowers and cumulus clouds that give the impression of simple rainshower clouds." [804]

A final section of the guidelines focus on the documentation of recommendations that address non-causal factors. The US Army handbook focuses narrowly on "findings that did not cause or contribute to the cause of the accident but contributed to the severity of injury or accident". An example would include a drivers failure to wear a seatbelt. This would not have caused a collision but would have significantly affected the injuried that the soldier sustained should a collision occur. This narrow definition of non-contributory factors might, however, be revised following the arguments that have been made in previous sections. For instance, non-causal factors should be extended to include hazards that have been detected during the previous analysis but that did not contribute to the particular incident under investigation. The Army handbook recommends that these non-contributory factors should each be recorded in a single paragraph; 'they are recorded to inform the command of problems that, if not corrected, could adversely affect the safety of future operations'. Recommendations that address these potential hazards are documented after recommendations that deal with human 'errors', material failures and environmental factors.

This section has argued that investigatory organisations must publish guidelines that support the documentation of particular recommendations. It is important to identify those hazards or causes that are address by particular findings. This helps to ensure that important lessons are not overlooked if potential hazards are not addressed by particular recommendations. Investigators must also document the perceived significance or importance of those hazards that are addressed by a recommendation. This information is necessary if others are to determine the best allocation of finite resources when implementing several, possibly conflicting, findings. Investigators must document the intended consequences of a recommendation. They must explain what it is intended to achieve rather than how it is intended to achieve it. This provides a degree of flexibility to engineers who must determine the best mans of implementing a particular recommendation. The documentation of recommendations must determine who is responsible for ensuring that a finding is acted upon. They should also be provided with documents that describe a potential timescale for their actions. The importance of these documentation requirements varies from organisation to organisation. For instance, in local reporting systems the investigator may also be responsible for implementing any recommendations. In such contexts, much of this information may be superfluous unless for auditing purposes. Many larger organisations, including the US Army, draft regulations and guidelines to ensure that most of this information is documented. These requirements are intended to ensure that the recipients of particular recommendations have sufficient information for them to validate any proposed changes in working practices.

12.3.2 Validation

Previous sections have focussed on techniques that investigators can use to draft recommendations that avoid or mitigate future failures. Such techniques only provide a partial panacea to the problems of incident reporting. A number of additional issues must be addressed before particular recommendations can be introduced to support the operation of safety-critical systems. For instance, there is a danger that valuable resources will be allocated to ineffective remedies. Some recommendations have been motivated by organisational politics and managerial ambition rather than a concern to address the causes of previous failures. There is also a danger that by addressing one set of problems, recommendations will inadvertently introduce other potential problems into an application. It is, therefore, important that recommendations are validated before they are implemented.

The way in which recommendations are validated can differ greatly between reporting systems. Many local systems rely upon informal meetings between the colleagues who are responsible for running the system. Large-scale systems often validate recommendations at several different levels within an organisation. Investigators may pass on the initial findings to their immediate superiors. They perform an initial check and then pass a revised version of the recommendations to their superiors and so on. Some incident reporting systems also encourage dialogues between investigatory bodies, regulatory organisations and system management. These joint meetings help to ensure that each party understands the implications of a particular recommendation. Chapter 8.3 has described how these dialogues can, occasionally, introduce unacceptable delays into the implementation of important safety measures, such as Excess Flow Valves into gas service lines [589].

The US Army's Accident Investigation and Reporting Procedures Handbook contains detailed guidance on the different review procedures that are to be implemented at different levels within the command structure [807]. Reports about high-consequence incidents are validated at a local review, by installation level safety-managers, by an approving authority appointed to represent the Major Army Commands and by the US Army Safety Centre. The initial review is normally conducted by the commander of the unit or by the commander of the supervisor directly responsible for the operation involved in the incident. Their must review the report and provide written feedback about whether or not they concur with the findings and the recommendations. They must ensure that any evidential data is circulated within the unit so that it can be used to inform future decision making. They are also responsible for ensuring that any immediate actions are implemented as a local level. The local reviewing officer then hands the report through the designated chain of command to the 'approving authority', see below.

There is a danger that incidents and accidents may form part of a wider pattern within a partcular installation. Similarly, there is a danger that particular recommendations that are intended to protect the operation of particular processes will have knock-on effects for the safety of other workers elsewhere in an installation. The installation-level safety manager's review is intended to identify any of these issues. The US Army reporting froms (DA 2397-R-series form, DA Form 2397-AB-R, DA Form 285, or DA Form 285-AB-R) contain special sections that are intended to help safety-managers identify these potential problems. Safety managers must review the data in these sections, not so much to validate particular recommendations, but to ensure that as much as possible can be learned from an incident. If primary and secondary investigators have missed previous incidents or patterns of systemic failure then this stage of validation is intended to identify them.

The 'approving authority' provides a further level of review within the US Army procedures. Major Army Commands appoint these representatives to accept or reject each finding and recommendation made by an investigation board. This takes place after the reports have been amended by local reviewing officials, using the procedures described above. In addition, the Safety Office of the Major Army Command ensures that the report is complete with respect to the Army guidelines [807]. Major Army Commands-level recommendations will be tracked using a computerised tracking system. At this stage, the approving authority will also be concerned to identify any additional recommendations that might be made to 'higher headquarters'. Finally, the US Army Safety Centre reviews all reports to ensure that they conform to regulatory and technical requirements. They are also responsible for maintaining the automated tracking system that the Major Army Commands use to track the implementation of particular recommendations. The Safety Centre is also responsible for disseminating information about the implementation of accepted recommendations to the relevant elements within the Army command structure.

It is important to emphasise that such elaborate validation procedures can create a number of potential problems. In particular, the responsibility for validating and implementing particular recommendations can become lost between the various exchanges that take place at different levels within the command structure. The opportunity for administrative delays is, therefore, acknowledged by guidelies that are intended to keep investigators and contributors notified about the course of the validation and implementation process:

> "Acknowledgements: upon receipt of written notification of recommendations, the responsible Department of the Army-level organisation will provide an initial response to the US Army Safety Centre within 60 calendar days as to corrective action(s) initiated or planned. Interim and follow-up reports are required every 90 days after initial response until the action(s) is closed.
>
> Return non-concurrence or rebuttals: all Department of the Army-level recommendations not accepted or implemented by the responsible command, organisation, agency, or activity will be returned to the Commander, US Army Safety Centre, with support rationale within 60 calendar days after initial notification." [807]

Local reporting systems provide a strong contrast to the elaborate procedures and mechanisms that are exploited by large organisations such as the US Amry. Peer review is often the only form of validation that is used to assess potential recommendations. These are often ad hoc, undocumented and informal. For example, many hospital-based systems hold monthly meetings between clinical and nursing staff. These discussions are, typically, unminuted. They are focussed to ensure the rapid implementation of changes providing there is general agreement about the utility of a particular proposal. There are, however, increasing pressures for such local initiatives to follow more documented processes [635, 453]. The importance of clinical audit within the medical domain and the wider public concern over high-profile accidents has led to a requirement the individuals and organisations explain *why* particular recommendations are not implemented. In consequence, the following paragraphs concentrate on the more formal mechanisms that have been exploited by large-scale systems. These may, of course, have to be scaled down to meet the more constrained budgets and scope of local systems.

