Risk and Decision-Making in Military Incident and Accident Reporting Systems

C.W. Johnson
Department of Computing Science, University of Glasgow, Glasgow, G12 9QQ, Scotland.
johnson@dcs.gla.ac.uk

Keywords: Human error, incident analysis, causation, root cause analysis.

Abstract

Incident and accident reporting systems can be used to identify patterns of operator behavior in the causes and mitigation of adverse events. Most attention in this area has, however, focused on the civilian process, healthcare and transportation industries. In contrast, this paper focuses on human factors issues in military incident reporting. We identify important differences both in the incidents that are reported and in attitudes towards human 'error'. For instance, military systems contain far more training related mishaps than might be expected in civilian systems. These incidents often stem from tensions between the need to prepare staff for operational situations and the need to control the hazards that form a necessary part of complex, military training scenarios. Further differences stem from the need for military personnel to make complex risk assessments in uncertain environments in strictly limited time periods. For example, leaders may have to choose between a short exposure to a relatively high-risk situation and prolonged exposure to a lesser risk. One consequence of this is that military reporting systems often focus more on the risk-decision making process than they do on the immediate actions that lead to an adverse event. It is also possible to identify a strong form of hindsight bias in which individuals may be blamed irrespective of the risk exposure that they accept.

1. Introduction

Incident reporting systems provide an important means of learning from failure in many safety-critical applications. For instance, British Airways operate their confidential BASIS reporting system (http://www.basishelp.com). The NASA Safety Reporting System gathers mishap information from across their diverse operations (http://www.hq.nasa.gov/office/codeq/narsindx.htm). In the medical domain, the Australian Patient Safety Foundation (http://www.apsf.net.au), the US National Patient Safety Foundation (http://www.npsf.org) and the UK National Patient Safety Agency (http://www.npsa.org.uk) all either operate or are establishing national incident reporting systems. These systems share many a number of common problems. For example, it can be difficult to elicit information about 'near miss' events when individuals are concerned that this might initiate disciplinary action. Similarly, once mishaps have been reported, there are few guarantees that different investigators will identify similar causal factors for similar incidents.

In previous papers, I have described techniques that can be used to support the development of mishap reporting applications in the civilian healthcare, transportation and process industries (Johnson, 2002a). Military incident reporting systems face a number of additional problems. For example, the command structure can make it difficult to sustain promises of confidential, blame-free reporting. This is a significant barrier because other systems have identified such assurances as a prerequisite for the development of trust in any reporting application (Johnson, 2002). Such concerns can have an important impact on the range of human factors issues that are elicited by military reporting systems (US Army, 1998). There are further differences. For instance, military organizations recruit young people and place them in what are often high-risk situations. These individuals are expected to make highly complex decisions, often involving a range of different technologies. They are, typically, expected to work in teams and to coordinate their activities with those of their colleagues who may be collocated or who may be hundreds of miles away. They face physiological and cognitive stresses that are seldom seen in any other domain. Equally, however, military personnel must often face hours of inactivity or of repetitious training that induces fatigue, boredom and inattention.

Much can be gained from studying the diverse incidents that are elicited by military reporting systems. As we shall see, many of these incidents reveal the limited support that existing models of human 'error' provide for the investigation of these complex, multi-party incidents (Johnson, 1999). Some models focus on performance shaping factors. These approaches neglect the ways in which environmental factors change rapidly from moment to moment as systems fail and colleagues improvise temporary solutions and coping strategies. Other more recent approaches focus on organizational factors. These underemphasize the role that individual responsibility, autonomy and local decision-making must play in situations that cannot easily be predicted.

2. An Overview of Military Incident Reporting

It is impossible in a single paper to adequately cover the range of reporting systems that support land, sea and air forces. This paper, therefore, focuses on army reporting systems. The interested reader is directed to Johnson (2002) for an analysis of other military systems. Table 1 illustrates the importance of military incident reporting systems by presenting the US Army's casualty statistics for recent military operations. As can be seen, accidents continue to represent a significant cause of injury to military personnel. Questions can be raised about the reliability of such statistics. They were released with the specific intention of reducing accident-related injuries. However, it is important to recognize the US Army's concern that the proportion of accident related casualties might rise because of the increasing use of complex, highly integrated technological systems. Table 1 also illustrates the disparity between accident related casualties and what are termed 'friendly fire' incidents. This is important because the 1% of casualties that stem from these incidents receive a disproportionate amount of public and military attention compared to the more mundane occupational injuries that represent the bulk of incidents and accidents.

