Safety and error management: The role of Crew Resource Management

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I (RLH) had the honour of speaking to the first Australian Aviation Psychology Symposium, where I reviewed the history of Crew Resource Management (CRM) during its first fifteen years using the metaphor of war to describe the battles fought to establish and maintain meaningful programs (Fifteen years of the CRM wars: A report from the trenches, Helmreich, 1993). Four years later, Daniel Maurino continued the metaphor and brought the history up to date (Eighteen years of the CRM wars: A report from headquarters, Maurino, 1996). We also examined the status of CRM at the 1995 meeting (Merritt & Helmreich, 1996). Today we revisit the role of CRM in safety (albeit without the militaristic metaphor).

Looking at the status of CRM as the Millennium approaches, we see encouraging signs of health, but also unresolved and even growing problems. Let us start with the downside. CRM has come under the attack in the USA because it has not eliminated accidents and incidents where human factors is a causal element. (Perhaps we should not have abandoned the battle metaphor so rapidly.) The following events have been alleged to represent CRM's failure.

- An aircraft lands at the wrong airport.
- An aircraft lands in the wrong country.
- An aircraft strikes pilings on final approach.
- An advanced technology aircraft flies into a mountain.

In each of these, the crew had received CRM training, but still showed the classic failings in co-ordination and situation awareness that precipitated the creation of the programmes. We will discuss later the validity of these accusations. While we argue that these criticisms are ill founded, there are recognised limits on the effectiveness of CRM training.

Limitations of CRM

A known limitation is the oft-cited fact that not every participant responds to the training. Indeed, some may become less accepting of CRM concepts after training. Those who reject CRM concepts have been referred to as 'boomerangers' or 'Drongos', although there is no

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implication that Australia is the centre of such problems (Helmreich & Wilhelm, 1991, Helmreich & Foushee, 1993).

The lack of generality of CRM training has also emerged as a problem (Helmreich & Merritt, 1998). Programmes exported from the USA were not well received in other cultures. For example, the concept that junior crew members should be assertive and question decisions and actions by the Captain is often met with incredulity in high Power Distance cultures where tradition dictates that juniors do not question their superiors (Helmreich & Merritt, 1998). To a lesser extent, curricula developed in one organisation proved less effective when exported to another airline since they did not reflect the culture of the receiving organisation.

How justified are criticisms of CRM?

CRM remains a success story of aviation and improvements in crew attitudes and effectiveness as a result of training have been documented (e.g., Helmreich & Foushee, 1993; Helmreich & Wilhelm, 1991). However, it is also true that human error accidents and incidents continue to plague the aviation system. Nonetheless, the charge that CRM has failed is patently absurd and reflects a lack of understanding of human nature and of the role of CRM in organisations.

Humans are imperfect organisms and will necessarily make errors, particularly under conditions of overload, stress and fatigue. There is also a growing awareness that most disasters in high technology environments are system accidents with multiple causes (Maurino; 1998; Maurino, Reason, Johnston, & Lee, 1995). As Reason (1990; 1997) has pointed out, the organisational context allows the development of latent failures that can combine to produce disaster. To blame a training programme centred on the flight crew for failings in the safety culture of organisations is completely unwarranted. On the other hand, the advocates of CRM must bear some of the responsibility. There is no question that some CRM 'zealots' proclaimed that it was the route to a zero-accident aviation system. Perhaps worse, some expanded the definition of CRM to include marital and family issues and even sexual harassment in the workplace. The end result was that the original goals of reducing pilot error and increasing safety became lost to many. In fact, informal surveys of crew members revealed that the modal reason given for CRM was 'to make us work better as teams'. In sum, CRM is an effective, but imperfect, tool in the service of safety and operational effectiveness. Improving team skills is a means toward this outcome, not an end in itself.