Both ad hoc and more formal validation procedures must determine whether or not to accept particular recommendations. If a proposal is accepted then the review panel implicitly accepts a degree of responsibility for the proposed intervention. It is, therefore, important that they agree both with the form and the purpose of a recommendation. In consequence, many review bodies have introduced further distinctions beyond a simple accept or reject decision based on the recommendation that they have been asked to review. For example, the following quotation is part of a letter from the Commander in Chief of the US Army's Central Command. This letter reviews the recommendations that were made in the aftermath of an incident on a firing range in Kuwait.

Rather than simply accepting the recommendations outright, the review approves of the intention behind the proposal but modifies it and also clarifies that the modification should not bias the implementation of the recommendation:

> "d. Recommendation 1403 provides, That appropriate administrative action be taken against the Ground Forward Air Controller. The recommendation is modified, as follows; That administrative or disciplinary action, as appropriate, be considered with regard to the Ground Forward Air Controller. The recommendation, as modified, is approved. My modification does not in any way reflect my view as to what action may or may not be appropriate. It is intended to assure the appropriate Service official of his or her complete discretion in the matter." [825]

These distinctions can be summarised as follows:

- *Accept.*
  Given the investment in time and money that is often made to support incident investigation, it might be expected that most review boards will concur with the findings of an inquiry. Unfortunately, this can be surprisingly rare. As we have seen, some guidelines explicitly argue that investigators should not consider the costs associated with the implementation of their recommendations. These considerations often prevent regulatory organisations from sanctioning the implementation of particular interventions. A host of other issues can prevent review boards from accepting the findings of incident investigators. For example, the members of these boards typically do not take part in an initial investigation. It can, therefore, be hard for them to follow the detailed causal arguments that motivate particular recommendations. Review boards, therefore, often request further clarification or additional forms of evidence before they will accept many proposed interventions.

- *Accept with provisos.*
  Most review boards do not immediately accept all of the recommendations that are proposed by investigators. Instead, they may request additional evidence to support a causal analysis. Alternatively, review boards may propose alternative causal explanations that, if proven, would support other forms of intervention. Even if a recommendation is accepted, review panels may advise that its implementation is delayed or staged. Such ammendments can be motivated by the financial constraints, mentioned above. They can also reflect the pragmatic problems of ensuring conformance to any proposed changes in working practices and equipment. These provisos are typical of reporting systems in which investigators are independent from any regulatory function. They also characterise more local systems in which investigators must secure the support of higher levels of management before any commitment can be made towards increased investment. In such circumstances, review boards can accept recommendations 'subject to approval' from upper management.

- *Reject.*
  Review boards, typically, exploit one of several standard 'forms' of argument when attacking investigators' recommendations. The first line of attack rejects the arguments that investigators make during the causal analysis of an incident. For example, review boards can use variants of the counterfactual arguments proposed during a causal analysis by suggesting that an accident would still have occurred even if particular recommendations were implemented. Alternatively, it might be argued that proposed interventions only address the specific causes of an incident but fail to address more general failures. A second line of attack can be based around the risk assessment techniques that were introduced in previous paragraphs. It can be argued that the expected frequency or consequences of any future incident would be too low to justify the expenditure that is required to implement the investigators' recommendations.

- *Reject with provisos.*
  Review boards must exercise a considerable degree of caution when rejecting the recommendations in an incident report. They run the risk of alienating the investigators who constructed

such documents. There are obvious dangers in praising a review board for their careful use of resources if an incident does not recur within a given time period. Such rejections can also create a form of implicit responsibility should an incident recur. If an incident does recur then it can be argued that the failure might have been avoided if they had only approved the proposed intervention. It is, therefore, particularly important that review bodies document their reasons for rejecting a recommendation. In practice, this often leads to partial rejections or a refusal to implement a particular finding until some other condition is satisfied. This condition may involve eliciting additional evidence. It might also involve a commitment to perform additional studies should further incidents be reported.

- *Referral.*
  Given the potential consequences of rejecting a recommendation and the possible costs associated with implementing some proposed interventions, it is hardly surprising that many review boards defer to another authority rather than reach a premature decision. Often validation exercises result in panels deciding that they are not competent to reach particular decisions. Alternatively, they may accept the high-level arguments associated with a particular recommendation but refer to another body who must then develop a more detailed implementation plan. This is an interesting strategy because that body then assumes partial responsibility should the costs exceed expectations or the implemented remedy fail to prevent future incidents.

This list illustrates the range of outcomes that validating bodies might consider when assessing a recommendation. It is remarkably rare for a review panel to accept every recommendation without some caveat or proviso. Most validation exercises accept some proposals, reject a few recommendations and request that the remaining proposals be amended in some form. It is important to note, however, that a number of comments can be made about these general remarks. For example, many incident and accident reporting systems exploit a hierarchical validation process where review committees at a lower level in an organisation review the investigators' proposals before they are validated at a higher level. At each stage in this validation process it becomes less and less likely that higher authorities will reject a recommendation that has been accepted at a lower level. A cynical interpretation of this process might be that political and organisational pressures can help to mould recommendations into an acceptable format before they are presented to the highest levels within an organisation. A more favourable view is that upper management are less likely to question the detailed operational decisions of their subordinates.