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

Table 1: Percentage of Reported Casualties (US Army, 1998)

Incident reporting systems form part of a wider risk management process. For instance, the US Army's (1998) Technical Field Manual FM100-14 identifies five stages in risk management: 1. Identify Hazards; 2. Assess Hazards; 3. Develop controls & make risk decisions; 4. Implement controls; 5. Supervise and evaluate. Incident reporting helps all of these activities. For instance, accounts of previous adverse events or near miss incidents can directly inform the identification of potential hazards. For example, the US Army recently released a safety notification when its reporting system showed that drowning and water-related mishap were occurring at almost twice the anticipated rate during the Summer of 2002. An analysis of the incidents revealed that most of the incidents stemmed from the incorrect handling of small boats. This triggered an analysis of the previous decade's incident statistics. Over this period there were 141 reported incidents, some involving more than one fatality. Only 1 death occurred at a swimming pool with Army lifeguards. Most incidents occurred in open water or near the shoreline. Lake and river recreation produced 41% of the drowning incidents. Ocean swimming fatalities accounted for a further 16%. Military training operations accounted for 11% of the drownings. 9% drowned after vehicle accidents (US Army Safety Center, 2002).

Incident reporting can also support the third stage in the US Army's risk management process because accounts of previous mishaps often describe ways in which barriers failed. This enables safety officers to refine the measures that are intended to prevent the causes or mitigate the consequences of adverse events. For instance, a recent incident report described how a soldier fell while attempting to negotiate an 'inverted' rope descent. Previous training related incidents had led to the development of US Army 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 did 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' and the diagram was revised to remove any potential inconsistency. The incident not only helped to reinforce the need for the physical protection of the safety net, it also helped to clarify the procedures and guidance that were intended to ensure that a net had been provided in the first place (US Army Safety Center, 2001).

Figure 1 shows two military incident reporting systems. The image on the left is the opening screen to the US Army's Center for Army Lessons Learned (http://call.army.mil/). This illustrates the way in which many safety-related reporting systems are also used to elicit more general operational information. This should not be surprising given that more operational failures in a military environment will have safety-related consequences. US Army personnel can exploit this lessons learned system to find a host of more detailed safety-related publications and information sites, for instance covering engineering incidents. The figure on the left is the Canadian Defense Force's Safety Digest (http://www.vcds.dnd.ca/dsafeg/digest/intro_e.asp). This illustrates how military reporting systems provide feedback about adverse events. Each edition identifies a number of general safety concerns from the individual incidents and accidents that have been identified over the previous months. The intention behind the bulletin is not to provide statistical information. The problems of under-reporting make it difficult to derive reliable incident frequencies. In contrast, the intention is to remind staff of the importance of safety concerns and also to inform them of changes in operating procedures or acquisition policy that have been triggered by previous adverse events.

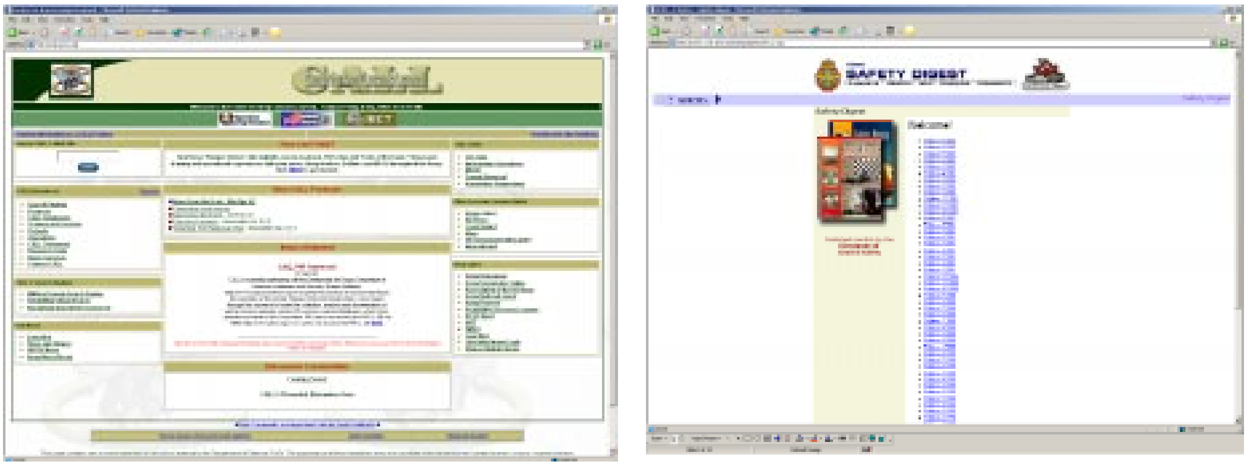

Figure 1: Military Incident Reporting Systems and Lessons Learned Applications

The US Army's Picatinny Arsenal reporting system illustrates the human factors and other operational insights that can be gained by these applications (US Army, Product Manager, Paladin/FAASV, 2000). The Arsenal maintains a lessons learned system for technicians working on the 155mm M109A6 self-propelled howitzer, known as the Paladin. A series of problems stemmed from situations in which the driver's hatch was opened with 'extreme' force. This caused the pin that secures the drivers hatch-stop to break. This defect could have rendered the vehicle inoperable according to the Paladin Operators Manual (TM 9-2350-314-10). Rather than follow this procedure or order new parts, many technicians applied ad hoc 'field solutions' using poorly fitted cotter pins, nails, and similar devices. These fixes resulted in more sustained damage to the expensive hatch stop assembly, which in extreme cases became totally inoperable. The Army's analysis of previous incidents, therefore, advocated that each unit hold a small number of spare Grooved Pins at a cost of $1.78 each. This simple measure was intended to reduce the need for ad hoc maintenance procedure and thereby avoid the safety risks associated with damaged hatch assemblies.