Evolution or Revolution

CRM training has evolved continuously during its nearly two decades of existence. We have documented four generations since the first training was developed as a means of reducing 'pilot error' (Helmreich, Merritt, & Wilhelm, in press). We have proposed a fifth generation with the goal of defining an approach to CRM that would be more broadly accepted culturally than the earlier ones. We felt that the concept of error management could serve this function. Of course, the earliest CRM programmes had also been based on error, but, as we have noted, this purpose had been largely lost over the years. The fifth generation differed from its predecessors in another way – the goal of CRM would be not just the avoidance of error (obviously the most felicitous outcome) but also trapping errors before they became consequential, and finally, mitigating the consequences of those errors that

eluded all defences. Thus, rather than being a revolutionary change, fifth generation CRM, which we can call Error Management CRM (EMCRM) reflects a renewed emphasis on error embedded in a broader context. Figure 1 shows the responses to error ranging from exacerbation to avoidance.

The role of national culture. Although we began our research with the conviction that the cockpit was a culture-free environment, we rapidly learned that national culture plays an important role in determining how the flightdeck is managed (Helmreich & Merritt, 1998). We thus sought overarching concepts that could justify CRM in every culture. It was also evident that every culture has characteristics that both increase and decrease the probability of accidents.

We began with the premise that safe flight is universally valued as is the reduction or avoidance of error. In this framework, EMCRM could be accepted as an essential set of countermeasures against error. In cultures where leadership tends to be autocratic, more open communication can be espoused as a necessity for error avoidance and trapping. Error management can also support more cautious use of automation, important since attitudes about appropriate use of automation vary significantly across cultures (Sherman, Helmreich & Merritt, 1997). Figure 2 shows some of the positive and negative aspects of national culture that influence the safety of flight and can be subsumed under the error management framework.

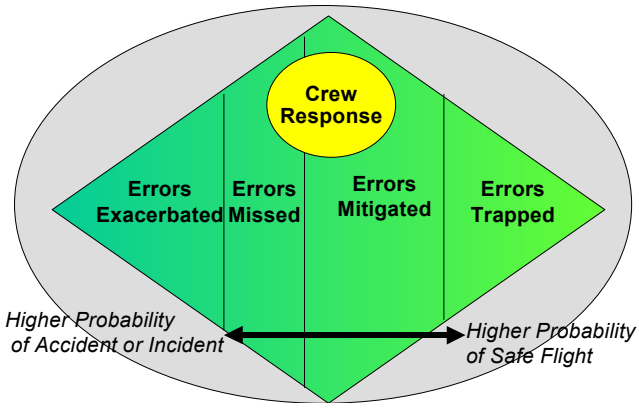

Figure 1. Crew responses to human error

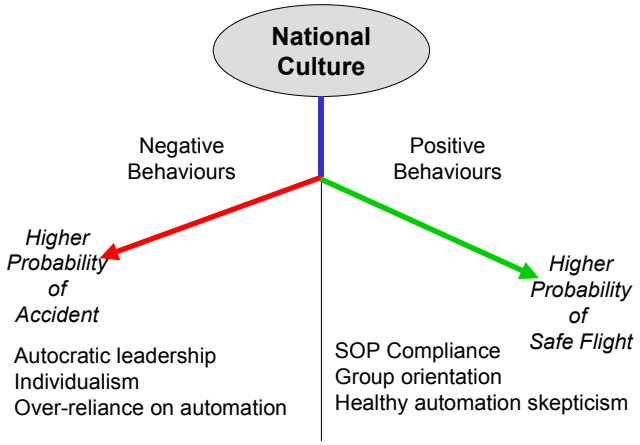

Figure 2. National culture and safety of flight

Professional culture and error. The error management approach also allows us to address one of the negative aspects of the professional culture of pilots – the universal denial of vulnerability to stressors such as fatigue, danger, and personal problems (Helmreich & Merritt, 1998). We saw as central to error management the task of convincing pilots that human error is ubiquitous and inevitable and cracking defences against admitting to human failings. If successful, fifth generation EMCRM should capitalise on the strengths of the professional culture, such as pride in the job and the motivation to succeed, while avoiding the negatives as shown in Figure 3. In an error-managing organisation, crews of all nationalities will have open communication regarding current actions supported by positive leadership. They will also practice full and interactive briefings and strong adherence to SOPs. *They will also profit from their errors and those of others.* Learning the lessons to be gained from errors is an essential element of error managing organisations.