A recent incident involving an Australian Army cadet helps to illustrate how different individuals and groups play different roles in the validation of particular recommendations. This incident occurred when a regional cadet unit were completing an exercise in which they had to swim to retrieve an object from a boat that was some twenty meters from the shoreline of a Dam. The cadets were wearing their army fatigues and boots. Several of them became entangled in weed beneath the surface of the water. One cadet became exhausted and went under the water approximately seven meters from the shorelines. Efforts to rescue him were unsuccessful. Arguably the highest level of validation for the Board of Inquiry's findings came from the Hon. Bruce Scott MP, Australian Minister for Veterans Affairs and from Dr Brendan Nelson, Parliamentary Secretary to the Minister for Defence . They concluded that the Board "conducted a thorough and open investigation into the circumstances" surrounding the incident [732]. They agreed with the Boards finding that the "swimming activity was not authorised by (the) Army and that there was inadequate supervision or monitoring of the Army Cadet Corps activity". In consequence, they took actions to suspend all swimming activities conducted in areas other than supervised swimming pools were immediately suspended, and will continue to be so, until a new policy on swimming activities is issued. They also implemented a review of the Australian Services' Cadet Scheme policy on safety, risk analysis and activity clearance by the Defence Safety Management Agency.

Such actions illustrate the way in which a final stage of validation is usually performed by organisations that exercise budgetary or political control over the implementation of particular recommendations. Their approval is required in order to approve the investment that may be required to support large-scale change. They must also provide the political support that is often necessary to implement what are often unpopular 'systemic' changes to establish working practices [702]. It is important to note, however, that such press statements and ministerial announcements represent the final stage in a range of more detailed validation activities. For example, the Australian Army's Board of Inquiry into the previous incident initially presented its findings to the Chief of Staff, Headquarters Training Command. He then issued a detailed appraisal of their findings. These illustrate the different forms of response that were sketched in previous paragraphs. For example, some of the Boards findings were accepted without comment:

> "I accept the Board of Inquiry finding that Cadet Sperling drowned as a result of a combination of factors namely, the amount of weed in the water, the depth of water, the wearing of GP boots (with socks) and Disruptive Pattern Camouflage Uniform (DPCU) clothing whilst in the water and the absence of safety devices (such as flotation vests) and inadequate safety precautions for the swimming activity. These factors contributed to Cadet Sperling's drowning. The wearing of GP boots and DPCUs whilst swimming or treading water is a difficult activity for persons of average physical fitness. A swimming activity undertaken by cadets as young as 13 years with unknown fitness levels and unknown medical conditions in the circumstances existing on 18 Nov 00 at the Bjelke Peterson Dam, was inherently dangerous." [33]

This acceptance illustrates the way in which validating bodies do not simply consider the recommendations that are issued by investigators. Review boards, typically, begin by assessing the evidence, the course of events and the causal analysis that are presented in the opening sections of most reports. For example, the Chief of Staff disagreed with the Board's analysis of one of the causal factors that was cited as a contributory factor in the incident:

> "I do not accept the finding of the Board of Inquiry that Corporal (Army Cadet Corps) ____ was not fully qualified as an instructor of cadets in the Army Cadet Corps in accordance with the Army Cadet Corps Policy Manual. Corporal (Army Cadet Corps) ____ had completed the Instructor of Cadets Course and First Aid Course in compliance with the Army Cadet Corps Policy Manual and was qualified as an Instructor of Cadets." [33]

Such validation actions illustrate the importance of explicitly documenting the causal findings that support particular recommendations. Without such analysis, it can be difficult to determine which recommendations might be affected by the review board's rebuttal of the investigators' analysis. It is for this reason that Tables 12.6, 12.8, 12.9, 12.10 and 12.11 were introduced to provide a bridge between the products of a causal analysis and the interventions that are intended to safeguard future operation. Such documentation can help investigators to determine whether or not a recommendation must be abandoned after such a rebuttal. If, for example, a recommendation is supported by several lines of causal analysis then it may still be retained even though one line of argument has been challenged.

If reviewers accept that incident investigators have identified a cause of the incident then they may continue their validation by asking whether or not that cause is 'adequately' addressed by the proposed recommendation. At first sight, this might seem to be a relatively trivial task that should be based around an engineering assessment of whether or not an incident is likely to recur if a recommendation is implemented. As we have seen, however, such subjunctive reasoning is fraught with problems. Many of these relate to the psychological processes involved in reasoning about alternative possible futures without the support of some underlying model of formal reasoning [403]. Other problems stem from the way in which some recommendations are not intended to entirely avoid future incidents but to control or mitigate their consequences. The effectiveness of these measures often depends upon the nature of any future incident and this, in turn, may depend upon other defences functioning in the manner intended. As we have seen, however, many incidents stem from the failure of these 'defences in depth' [702]. Further problems arise when recommendations have social or political consequences that can prevent review bodies from adopting them. For example, the Chief of Staff, Headquarters Training Command could not accept one of the recommendations that would have had considerable implications on the size of the Australian Army's Cadet force: "I do not accept the Board of Inquiry recommendation (Reference A para 268(d)) that cadets suffering from asthma should be required to comply with Army recruiting standards" [33]. Such a recommendation would reduce the likelihood of future incidents. It would also sacrifice some of the wider objectives that motivate the Army and the Department of Defence to run the Cadet Force.

Previous sections have explained why it can be relatively rare for validating bodies to accept the recommendations of incident investigators without raising caveats and objections. There are, however, examples of proposed interventions that are accepted in this way. It is important that the review board explicitly documents the extent of their agreement so that there can be no subsequent disagreement about what was intended by their approval for particular measures. For example, the following review paraphrases the Board of Inquiries recommendation and uses their paragraph reference scheme, Reference A para 268(f), to make sure that the reader can trace their agreement back to the original proposal:

> "I accept the Board of Inquiry recommendation (Reference A para 268(f)) that the Application for Activity Approval be forwarded through the cadet unit's foster unit with the provision for comment and then on to the respective Regional Training Center for consideration. On approval or rejection, a copy of the Activity Approval Form should be returned via the foster unit who should then confirm the availability of requested equipment and other support. The revised arrangements are to be incorporated into the Army Cadet Corps Policy Manual. Action: COMD Army Cadet Corps by 14 Mar 01." [33]

Previous paragraphs have described how review bodies can respond in several different ways to the recommendations that are proposed in incident reports. They may accept them, reject them or request modifications. They may also defer comment and request additional evidence or support from others at different levels within an organisation. The following list uses the previous analysis to derive a list of requirements that might guide the validation of recommendations in incident reporting systems:

1. *Clearly identify each stage of the review process.*
   There are increasing pressures, especially within certain sectors of the Healthcare and transportation industries, to ensure that recommendations are not dismissed without due consideration. One consequence of this is that any proposals must be subjected to a clear and coherent review process if they are not to be implemented. From this it follows that each party in an investigation must understand the nature and extent of each validation. In particular, it is important that time limits be associated with each stage of a review so that investigators, regulators and contributors can track the progress of a report towards implementation.