3. The (Un)usual Suspects

Military reporting systems remind personnel of the hazards that can arise in a range of different contexts. For example, the Canadian Defense Force Digest recently described an electrocution incident. Co-workers exposed themselves to considerable risk in trying to rescue their injured colleague. The editors of the digest concluded by reminding staff that electrical canes can help to reduce the risks involved in isolating electrocution victims. This incident not only shows that role that reporting systems can play in reminding staff of hazards and counter-measures, it also illustrates the way in which they help to open dialogues across an organization. Engineering staff criticized the recommendations made by the editor of the Defense Force Digest. Canadian national rules require that trained personnel should be no closer than 0.9 meters from the victim during incidents involving 425V to 12,000V. This would prohibit the use of electrical canes. The correspondent argued that the focus should have been less on rescuing the injured person and more on the prevention of such incidents; “unless management creates a safety culture based on risk management and unless supervisors instill this workplace ethos in their workers… and then enforces this view consistently, we will never break the chain and accidents will continue to occur" (Canadian Department of National Defense, 1999).

Many of the incidents reported to military systems are similar to those that are elicited by civil applications. The previous incident could have been reported in the process industries or in power generation. There are, however, some important differences. In particular, the age profile of the personnel involved in military operations tends to be much younger than that for civilian occupations. Military reporting systems also often reflect an extended ‘duty of care’ that is not present in other domains. For instance, many army systems analyze road traffic accidents involving their personnel even when they are off duty. In most commercial systems, these incidents would be left to the police. This additional level of involvement not only reflects the duty of care that military organizations extend to their personel; it also reflects an appreciation of the particular demands that are created by life in the forces. For instance, the geographical distribution and rotation policies employed by armies often leads individuals to travel enormous distances to meet family and friends. A US Air Force commander recently described how one of their staff attempted to drive 2,000 miles for a weekend reunion.

The particular characteristics of military life not only affect the circumstances that surround more familiar adverse events, such as road traffic accidents. They also affect the recommendations that are made in the aftermath of an adverse event. For example, a recent report on road traffic accidents involving military personnel pointed out that the fatality rate for car passengers increased by 1.1% for every 100lb decrease in the weight of the car. Occupants of a lightweight car are, therefore, four times as likely to die in a collision with a Sport Utility Vehicle (SUV) than the occupants of the SUV. The recommendations made from this investigation caused one correspondent to question the underlying argument. He responded, “…by this logic, our family car should be a multi-wheeled armored fighting vehicle” (Canadian Department of National Defense, 2000).

The superficial differences between military and civilian incidents can also hide deeper similarities. For example, the US Army Safety Center recently investigated an incident in which a seventy-ton Abrahams tank (M1A1) was overturned. The outcome was exacerbated because some of the occupants were not in safely secured within the vehicle. The report has strong similarities with many recent investigations into the lack of seatbelts in civilian road traffic accidents; “once again, human error became a contributing factor in the loss of a soldier. Leaders must ensure that they and their crewmembers 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" (US Army Safety Center, 2001a). Unfortunately, incidents involving incorrect positioning within military vehicles are almost as common as incidents in which drivers did not wear their seatbelts. The following month, the US Army Safety Center received a report of another incident in which a soldier was crushed by an M551A1. This overturned after being accidentally driven into an excavated fighting position. The injured soldier was standing in the hatch above the nametag defilade position.

Human factors techniques can be used to analyze these military variants of civilian accidents. For instance, it might be argued that they represent an extreme form of risk homeostasis. The over-engineering of vehicles such as the M1A1 and the M551A1 provides soldiers with an impression of safety that they then trade against performance. They will perform more dangerous maneuvers and expose themselves to greater risk because they are confident that the vehicle will protect them against the adverse consequences of any hazard. The two previous incidents illustrate the dangers of such a view. Unfortunately, the human factors analysis of risk homeostasis provides few insights that can be used to avoid future incidents. Without these insights we are as likely to eliminate crush injuries from nametag defilade incidents, as we are to persuade everyone to wear seatbelts. I would also argue that this analysis misses important characteristics of military incidents. The soldiers were performing maneuvers that the vehicles had been designed to execute. They had been informed of the correct seating positions and yet still exposed themselves to the risk. Such incidents illustrate the tension at the heart of military incident investigations. To what degree should we attribute responsibility to individual operators? To what degree should we attribute responsibility to those that manage the personnel involved? If we focus on the individual operator then we may miss the wider systemic factors that influenced their behavior. Equally, the focus on management responsibility often makes unrealistic assumptions about military organizations' ability to ensure personnel follow 'safe operating procedures' in the face of dynamic demands and complex problem solving situations.