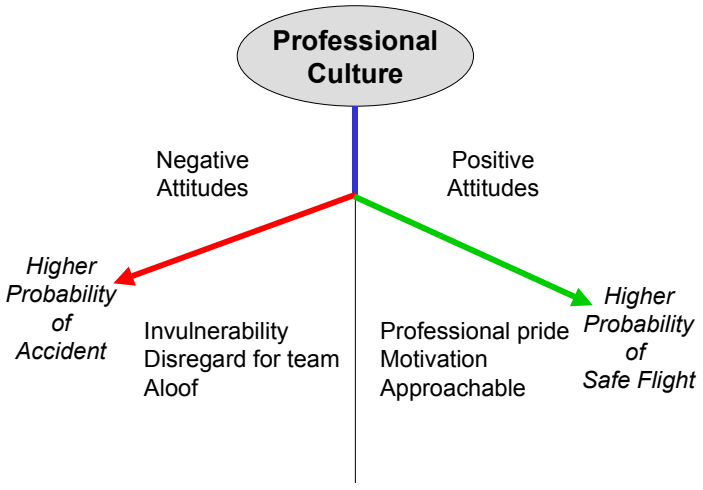

Figure 3. Elements of professional culture related to safety

Organisational culture, error management, and CRM

The criticisms of CRM as a failed endeavour in aviation safety did not take into account the organisational context in which CRM was delivered. Organisations may adopt a proactive stance toward safety in the service of a safety culture or they may give only perfunctory and reactive responses to threats to safe operations (Merritt & Helmreich, 1996; Reason, 1997). To expect a training program such as CRM to counter all of the latent failures in a complex system is completely unrealistic. In reality, error management (as opposed to error elimination) is the primary mission of a safety culture and CRM programmes are but one tool (albeit a critically important one) in the service of this end.

There are multiple sources of error, which can beset even the best-prepared and most motivated flight crews. These include the cognitive limitations of all humans, fatigue, work overloads, inadequate training and procedures, poor maintenance of equipment, and errors committed or induced by air traffic control. Finally, chance events can take place. In the words of the counterculture, 'S___ happens'. Posed against these challenges is an array of defences and weaknesses that can deflect or exacerbate latent errors or permit them to pass through unhindered. These include the positive and negative aspects of national culture, the strengths and failings of the organisational and professional cultures and the nature and quality of training provided by the organisation. The personal attributes of crew members (including their abilities and the mix of personalities in the cockpit) also increase or decrease the probability of accidents or incidents. Figure 4 summarises the rain of error and associated defences.

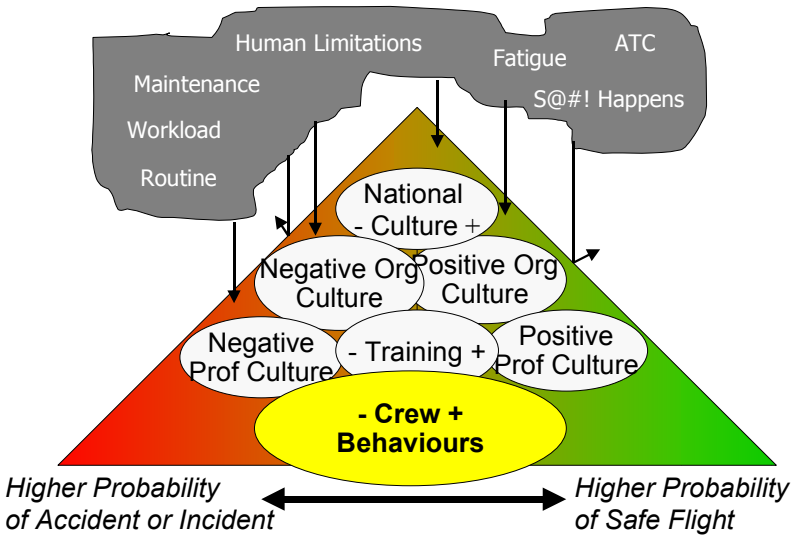

Figure 4. The rain of error and defences against them

The observable outcomes of the flow of errors through the defence line of the organisation are the behaviours of the flight crews as they reflect the concepts taught in CRM and reinforced (or ignored) by management and role models such as instructors and evaluators. These behaviours, both positive and negative, are shown in Figure 5. When the crew's actions