2. *Establish that the report is complete.*
   Given that many incident reporting systems cover diverse geographical and functional areas, it is likely that some reports may omit important details about an incident. If such reports are dismissed late in the review process then there is a danger that important insights will be ignored. It is, therefore, important that an initial validation ensures that any potential report is considered complete so that any consequent recommendations will not be immediately dismissed. For instance, checks may be conducted to ensure that all relevant evidence is available and is cited correctly. Other forms of integrity check can also be carried out. For instance, if the US Air Force guidelines are followed then each recommendation must clearly identify an initial implementation route.

3. *Validate the evidence.*
   Review boards must ensure that evidence is cited in a consistent manner and that all of the necessary data about an incident has been presented in an incident report. There is an increasing recognition that complex incidents often stem from interactions between systems failures, human 'error', managerial problems and so on. Less 'severe' incidents often cannot command the resources that are required to fund multi-disciplinary investigations. It can, therefore, be difficult for investigators to identify all of the information that might be relevant

to an incident. This is especially true when individuals are unaware of similar incidents in other units or regions. In consequence, review boards must satisfy themselves not only that the relevant information has been collected but that it is also presented in a fair and impartial manner within the body of the incident report. Chapter 13.5 describes some of the pragmatic problems that can arise when attempting to satisfy such an abstract requirement.

4. *Validate the causal analysis.*
Chapters 9.3 and 10.4 have described a range of techniques that support the causal analysis of adverse incidents. These approaches provide procedures to guide the analysis of adverse occurrences. They also depend upon a range of subjective decisions that must be validated. Even within the formal systems of reasoning, investigators must identify those elements of an incident that are to be represented within the abstractions of a formal logic. It is also important to emphasise that none of these techniques is 'error proof'. The correctness of any causal reasoning must, therefore, also be verified. Any omissions or errors at this stage in the analysis can result in recommendations that fail to address the causes of an incident.

5. *Validate each recommendation.*
This chapter has reviewed a range of heuristics that can be used to validate particular recommendations. For example, investigators may lack the time and the experience necessary to identify the best means of implementing particular recommendations. It is, therefore, important that any proposals should focus on what is to be achieved rather than the particular mechanisms that will be used. Similarly, we have argued that clear timescales must be associated with each recommendation so that their implementation is not indefinitely delayed. Proposed interventions should focus on specific actions rather than on additional studies that may or may not identify potential safeguards. It is important that review bodies consider these various heuristics when validating particular requirements. Clearly, there may be instances in which some of these guidelines cannot be satisfied. For instance, if it would be dangerous to impose additional requirements without further investigations. Validation authorities must, however, satisfy themselves that there are indeed good reasons for violating these recommendation heuristics. This analysis must also consider any priorities that are associated with any proposed interventions. The risk analysis techniques, described in previous sections, often depend upon subjective assessments both of frequency and consequence that can have a profound impact upon any subsequent resource allocation.

6. *Document the reasons for any rebuttal.*
There can be profound implications if a review body decides not to accept a particular recommendation. If a similar incident occurs in the future then they may be blamed for opposing a necessary safety improvement. It is, therefore, essential that some auditable justification should be recorded to support such decisions. This argument applies to the rebuttal of particular recommendations. It is also important to document any challenge to the evidence and any causal analysis in an incident report. For example, if a line of analysis is questioned then it is important to ensure that any associated recommendations are not supported by alternate causal arguments. If the recommendation is dismissed without such an additional check then there is a danger that s potential cause of future incidents will not be addressed by any proposed safeguards.

7. *Validate implementation plans.*
The next section will identify some of the problems that can frustrate the implementation of recommendations once they have been approved by validating bodies. It is important, therefore, that review organisations should consider these potential barriers when assessing particular recommendations. If they request resources that cannot be made available at a local level then the validating authorities must provide some means of ensuring that additional resources are provided. If such resources cannot be found then they must either recommend that a proposal be redrafted or, in extreme cases, that production should be halted until some remedy is identified. This validation activity does not simply focus on the staff and equipment that may be necessary to perform any changes to an application. It also focuses on the key

personnel who must supervise those changes. In particular, the implementation of particular recommendations should not impose additional burdens that may result in other forms of failure being introduced into a system.

8. *Initiate recommendation tracking.*
   The problems that exacerbate the implementation of potential recommendations have motivated many organisations to create automated tracking systems. These enable safety managers to request and review reports from individual units as they are scheduled to adopt any changes in their working practices. These tracking systems are often integrated into the final stages of validation. Once a recommendation has been approved for implementation then an entry is created in the tracking system. This is tailored to reflect the timetable and monitoring responsibilities that have been proposed by investigators and approved by successive reviews.

The validation of particular recommendations provides no guarantees that they will ever be implemented. The complexity of many safety-critical applications can provide numerous barriers to the introduction of process improvements. It can be difficult to ensure that key personnel understand what they must do in order to avoid future incidents. Similarly, it can take months and even years before obsolete components are removed from a system. Even within the best resourced systems, engineers are often found to retain stocks of spare parts that have been condemned in previous incident reports [807]. The following section, therefore, briefly considers some of the challenges that must be addressed when investigators and safety managers must implement particular recommendations.

12.3.3 Implementation

The implementation of recommendations involves the development and monitoring of a corrective action plan [572]. These plans are prepared by individuals who are, typically, appointed by the most senior validation board. These 'implementation officers' may or may not have been involved in the initial incident investigation. Their action plan must explain how they propose to address all of the recommendations that have been accepted following ammendment and clarification. Each item in the action plan must address the following questions:

- *What causes are addressed?*
  In order for managers and operators to understand the importance of a corrective action, information should be included about those causes of previous incidents that are to be addressed by a particular intervention. NASA explicitly recommend that portions of a recommendation matrix should be included with an action plan [572]. This may, however, prove to be too cumbersome a requirement for smaller scale systems.

- *What is to be done?*
  The recommendations that are validated by review boards should describe what is to be achieved without describing how any particular requirement will be satisfied. Hence, this information can be directly derived from the final version of a recommendation that is approved by any review board.

- *How is it to be done*?
  It is important that managers and operators can plan how to satisfy a particular recommendation. As mentioned above, this detailed information need not form part of the documented proposal that is validated by review boards. It must, however, be documented in an action plan that can be approved prior to implementation.