The need to balance systemic factors and individual responsibility does not absolve the military command structure from responsibility in adverse events. Many mishaps stem from the same flawed 'safety culture' that affects civilian organizations. For example, the US General Accounting Office (1997) monitored the implementation of recommendations following a series of Army Ranger training incidents. They identified problems not simply in the implementation of those recommendations but also in the way in which they were drafted in the first place. For example, one recommendation required that the Army develop 'safety cells' at each of the three Ranger training bases. These were to include individuals who had served long enough to develop experience in each geographic training area so that they understood the potential impact of weather and other local factors on training safety. However, the National Defense Authorization 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. They also found problems in the conduct of annual site safety inspections. Those inspections that took place often-focused on 'checklists of procedural matters' such as 'whether files of safety regulations and risk assessments are maintained' rather than on monitoring the effectiveness of recommendations after incidents have been analyzed.

The tension between identifying systemic causes and punishing individual violations can be seen in the relationship between reporting systems and the mechanisms of military justice. For instance, the US Army's (2000) Accident Investigation and Reporting Procedures Handbook states that recommendations should not "address an individual's failure in a particular case" but should instead be "directed at the level of command/leadership having proponency for and is best capable of implementing the actions contained in the recommendation". However, this more enlightened view can be contrasted with the legal provisions that govern military courts. For instance, Chief Justice Lamer of the Supreme Court of Canada explained in R. v. Généreux in 1992 that "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".

4. Factors that Complicate Military Incident Reporting

The previous section has argued that there are many similarities between military and civilian reporting systems. The majority of adverse events reported to armed forces are slight variations on the occupational injuries, the slips, trips and falls that many human factors practitioners will be familiar with. In contrast, the following paragraphs describe a number of factors that complicate and characterize military reporting systems.

4.1. Achieving Safety AND Mission Success?

Individuals must be able to decide whether or not a particular incident ought to be reported for further investigation. Some organizations provide guidance by listing the types of adverse event that should be reported to their systems. The obvious limitation of this approach is that some safety-related incidents may not be listed. Other organizations identify a reporting threshold in terms of consequential loss. A report may be required if particular items of equipment are damaged or if the repair costs of any damage exceed a particular threshold value. The task of making such assessments is complicated if the costs of an incident are taken to include environmental impact. Similarly, it can be difficult to account for injuries and diseases or psychological adverse effects using such financial thresholds. Most organizations, therefore, define additional reporting criteria to explicitly list the types of physical harm that should trigger an incident report. The following excerpt from the US Army's Countermeasure illustrates the most clear-cut triggering condition; a fatality initiates attempts to learn lessons about the safety of particular military operations. "The unit was engaged in a 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. 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. Leaders must re-emphasize when encountering an unsafe situation, the mission must now become safety" (US Army Safety Center, 2001b).

Ideally, however, we would like to identify potentially hazardous operations before a fatality occurs. We must, therefore, identify the lesser consequences that should also trigger an investigation. This creates problems because if we set the criteria too low we can be swamped by reported and may lack the resources to conduct a proper investigation into adverse events. Conversely, if the criteria are set too high then we may lose valuable opportunities to learn before a fatality occurs. There are further complications. Outcome measures cannot be directly used to assess the criticality of near-miss incidents. The fact that an adverse event was avoided forces investigators to make crude estimates of the 'worst plausible outcome'. Similarly, there may be certain types of adverse event that should be investigated even though they resulted in outcomes that would not normally be serious enough to warrant an investigation. For instance, public anxiety over previous injuries to recruits or conscripts during initial training has persuaded many armies to devote additional resources to the investigation and analysis of these mishaps. It is for this reason that some military organizations hold review boards to discuss the circumstances surrounding an adverse event or near miss before deciding whether or not it should be analyzed in greater detail. This approach creates problems when inconsistent decisions are made to investigate some mishaps but to ignore other similar events. Most military systems rely upon a compromise approach that publishes a list of 'typical incidents' but also allows considerable scope for individual discretion (Johnson, 2002).

The task of identifying an adverse event is, however, more complicated in military systems. Many operations carry an intrinsically high level of risk. One consequence of this is that military incident reporting systems often elicit information about hazards that were well understood before the incident occurred. In many cases, it is impossible to entirely eliminate the potential hazard from occurring again without also sacrificing military objectives. For instance, the risk of drowning in river crossing exercises is well understood but most armies cannot avoid these operations. Steps can be taken to reduce the risks involved in such operations but they are unlikely to entirely eliminate the risks (Johnson 2002, Perrow 1999). The focus of military reporting is, therefore, often directed towards the particular decision making processes that led to a risk being accepted rather than to the individual actions that immediately led to an adverse outcome. For example, if soldiers choose not to accept a risk then they must often seek alternative means of achieving their objectives. This creates complex situations in which it might be preferable to accept a short-term safety hazard than adopt an alternative strategy that might involve prolonged exposure to a series of lesser hazards. It might be ‘safer’ to cross a river and take the risk of drowning than lead a team on a longer route through mountainous terrain. Sadly, however, individual blame is often assigned if the hazard is realized irrespective of the decision that was made. Hindsight bias is a familiar aspect of military incident reporting systems.