reflect adherence to CRM concepts, the probability of safe flight is increased, when they do not, the chances of mishap rise.

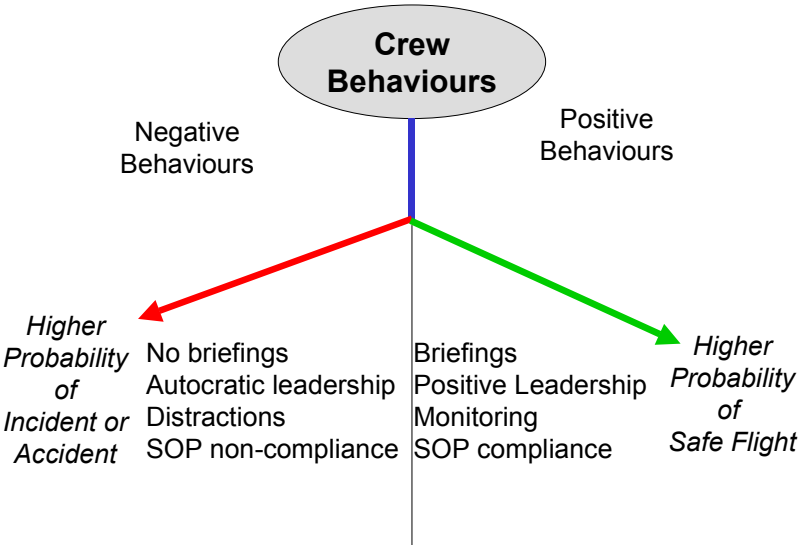

Figure 5. Crew behaviours changing probability of error

In the USA, Continental Airlines has refocused its CRM programme as training in error management and has administered it to all flight crewmembers. Reactions to the training by participants are highly favourable. In addition, the airline has provided special training for instructors and evaluators in the assessment and reinforcement of error management – thus changing the role of these key personnel from error detector to assessor of error management (Tullo, in press).

The neglected element in CRM has been how the three cultures, national, organisational, and professional function to enhance or suppress the impact of training. Within every culture, an essential for the success of EMCRM as error management training is a credible safety culture and an organisational policy that accepts the inevitability of human error and adopts a non-punitive stance towards those who err. This is not to imply that organisations should be tolerant of the wilful violation of company or regulatory rules. Instead, it is the reflection of the position that understanding the errors that inevitably occur is essential to their avoidance or mitigation.

Understanding the roots and nature of error

The challenges to effective error management at the organisational level include determining the incidence of errors and understanding their causes – including instances of complacency and disregard of procedure. The record of behaviour that is collected on performance in training and in formal evaluations (either in simulator or line operations) is inadequate. One of the things we know about pilots as a group is that they are of above-average intelligence and not likely to show sub-standard performance when their certification is at stake during formal evaluation. We turn now to discussing the components of a system assessment approach using multiple and disparate sources of data. It should be emphasised

that this approach is predicated on one essential characteristic – trust. The essentials for error management are the following:

- Trust
- A non-punitive policy toward error
- Commitment to taking action to reduce error-inducing conditions
- Data that show the nature and types of errors occurring
- Training in error avoidance and management strategies for crews
- Training in evaluating and reinforcing error management for instructors and evaluators