- *Who is responsible?*
  The proposed action plan must clearly identify who is to implement any intervention. This can involve a detailed consideration of which branch of an organisation or subcontractor is responsible for ensuring that a corrective action is completed.

- *What are the wider consequences of any corrective action*?
  The corrective action plan must consider any wider implications that result from the implementation of a particular recommendation. Previous sections have mentioned how some

interventions can increase the risk of other forms of incident. Such trade-offs may have to be accepted if the benefits of preventing other forms of failure are perceived to outweigh this collateral risk. Corrective action plans must also review any wider process changes that may be necessary following the implementation of a recommendation.

- *How will the corrective actions be tracked?*
  It is important to ensure that corrective actions are implemented correctly if they are to have the intended impact upon overall system safety. An action plan must, therefore, consider how any interventions will be tracked. This analysis should ideally provide for interim status reports and for documentation to confirm the completion and closure of corrective actions.

The Canadian Forces provide an example of such action plans being used to direct the implementation of particular recommendations, known as needs assessments [149]. They encourage the development of specific implementation programmes that are intended to meet these needs assessments. In addition to the high-level requirements mentioned in th previous list there is also a concern to ensure that any action plan considers an appropriate range of potential implementation mechanisms. Implementation offers 'border on the negligent' if they only propose solutions that involve additional training. Improved tools, procedures and job-aids provide alternative solutions to inadequate knowledge or skills. It is ironic, however, that if these planned changes are not implemented then there may be future incidents are likely to be reported as training failures.

As with the approval process that is used to validate individual recommendations, implementation officers must identify a timetable both for the drafting and the approval of an action plan. For example, it might be specified that these actions should be completed within 30 working days of a validation panel accepting a particular recommendation unless they provide a written justification for extending the deadline. As mentioned, implementation plans are often not developed by investigators. It is important. however, that any action plan should be passed to them so that they can provide high-level feedback about whether or not the proposed intervention will fulfill their particular recommendations. Copies of an action plan may also be passed by the validating panel to safety managers and to regulators for further review. Their comments must be considered by the validation panel within the timescales, described above.

If an implementation plan is rejected by the validation panel then it is returned to the responsible organisation for revision and resubmission. As before, a timescale for resubmission must be developed to ensure that potential safety improvements are introduced as soon as possible, It is important to emphasise that this process of working out how to implement a particular recommendation can help to uncover further recommendations that might not have been considered during an initial investigation. For example, 'cook-off' incidents occur when the heat that is generated by a gun can cause premature firing of ammunition. A series of incidents persuaded the US Army to focus on the M60 machine gun. During a more detailed analysis of potential solutions to this problem, it was realised that 'cook off' incidents also affect a range of other weapons that had not been considered during the initial analysis [821].

If a plan is accepted then the implementation officer must initiate the proposed corrective actions, for instance by putting out any proposed work to tender or by disseminating relevant safety information. In larger organisations, these actions will, typically, be performed in close collaboration with safety management. In smaller organisations, an action plan may simply be approved by higher management and then be initiated by the staff running the reporting system. In either case, audit actions are often introduced so that review bodies can determine whether corrective actions have been implemented and whether they can be shown to produce the desired effects. Previous sections have mentioned the difficulties of measuring safety improvements when adverse incidents are likely to be rare events. A range of further problems complicate these audit activities. For examples, the individuals and groups who are responsible for executing an action plan may discover that certain actions are unnecessary or unwise. In such circumstances, the implementation officer must seek approval to alter the implementation plan. Such changes must be well-documented and validated by a review board and by safety management before they can be accepted.

It is important to determine who is responsible for monitoring compliance with particular safety recommendations. In smaller-scale systems, this is likely to be the same person who is responsible for ensure the implementation of any corrective actions. In larger scale systems, this monitoring function is more likely to be performed by an independent safety manager who must report any concerns about non-compliance to the validating panel. This feedback is necessary for several different reasons. For example, it can be difficult for validating bodies to identify whether or not a proposed intervention will be effective unless they are informed about the success or failure of previous initiatives. Similarly, review bodies may be able to act if they identify patterns of non-compliance within particular geographical areas or functional units. Chapter 14.5 will discuss the problems of interpreting and acting on such feedback in greater detail.

The implementation officer uses the responses from any monitoring together with any independent analysis from safety managers to determine whether or not it is possible to close a corrective action. Some organisations require approval from the validation or review body [572]. This approval can be obtained once the implementation officer submits a final incident review. This review includes the investigators' incident report, the corrective action implementation plan and a list of any additional lessons that have been learned from an adverse occurrence. The review should also document any significant departures from the approved implementation plan as well as any non-compliance concerns that had to be addressed. Final review documents should be archived for future reference. This is increasingly done using electronic databases and information retrieval systems. Such tools enable investigators and safety managers to automate the search tasks that can be used to identify previous recommendations for similar incidents. Chapter 13.5 considers a range of potential technologies that can be used to support these tasks.

The US Air Force provide a specific example of the generic final review document mentioned in the previous paragraph. Their Air Force Instruction (AF 91-204) sets mandatory standards for incident and accident reporting [795]. This refers to a memorandum of final evaluation. The Headquarters Safety Centre must draft one of these documents for each high-criticality incident that is reported to them. This is an important caveat, clearly the extensive implementation procedures mentioned in previous paragraphs might place too high a burden on organisations responding to low criticality events. If individual operators and investigators felt that the procedural burdens outweighed the potential benefits from a particular recommendation then their might be a tendency to suppress or limit the number of proposed interventions. The Air Force, therefore, is careful to specify when these procedures must be followed. For instance, a Memorandum of Final Evaluation must be prepared for Class A and B incident reports even when the requirement to produce a formal report has been waived. Class A mishaps include 'failures' that incur cost of $1 million or more. This classification covers fatalities, permanent injuries or the loss of an aircraft. Class B mishaps include 'failures' costing between $200,000 and $1 million. Events may result in permanent partial disability or hospitalisation.

The Memorandum of Final Evaluation collates input from various sources including the Major Commands that convene an investigation, the commander of the mishap wing, statements from individuals and groups who are cited in an incident final report and so on. It is intended to provide an overall assessment both of the incident report and of any subsequent responses to the investigators' findings. The US Air Force procedures also state that the Headquarters Chief of Safety must publish these memorandum using an electronic database (AUTODIN) and the Defence Messaging System. At this point, the memoranda become the "official Air Force position on findings, causes and recommendations" that relate to the incident [795]. The Headquarters Chief of Safety, therefore, explicitly validates the recommendations that are embodied within the memorandum through this act of publication via these information systems. Any associated actions become active and must be executed by the named agencies that are associated with each recommendation. Suspense dates are also associated with these actions. Action agencies must report on completed actions or on progress toward completed actions by that date.