4.2. Tensions Between Training and Operations

One of the most significant differences between military and civilian incidents is that troops are often deliberately exposed to hazards in training exercises so that they can acquire necessary operational skills. Military training exercises are carefully designed so that any exposure occurs under controlled circumstances. Initial exercises using simulated munitions are mixed with ‘live fire’ exercises. These simulated operations are choreographed; the position of every participant and every system is often predetermined down to the last second.

Unfortunately, training mishaps still occur even under carefully controlled conditions. This can be illustrated by an explosives incident that took place during a US Army nighttime training exercise. The intention was that two platoons would lead engineers across the line of departure. They would then 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 before attempting to breach a triple-strand, concertina wire barricade. Such nighttime maneuvers require considerable preparation and the exercise was rehearsed several times. A daylight walkthrough was conducted without weapons, munitions or explosives. This was followed by a ‘dry fire' exercise with weapons but without munitions or explosives. The detailed breaching plan involved a team leader and two team members. The supporting members were to deploy 1.5-meter sections of M1A2 Bangalore torpedo into the concertina obstacle. The team leader would then pass elements of the initiation system to the team members who were to tie in the torpedoes to the detonating cords. The initiation system ‘consisted of a ring main (detonating cord about 1 meter formed into a loop) with two M14 firing systems (approximately 1 meter of time fuse with blasting cap affixed to one end) taped to the ring main' (US Army Technical Center for Explosives Safety, 2000). 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 team leader was to 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 was then to retreat to their original hiding place. The detonation was to act as a signal for a marking team to use chemical lights to help the following platoons locate the breach.

The incident 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 3-5 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.

Johnson (2002) provides a more complete analysis of the causes of this incident. The key point here is to stress the human factors challenges that are created by the safe conduct of nighttime military exercises involving multiple teams coordinating the use of sophisticated and potentially hazardous munitions. The complexity of such exercises makes it difficult to both predict and control all of the potential hazards that arise. The additional charge moved the training exercise beyond the carefully choreographed scenarios that had been practiced before the event. Subsequent investigations argued that the individuals involved should not have had access to the extra detonating cord and M14 initiation system. The excess munitions should have been relinquished before this phase of the exercise. However, it can also be argued that the ability to deal safely with such unexpected conditions is an intrinsic part of military training.

The previous incident illustrates the consequences of exposing personnel to hazards, such as the additional explosive, that were not intended to form part of the training exercise. Conversely, reporting systems can also document operational problems when training does not adequately expose personnel to particular hazards. For instance, the Canadian army's review of their participation in the NATO Implementation and Stabilization Force in Bosnia-Herzegovina found that: "Many units stated first aid training packages lack realism and should be oriented to injuries sustained in combat. IV and morphine training were essential... During 6 months in theatre, no soldier gave artificial respiration, treated a fracture or did a Heimlich maneuver. However, they did treat 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…" (Canadian Army Lessons Learned Center, 1999). These comments illustrate the complex problems that military systems pose for human factors specialists. Simulations can be exploited to determine whether units can be trained to safely exploit these techniques under combat conditions. Such exercises cannot, however, provide guarantees that future mishaps will not occur. The troop's perceived operational need for IV and morphine training cannot easily be balanced against the potential dangers of inappropriate use during subsequent operations.

4.3. The Politics of Acceptable Risk

Military organizations must often focus finite investigation resources on those adverse events that the public and politicians perceived to be of greatest importance. Incidents involving recruits provide one example. Heat related injuries during acclimatization training are another. For instance, a series of incidents involving the Singaporean military led to the development of detailed heat exposure regulations (Singapore Army Safety Organization, 2001). For the first 2 days of exposure, personnel should only perform light duties. For the next 2-3 days, the intensity of exercise can gradually be 1-2 weeks if exercise is limited to 2-3 hours in the heat. If the expose is less than 90 minutes then a carbohydrate-electrolyte beverage should be offered with no more than 8%, or 2 tablespoons of sugar per liter. If the exposure is greater than 240 minutes then this should be supplement with 1teaspoon of salt per liter. As a result, the frequency of heat-related injuries in the Singaporean army has declined since 1987. However, these recommendations have not eliminated the problem. In 2000, the Singaporean army's reporting systems found that there were still approximately 3.5 cases of heat related injury per 1,000 soldiers in service. In spite of the changes that have been made, the reporting systems continue to reveal an uneven distribution of cases. The majority occurs in training schools that prepare National Service recruits for military life. Cases are still clustered around the periods of physical activity that are allowed in the morning and the afternoon when the heat is less severe.

The Singaporean army faces particular problems in address heat-related injury because of the climate in which it operates and the diverse pool of recruits that it receives from the National Service intake. Similar adverse events are mentioned in every military reporting system that I have reviewed over the last decade. For example, a US General Accounting Office (1994) report highlighted a case in which a Marine's death in training was classified as being due to 'natural causes' even though he had just completed 5 pull-ups, 80 sit-ups, and a 3-mile run. Perrow (1999) has argued that we will never entirely eliminate accidents because of the desire to introduce increasingly complex and tightly coupled technologies. In contrast, I would argue that the stubborn nature of heat-related military injuries points to a less sophisticated form of 'normal accidents'. These do not stem from the economic pressures for technological innovation. They stem from the organizational pressures that enable individuals to escape the lessons of the past. Operational and training procedures continue to depend upon a physiological mismatch between the environments in which a recruit must operate and their own physical resources. If we remove this mismatch, for example, by introducing more stringent exposure controls then incidents can be reduced. The point of the exercise may be lost, however, if individuals are left unprepared for their operational environment when training finishes. This again illustrates the tension between the need to avoid adverse events and yet provide individuals with experience in controlling or avoiding the hazards that arise in operational contexts.

As we have seen, military forces have allocated considerable resources to understand and combat the causes of heat related injuries. The importance of learning from these incidents has increased in recent years partly as a result of political and public concern, especially over incidents involving new recruits or conscript and national service units. It is difficult to underestimate the impact of such influences on military operations. In democratic countries, armies must account for any adverse events to the politicians and public who employ their services. It, therefore, follows that operational concerns or training priorities cannot solely be used to determine what is an acceptable military risk. This is at least in part a political decision. The US and UK forces have recently felt these influences following apparent clusters of suicides within particular units. Given the diversity of military operations, however, it is impossible for politicians and the public to provide detailed guidance about every possible hazard that soldiers might be exposed to. There is an assumption that operations will be conducted in a 'safe' manner. In consequence, single incidents will often act as a trigger for political and public interest in hazards that have not previous attracted widespread attention. This can be illustrated by the findings of a Board of Enquiry into the drowning of an Australian cadet. The Chief of Staff of Headquarters Training Command found that: "I accept the Board of Inquiry finding that Cadet S drowned as a result of the amount of weed in the water, the depth of water, the wearing of GP boots and Disruptive Pattern Camouflage Uniform clothing whilst in the water and the absence of safety devices and inadequate safety precautions for the swimming activity. These factors contributed to Cadet S's drowning. 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…I do not accept the finding of the Board of Inquiry that Corporal X was not fully qualified as an instructor of cadets in the Army Cadet Corps in accordance with the Army Cadet Corps Policy Manual. Corporal X 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" (Australian Army, Brigadier Chief of Staff, 2001). As we have seen, however, incidents involving new recruits and cadets often trigger greater concern than those involving more experienced soldiers. The political and public reaction to this incident went well beyond the immediate events surrounding the drowning. It motivated a more sustained review of Cadet activities that questioned the Chief of Staff's assessment of the competency of the individuals concerned. For instance, the Australian Minister for Veterans Affairs contradicted parts of the previous statement when he argued that "the swimming activity was not authorized by (the) Army and that there was inadequate supervision or monitoring of the Army Cadet Corps activity" (Scott and Nelson, 2001). In consequence, he suspended all cadet-swimming activities conducted in areas other than supervised swimming pools until there was a more systematic analysis of the risks involved in their training.

4.4. Issues of Scale

It is important to emphasize the considerable differences that exist between military incident reporting systems. Many of these differences stem from variations in the types and scale of operations that are conducted by the armies of different nations. Some perform relatively limited, ceremonial duties within their own borders. Others are simultaneously engaged in offensive military operations, policing and peacekeeping missions throughout the globe. The diversity of such operations and the geographical distribution of people and material makes for pathological problems. Any recommendations that are made following an investigation have to be communicated across huge distances to potentially very remote locations. They must also be acted on before any recurrence could happen. It is for this reason that many of the larger military organizations impose tight timing constraints on their investigation processes. The US Army's (2000) Accident Investigation and Reporting Procedures Handbook states that the responsible Department of the Army-level organization has 60 calendar days to provide an initial response to the US Army Safety Center describing any corrective actions. Interim and follow-up reports are required every 90 days after this initial response until the actions are closed. If the responsible command does not accept the recommendations then a report must be filed with the Commander of the US Army Safety Center, with a supporting rationale within 60 days of the initial notification.

Such procedures are necessary because of the extreme complexity of military systems and the organizational structures that support them. It is extremely easy for safety lessons to be lost amongst a mass of other operational updates. For example, the US Army issued at least eight revision requests for the M9 Armored 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 (US Army Safety Center, 2001c). In addition to these sources, Armored Combat Earthmover operators also had to monitor two additional 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. In consequence, US Army engineers did not always receive necessary technical information. The US General Accounting Office (1997a) describes how division personnel did not receive revisions to the manual describing the fuel subsystem on Apache attack helicopters. The aircraft were then grounded and the maintenance teams wasted many hours troubleshooting because the old manual did not provide necessary information about how to fit new fuel transfer valves. The lack of an adequate monitoring system created further logistical problems. 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. 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.