All agencies and organisations within the Air Force are required to review each Memorandum of Final Evaluation to determine whether any of the deficiencies leading to the mishap apply to their commands. This involves a filtering process in which each memoranda is forwarded by a receiving officer to the technical units that might be affected by any particular recommendation that is contained within it. The directors of these units review the memoranda to determine whether or not they are applicable to their systems an working practices. If they are then changes are initiated at this level. The incident reporting process does not finish with the local implementation of any recommendations in a Memorandum of Final Evaluation. Mishap Review Panels must be established within individual commands to ensure that recommendations continue to be addressed. The regulations require that these panel meet *at least* once every six months. These meetings are intended to ensure that preventive actions are implemented and that all parties review the status of open recommendations. Recommendations must remain open until Headquarters Safety Officers agree that either all recommended changes to publications have been made and the updated versions are issued or the recommended modifications have been completed on all applicable systems or that all recommended studies and evaluations have been completed and that actions on all validated requirements have been closed. It is possible for recommendations to be closed if they are considered to be impracticable within existing operational constraints or cost parameters. Similarly, a recommendation can also be closed if an item is removed from service. Such actions must again be validated at a central level so that the outcome is recorded in the electronic information systems, mentioned in previous paragraphs.

As mentioned above, these various reporting procedures apply to major incidents and accidents. A less formal approach is permitted for less serious mishaps. For example, an incident description can be drafted instead of the more formal incident report. It is important to note, however, that these descriptions must still be validated at the Major Commands level; "While (these) mishaps are not catastrophic, they are serious enough to require reporting on an individual basis and recommendations resulting from them require effective management". These less critical mishaps are not tracked by the Memorandum of Final Evaluation process, described above. The Air Force, therefore, introduces additional requirements to ensure that lessons are learned from the analysis of these incidents. The final description, mentioned above, must outline all of the local actions that were taken after an incident. As we have seen throughout this chapter, these remedial actions must be explicitly related to the causal findings that they are intended to address. These documents must also report any actions that are planned but not yet completed. Estimated completion dates must also be provided. These reports are also intended to provide local units with an opportunity for eliciting central support should it provide necessary in order to implement a particular recommendation.

12.3.4 Tracking

This book focuses on two different levels of tracking or monitoring within incident reporting systems. The first of these activities ensures that operators and managers conform to the individual recommendations that are made in the aftermath of incidents and accidents. We refer to this as recommendation 'tracking'. The second of these activities ensures that incident reporting systems as a whole are having their intended effect on the safety of an application process. We refer to this as the 'monitoring' of a reporting system. This section provides a brief overview of recommendation tracking. Chapter 14.5 provides a more detailed analysis of system monitoring.

Previous pages have described how implementation action plans must be developed if high-level recommendations are to protect the future safety of complex, application processes. We have also described how electronic databases and messaging systems have been used both by the US Army and Air Force to track outstanding actions plans until they are closed. Such systems provide a particular example of more general techniques that have been developed to help implementation officers track the progress towards achieving particular recommendations. These approaches must address a number of problems that can limit the effectiveness of any implementation plan. For instance, intended recipients may not receive a plan. Tracking systems must determine whether or not all appropriate personnel have access to the information that is necessary in order for them to implement a particular plan. This might seem to be a trivial requirement given the sophisticated communications infrastructure that supports many complex, organisations. As we shall see, many incidents recur because these communications systems are not completely reliable. For instance, paper-based instructions are frequently lost or destroyed. This creates particular problems when information must be passed between different shifts or teams of co-workers. Electronic information systems often suffer from usability problems that can prevent staff from accessing the information that is necessary for them to revise previous working practices. Technical problems and server loading can also prevent uses from accessing necessary information. Further problems stem from the difficulty of keeping up with the number of implementation plans that affect the many different items of equipment that particular members of staff may be responsible for. For instance, the US Army issued at least eight revision requests for the M9 Armoured Combat Earthmover manuals in a single month in 2000: TM5-2350-262-10, TM5-2350-262-10HR, LO5-2350-262-12, TM5-2350-262-20-1 & 2, TM5-2350-262-20-3, TM5-2350-262-34, TM5-2350-262-24P, TM5-2815-240-34&P [811]. These were published in paper form and disseminated via the Army Electronic products Support Bulletin Board (http://aeps.ria.army.mil/). In addition to these sources, Armoured Combat Earthmover operators also had to monitor at least two separate web sites (http://ncc.navfac.navy.mil and http://www.tacom.army.mil/dsa/) that contained further information about modifications and revised operating procedures for their vehicles. The difficulty of following all of the implementation plans and revised regulations that affect particular tasks can also be illustrated by the US Army's explosives safety policy. Between September and December 1999, the Office of the Director of Army Safety and the Office of Deputy Chief of Staff, Logistics issued revised guidance on loading Bradley Fighting Vehicles, on the Storage of Operational, Training and Ceremonial Ammunition in Arms Rooms and on Explosives Safety Site Plans for Ranges. Each of these involved major changes in the way that safety managers and operating units conducted many 'routine' tasks. For instance, the revised guidance on loading ammunition into the Bradley Fighting Vehicles gave the following explosives safety guidance:

> "If a BFV is uploaded with only 25mm ammunition and other small arms ammunition, with the hatches and ramp closed, then that BFV is considered heavy armour. The heavy armour qualification allows such a BFV to have reduced quantity distance separations. Uploading with TOW missiles or other high explosives items removes the allowed reduction in quantity distance." [820]

These revised policies and procedures were published via the the US Army's Explosives Safety Website (http://www.dac.army.mil/es/). However, the recipients of these revised guidelines were also warned that they were minimum guidelines and that even if they followed them they may also be in contravention of more restrictive practice regulations enforced by individual Major Army Commands; "before personnel act on these policies, personnel should check with their MACOM safety offices to see if MACOM policy mirrors Army policy" [820]. This duplication of authority creates considerable problems for the operators and managers of complex, safety-critical systems. This interaction between local requirements and the recommendations from central incident reporting systems complicates the problems of ensuring conformance with safety requirements. Tracking must, therefore, assess whether operational units meet the minimum recommendations proposed by an implementation plan. It must also determine whether those units meet the more stringent requirements that are often imposed when local units seek to enforce those recommendations.