The US Army's Modification Work Order (MWO) program was intended to address many of the problems described above. This intention was to ensure that 'any identified operational and safety problems' were consistently implemented across the US Army (US General Accounting Office, 1997a). A centralized database was developed to record the progress of different maintenance recommendations. Army headquarters officials and Army Materiel Command officers could issue queries to check whether individual units met the timescales and objectives that were recommended in safety notices. Unfortunately, the database was discontinued following a structural reorganization 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 centers that support particular pieces of equipment, such as the Squad Automatic Weapon. The result of this decentralization 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' (US Army Safety Center, 2001d).

The US General Accounting Office has triggered the development of several new military information systems that represent the 'state of the art' in incident and accident reporting. Few civil systems have the capacity to monitor the implementation of recommendations across distributed and diverse operations. Experience in the military domain has, however, shown that they cannot be regarded as a panacea. This is illustrated by an incident involving one of the US Army's M939A2 wheeled vehicles on a public road (US Army Safety Center, 2001e). 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 received their first two M939A2 trucks as replacements for older models. However, when the investigation board checked the Army Electronic Product Support Bulletin Board via the Internet website http://aeps.ria.army.mil/, they discovered two safety messages restricting the maximum allowable speed for M939A2 trucks to 45 mph until antilock brakes and radial tires were retrofitted. Further interviews with maintenance personnel determined that they had seen the messages when they came out. Since the unit did not have any M939A2 trucks at that time, they did not inform the chain of command.

5. Conclusion

We must learn from incidents in order to reduce the likelihood and mitigate the consequences of future accidents. Mishap reporting systems provide the feedback that is necessary to avoid recurrences of adverse events. Most previous work in this area has focused on the development of civilian systems. In contrast, this paper has examined the ways in which military reporting systems can help us to understand the causes of technical failure, of managerial problems and of human 'error'. There are some similarities between military and civil systems. For instance, both encourage investigators to look beyond the immediate or catalytic causes of human failure. Similarly, they are both faced with a tension between attributing blame to individual violations and the need to identify the systemic causes of accidents and incidents. We have also identified important differences. For instance, military reporting systems must make recommendations that protect personnel in peacetime training missions but which also leave them prepared for the demands that they may face in future operations. Military incident reporting is further complicated by the need to determine whether or not individuals were justified in reaching particular decisions about the complex risks that they must face.

This paper has used our analysis to identify fundamental differences between the nature of human 'error' in military and civil systems. Soldiers are often forced to make complex, real-time decisions about the risks that their personnel are exposed to. For instance, we have considered river-crossing operations where a brief exposure to hazards with high levels of risk might be preferable to prolonged exposure to lesser risks. There are, of course, civil parallels where individuals must optimize performance against risk. I would argue, however, that civil systems seldom provide the prolonged and explicit training that soldiers receive in making trade-offs between operational risks and performance gains. This is a repeated theme in the training scenarios that dominate military life. Further differences can be found in the way in which military personnel are punished when their gambles fail. A form of hindsight bias often 'informs' punitive actions by military tribunerals. Lessons learned systems and confidential reporting mechanisms provide valuable alternatives that reflect the growing appreciation of systemic causes in the failure of civilian systems.

Many military reporting systems contain incidents that reflect the wider tension between ensuring that training is 'safe' whilst still providing personnel with the necessary skills that help to ensure operational efficiency. Soldiers are often exposed to hazards in order to prepare them for the pressure of operational tasks. As we have seen, considerable efforts are made to sure that these hazards are controlled during training operations. Dry fire rehearsals are conducted. The movements and actions of each participant and their supporting systems are choreographed. Even so, mishaps continue to occur. We have argued that these accidents are 'normal'. Not because they are acceptable but because they continue to occur in every army throughout the globe. They stem from the complexity and interconnection of military operations. Many mishaps also have 'wicked' causes that cannot easily be predicted or controlled before the event. For instance, it would have been difficult to alter the plan behind the Bangalore torpedo incident to explicitly include a plan of what to do should additional munitions be available during the exercise. Only in hindsight can we identify this as a potential hazard for the personnel involved in the operation. Given that the material was available, it is similarly difficult to argue that planning staff should have considered the possibility of a preliminary explosion triggering the arrival of the breeching units before the torpedo exploded. The difficulty of predicting all of the possible ways in which mishaps might occur is further complicated by the 'risky' nature of many military operations. The Canadian Lessons Learned in NATO peacekeeping operations illustrated this point. Injuries from mines led soldiers to explicitly request training in the use of IV lines and morphine. This creates potential risk if these techniques are used inappropriately. The catch-22 of military safety management is that there is also a risk that lives can be risked if soldiers do not have these skills.

6. Acknowledgments

UK Engineering and Physical Sciences Council grant (EPSRC GR/M98302) has provided support for the work that is described in this paper. This work was also supported by a NASA/ICASE fellowship, funded under NASA contract NAS1-97046, Task 212.

7. References

- Australian Army, P. B. Retter, Brigadier Chief of Staff (2001), Board of Inquiry into the Death of Cadet K. P. Sperling of the South Burnett Regional Cadet Unit arising from an Incident at the Bjelke-Petersen Dam (QLD) on 18 Nov 2000: Findings, Action and Implementation Plan, (Headquarters Training Command: Canberra, Australia).
- Canadian Department of National Defense (1999) Letters to the Editor, *Safety Digest, (*Vice-Chief of the Defense Staff: Ottawa, Canada), Safety Digest, 7-99.
- Canadian Department of National Defense (2000) Letters to the Editor from L. Cdr. D. Alder, *Safety Digest, (*Vice-Chief of the Defense Staff: Ottawa, Canada), Safety Digest, 11-00.
- Canadian Army Lessons Learned Center (1999) Common Observations and Issues: Operation Palladium Rotations Zero to Four [Analysis 9901] (Canadian Army Lessons Learned Center, Vice-Chief of the Defense Staff: Ottawa, Canada)
- Johnson, C.W. (1999) Why Human Error Analysis Fails to Support Systems Development, *Interacting with Computers*, 11, 517-524.
- Johnson, C.W. (2002) Incident Reporting: A Handbook to the Detection and Resolution of Human Error and System Failure in Safety-Critical Applications, (Springer Verlag: London, UK).
- Johnson, C.W. (2002a) Reasons for the Failure of Incident Reporting in the Healthcare and Rail Industries. In F. Redmill and T. Anderson (eds.) *Components of System Safety: Proceedings of the 10th Safety-Critical Systems Symposium*, (Springer Verlag: London, UK).
- Perrow, C. (1999) Normal Accidents: Living with High-Risk Technologies, (Princeton University Press: Princeton, NJ, United States of America).
- Scott, B. and Nelson, B. (2001), Release of Board of Inquiry Findings and Action Into the Death of an Army Cadet [Min 096/01] (Department of Defense: Canberra, Australia).
- Singapore Army Safety Organization (2001), Preventing Heat Injuries: The Commanders Guide (Safety Organization, General Staff Inspectorate: Singapore).
- US Army (1998), Risk Management [Field Manual FM 100-14], (Headquarters Department of the Army: Washington, DC, USA).

- US Army (2000), Accident Investigation and Reporting Procedures Handbook, (Headquarters Department of the Army: Washington, DC and US Army Safety Center: Fort Rucker, Alabama, USA).
- US Army Safety Center (2001) Safety Notice: Confidence Course Obstacle [Note SAN 210800MAR00] (US Army: Fort Rucker, Alabama, USA).
- US Army Safety Center (2001a) A Turn for the Worse, M1A1, *Countermeasure, 22, 1, 14,* (US Army: Fort Rucker, Alabama, USA).
- US Army Safety Center (2001b) Accident Investigation: The Other Side of Risk Management, *Countermeasure, 22, 1, 1-16,* (US Army: Fort Rucker, Alabama, USA).
- US Army Safety Center (2001c) New Requirements for the M9 ACE, *Countermeasure, 22, 6, 15,* (US Army: Fort Rucker, Alabama, USA).
- US Army Safety Center (2001d) Safety Notice: HMMWV Seatbelt (US Army: Fort Rucker, Alabama, USA).
- US Army Safety Center (2001e) The Rest of the Story, *Countermeasure, 22, 5, 12-13,* (US Army: Fort Rucker, Alabama, USA).
- US Army Safety Center (2002) Safety Notice: Water Safety Trend (US Army: Fort Rucker, Alabama, USA).
- US Army, Product Manager, Paladin/FAASV (2000), Drivers' Hatch, *Paladin/FAASV Newsletters,* (Picatinny Arsenal: NJ, USA, 2nd Quarter, Financial Year 2000, 8.
- US Army Technical Center for Explosives Safety (2000), Last minute change is fatal: how could this happen? Explosives Safety Bulletin, 12, 1, 6-8.
- US General Accounting Office, M.E. Gebicke, (1994), Military Training Deaths: Need to Ensure That Safety Lessons Are Learned and Implemented, [GAO/NSIAD-94-82] (United States' General Accounting Office: Washington, DC, USA).
- US General Accounting Office, M.E. Gebicke, (1997), Army Ranger Training: Safety Improvements Need to Be Institutionalized, [GAO/NSIAD-97-29] (United States' General Accounting Office: Washington, DC, USA).
- US General Accounting Office, M.E. Gebicke, (1997a), Army Equipment: Management of Weapon System and Equipment Modification Program Needs Improvement, [GAO/NSIAD-98-14] (United States' General Accounting Office: Washington, DC, USA).