A further purpose of tracking is to ensure that operators and managers receive correct information about revised operating procedures. Many reporting systems translate the recommendations that are embodied within implementation plans into more accessible formats. For example, the US Amry publishes information about such changes in its *Countermeasures* magazine. Very rarely, mistakes can enter into a recommendation as it is translated between an implementation plan and the story that is disseminated through these publications. Such errors have important safety implications if they are not detected either by feedback from the recipients of this information or through careful tracking by the operators of the reporting system:

> "Thanks to all the sharp-eyed readers who noticed that we published the incorrect maximum allowable speed for the M939A2 trucks in last month s Countermeasure . In the article The Rest of the Story on page 12, the correct sentence should read, '...the board checked the Army Electronic Product Support Bulletin Board via the Internet website http://aeps.ria.army.mil/and discovered that there are two safety messages (GPM 96-04, 131807Z and SOUM 98-07,081917Z) restricting the maximum allowable speed for M939A2 trucks to 40 mph (not 45 mph as previously stated) until antilock brakes and radial tires are retrofitted. We're sorry for this error." [809]

Even if the intended recipients of an implementation plan successfully receive information about revised working practices or material changes, there is no guarantee that they will act upon them. Chapter 1.3 has described the problems of identifying the reasons that motivate non-compliance with safety instructions. Some incidents are due to deliberate violations; operators may not understand the safety implications of a failure to comply with particular instructions. Other incidents stem from the operators' failure to understand the procedures that are required of them. These problems can be illustrated by a recent incident in which the right-side track of an M113 Armoured Personnel Carrier snapped. This prevented the driver from steering effectively. It also prevented any braking maneuvers which increased the vehicle's pull to the left. Subsequent examination showed that the pin on one block had worn through the metal parts that held it within the adjacent track block. A deep gouge in the hull and significant wear patterns on various track parts indicating a history of improper track maintenance. The M113 crew had all of the necessary tools and manuals to identify the problems. However, neither they nor the platoon leadership nor the company commander ensured the proper implementation of preventive maintenance procedures (PMCS) and revised operating regulations (DA PAM 738-750).

It is important to emphasise that such incidents often stem from multiple failures in the dissemination of safety-related information. An individual's failure to act on a particular implementation plan can have consequences that are compounded by their lack of information about other safety issues. For instance, previous incidents had also resulted in a maximum speed limit of 25 miles per hour being imposed on tracked vehicles, such as the M113, for the type of road that the crew was driving on. The driver did not know these limits, and neither the vehicle commander nor the squad leader traveling behind him took any action to make him slow down; "excessive speed contributed to the track failure and to the rate of turn of the M113, which resulted in roll-over" [805]. Such incidents are important not simply because they reveal the problems of ensuring compliance with the recommendations that have been made following previous incidents. They also illustrate particular problems in the dissemination of information about the associated implementation plans. It is, therefore, important that the managers of incident reporting systems track the analysis of future incidents in order to assess whether or not previous recommendations are being disseminated and acted upon by operational units. Previous paragraphs have described how the recipients of an implementation plan may either explicitly refuse to revise their procedures or may neglect to follow their requirements. In other situations, personnel may be motivated to comply with an implementation plan but they may lack the necessary resources to follow its provisions. Necessary resources can include the time and skills necessary to perform new procedures. They also include any new components that are identified in particular recommendations. Finally, the recipients of an implementation plan may lack the financial resources that might otherwise be used to make-up any shortfall in other resources. Ideally, such problems will have been considered and addressed during the development of an implementation plan. It would, however, be unrealistic to assume that such preparations would obviate the need to track the recipients' ability to satisfy the recommendations in these plans.

There are situations in which the tracking of particular recommendations can reveal concerns about the effectiveness of an implementation plan. During 2000-2001, the US Amry introduced an Improved Physical Fitness Uniform (IPFU). This was intended to offer improved comfort during exercise. It was also intended to reduce accidents and incidents through the incorporation of reflective material into the uniform. Many of the personnel who were issued with these uniforms were clearly motivated to conform with these joint requirements; to increase personal comfort and ensure visibility during exercise. The Safety Centre, therefore, received several enquiries about the effectiveness of the improved uniform's reflectivity. Subsequent investigations found that the uniforms met their intended specification and the comments were not triggered by either a design or production defect. In consequence, the uniforms were not recalled in response to the end-users' concerns. Instead, the Safety Centre emphasised that the uniform was not intended to be a replacement for a luminous safety vest [812]. Such incidents are instructive because they contrast strongly with the use of implementation tracking to detect violations. In this case, staff were concerned to meet the recommendations that informed the development of the improved uniforms. They felt, however, that the improved designs did not, however, offer the necessary degree of protection. The US Army safety Centre's response is also instructive. Instead of recalling the uniforms, their analysis of the end-users comments revealed additional safety concerns. Personnel were potentially relying on the protection offered by the uniform's reflectivity rather than wear a safety vest.

Implementation officers must track whether or not these validation and dissemination processes have introduced undue delays into the implementation of safety recommendations. This can be determined if a number of similar incidents occur before necessary changes are made to working practices or to process components. Such tracking activities can also reveal a converse problem in which recipients receive warnings well before they can act upon them. This occurs, for example, when advisories are issued for equipment that has not yet been received by its potential operators. In such circumstances, there may be an assumption that such warnings do not apply to their current tasks and hence they may be ignored. This can be illustrated by the findings of an incident involving one of the US Army's M939A2 wheeled vehicles on a public road [813]. Weather and road conditions were good and the vehicle obeyed the planned convoy speed of 50 miles per hour. In spite of this, the driver of an M939A2 failed to prevent the trailer that he was towing from 'fish-tailing' as he started to descend a steep hill. One of the tires on the trailer blew and the truck rolled off the road. The subsequent investigation determined that the tires were well maintained and showed no defects. Witness statements and expert testimony confirmed that the vehicle was not exceeding the approved speed limit. The investigation board's maintenance expert asked if the unit was aware of any Safety-of-Use-Messages or Ground Precautionary Messages on the vehicle. At first, unit personnel said no. They had only recently receivied their first two M939A2 trucks as replacements for older models.

> "At that point, the board checked the Army Electronic Product Support Bulletin Board via the Internet website http://aeps.ria.army.mil/ and discovered that there are two safety messages (GPM 96-04, 131807Z and SOUM Investigators Forum 98-07,081917Z) restricting the maximum allowable speed for M939A2 trucks to 45 mph until antilock brakes and radial tires are retrofitted. Further interviews with unit maintenance personnel determined that they had seen the messages when they came out. However, since the unit did not, at that time, have any M939A2 trucks, they did not inform the chain of command. The lesson here is whenever your unit receives new equipment; it is good practice to check all relevant Safety-of-Use-Messages and Ground Precautionary Messages to ensure that you and your personnel operate the equipment safely." [813]

Such incidents illustrate the problems that can arise when attempting to ensure that implementation plans continue to be followed in the aftermath of previous failures. As we have seen, many modern organisations are characterised by their ability to change in response to their environment, to market opportunities and in response to technological innovation. This has several important consequences for those who must track the implementation of safety policies. New devices will be introduced into new working contexts. Those devices may be subject to previous recommendations that must be communicated to the operators who must employ them within these new contexts. Similarly, new devices may interact with other components or working procedures that were themselves covered by existing recommendations. These changes can force revisions to existing guidelines and procedures. It is also important to stress that many organisations benefit from a dynamic workforce that moves between different production processes and regional areas. These workers carry their skill and expertise with them. There is considerable potential for them to apply procedures and regulations that were appropriate in their previous working context but which can be potentially disastrous in their new environment. In consequence, safety managers must typically find ways of ensuring that implementation plans do not simply provide short term or local fixes for previous incidents. Tracking must continue until they are satisfied that revised procedures and components are seamlessly integrated into existing working practices throughout an organisation. As those procedures and components change, it may be necessary to revise previous recommendations and again track any consequent changes to ensure the continues safety of an application process.

12.4 Summary

This chapter has argued that recommendations are made in response to the causal factors that are identified by incident investigators. Some organisations, including the US Air Force [795], have argued that each recommendation must be related to a causal factor and that every causal factor must be associated with a recommendation. If a causal factor is not addressed then there is a possibility that a potential lesson will not be learned from a previous failure. If recommendations are not associated with causal factors then these is a danger that spurious requirements may be imposed for reasons that are unconnected with a particular incident. We have, however, pointed to alternative systems in which recommendations can be derived from a collection of causal factors. This often happens when investigators identify an incident as part of a wider pattern of previous failures.

This chapter has also identified a range of techniques that have been developed to help investigators derive the recommendations that are intended to prevent the recurrence of future failures or the 'realisation' of near-miss incidents. The 'perfectability' approach is arguably the simplest of these techniques. Given that many accidents and incidents are not the result of equipment failure, this approach focuses almost exclusively on the human causes of an incident. Recommendations are intended to perfect the performance of the fallible operators. An increasing number of researchers and practitioners have spoken out against this technique by arguing that investigators must focus on the context in which an error occurred [702, 344]. Instead they propose a more organisational view of failure that focuses recommendations on 'safety culture'. They have certainly provided useful correctives to the 'perfectability' approach. However, the backlash against 'prefectability' has often neglected the pragmatics of situations in which operators and managers assume some responsibility for their actions.

Subsequent sections reviewed the use of heuristics to guide the development of recommendations. These heuristics guide investigators away from interventions that are explicitly intended to rectify specific instances of human error. They also provide useful guidance on the presentation and format of potential recommendations. For instance, we have cited heuristics that encourage investigators not to propose additional studies. Such recommendations often defer actions that are then not taken when the results of additional research are not acted upon. Similarly, other heuristics are intended to ensure that investigators consider what a recommendation is intended to achieve and who must implement it.

A limitation with the heuristic approach is that it leaves considerable scope for individual differences to affect the detailed interventions that are proposed in the aftermath of an incident. Enumerations and recommendation matrices have been developed to ensure some degree of consistency between the findings of different investigators. For example, US Army publications provide lists of commonly recognise causal factors. The same documents also enumerate potential recommendations [797] These can be linked into matrices so that investigators can identify a number of potential recommendations that might be used to address a particular cause. Unfortunately, this approach only provides high-level guidance about potential interventions. The entries in a recommendation matrix tend to be extremely abstract so that they can be applied to the wide range of incidents and accidents that might be reported to complex and diverse organisations, such as the US Army. In consequence, a number of more detailed accident prevention models have been developed. These are generic only in the sense that they provide a high level framework for the drafting of proposed recommendations. The intention is that investigators can refine them to a far greater level of detail than is, typically, achieved in recommendation matrices. The barrier model has been described in previous chapters as a causal analysis technique. The same approach can also be used to guide the identification of proposed recommendations.

An important limitation with all of the approaches that have been summarised in the previous paragraphs is that they can be used to identify recommendations but not to assess their relative importance or priority. This is a significant issue for the safety managers who have to justify the allocation of finite resources in the aftermath of an incident or accident. In particular, they must ensure that the greatest attention is devoted to those hazards that are most likely to recur and which pose the greatest threat to the safety of an application. A number of proposals have been made to address these problems. Most of these attempt to synthesise incident analysis and risk assessment techniques. Many practical and theoretical problems are raised by this synthesis. we have illustrated those problems using the US Army's five stage process of risk analysis: identify hazards; assess hazards; develop controls and make risk decision; implement controls; supervise and evaluate. Previous paragraphs have described how the first three stages can be used to prioritise recommendations in terms of the difference between an initial risk assessment and the residual risk associated with both the particular causes of an incident and the more general hazards that an incident helps to identify.

The residual risk that motivates the promotion of a particular recommendation will only be achieved if the remedial actions are effectively implemented. The closing sections of this chapter show how difficult it can be to validate the claims that are implicit within a risk assessment and how hard it is to ensure conformance with recommended interventions. For example, we have brief examined the problems of documenting recommendations so that others can understand precisely what is intended and why it should be proposed. We have also looked at the difficulties of ensuring that accepted recommendations are implemented in good time across the many different operating units of complex organisations.

This closing sections of this chapter have stressed the importance of tracking recommendations. It is important to obtain feedback about how remedial actions are being implemented throughout an organisation. We have argued that implementation officers must guard against non-compliance and the deliberate violation of proposed interventions. Equally, they must ensure that the relavent personnel are provided with access to the information that is necessary to implement a recommendation. They must also ensure that this information is presented in accessible format that is easily understood by those who must use it. The following chapter examines these presentation issues in more detail. It not only considers how individual operators can be informed about the recommendations that are intended to avoid future incidents. It also addresses the more general problems of structure, format and dissemination that must be addressed when drafting incident reports. In contrast, Chapter 14.5 considers some of the problems that arise when investigators and safety managers must gain an overview of the many previous incidents that can motivate sustained interventions in safety-critical applications.