Line audits. We have collaborated in the conduct of line audits in a number of airlines and have analysed the data collected. It has been our experience and that of the airlines that the resultant data provide a highly accurate picture of line operations. The key to success of an audit is the credible assurance to crews that all observations are without jeopardy and that no information on any crew will be revealed to management. In practice, we have trained a group of expert observers from the airline (pilots from training, flight standards, the union, etc) in the use of our Line/LOS Checklist which elicits ratings of a number of safety and CRM-related behaviours (Wilhelm & Helmreich, 1996). The team of observers then sample flights in all fleets and types of operations, usually for a period of a month. That a veridical slice of the operation is being captured is shown by the fact that observers frequently see violations of SOPs and regulations. For example, as part of a *line audit* we observed many instances of failure to complete (or even use) checklists in one fleet in one airline. We had also found that this renegade attitude in this fleet was evident in anonymous surveys of crew members. But, neither line checks nor Federal Aviation Administration inspections had suggested that this might be a problem. Our findings indicate that the line audit, in combination with other confidential sources provides an accurate picture of system strengths and weaknesses. The resulting database gives clear guidance to management on what to emphasise in training and also indicates where problems in leadership or norms may be present. Most organisations augment line audit data with confidential surveys using the Flight Management Attitudes Questionnaire (FMAQ: Merritt, Helmreich, Wilhelm, & Sherman, 1996).[2]

Analyses of the aggregated, de-identified data from line audits gives insights into ubiquitous problems such as the use of flightdeck automation as well as an indication of the variability of performance in the system (Hines, 1998).

Incident reporting systems. Incidents (which are really accidents that didn't happen) also provide invaluable information about points of potential vulnerability in the aviation system. Confidential national incident reporting systems such as the Aviation Safety Reporting System are very useful, but do not provide individual organisations with the information they

[2]The Line/LOS Checklist (LLC), the Flight Management Attitudes Questionnaire (FMAQ) and technical reports showing data collected can be found on the project's Website -- http://www.psy.utexas.edu/psy/helmreich/nasaut.htm

need to optimise their own operations. The BASIS (British Airways Safety Information System) programme and ASAP (Air Safety Action Partnership; FAA, 1997) in the USA were designed to provide organisations with more complete data on incidents in their own operations. ASAP, for example, provides crew members with protections from regulatory or organisational reprisals under many conditions. Each reported incident is reviewed by a team (including representatives of management, the pilots' union, and the FAA) which recommends actions to prevent recurrences. Those reporting receive prompt feedback about the report and organisational response to the event. American Airlines has the longest experience with ASAP and is receiving reports at a rate of over 3,500 per year. As long as crews feel safe in submitting information to programmes such as ASAP and BASIS, the obtained data will arm organisations with an invaluable early warning system on potential threats to safety.

We also recognise the value of data collected from flight data recorders in normal operations. These data provide critical information on the nature and location of instances where normal flight parameters are exceeded. The problem with recorder data is that they provide no insights into why events occurred and the human factors issues associated with them.

Enhancing the effort: Ongoing research in support of error management. Our research group in Austin has mounted several efforts to enhance error management. One, of course, is the attempt to redefine CRM training in terms of countermeasures against error. A second effort augments the Line/LOS Checklist (LLC) observational system with information on the details of errors observed and how the errors were managed. We feel that this approach can provide data to supplement that gained from ASAP reports and lead directly to training and organisational interventions.

We have conducted a preliminary study in one airline using an experimental version of the LLC. First results indicate that observers can monitor the process and that the information will be extremely valuable. Narrative accounts also flesh out the analysis. In this study, errors were observed in nearly half of the short flights observed, and the range of errors observed in a single crew was between 0 and 6. The following are examples of the types of error management and mismanagement recorded by the audit team:

Error Avoidance. In this event, stopping a take off to verify information kept the crew from committing an error.

- 'FO confused about proper frequency approaching the T/O position. CA stopped A/C and handled situation smoothly, as neither pilot knew if they were cleared for the runway.'

Error Trapping. Here an error was committed, but effective cross-checking caught it before it became consequential.

- 'FO mis-set altimeter on the *In Range Checklist*. As the CA scanned the cockpit, he caught the error and corrected the FO's input.'

Error Mitigation. An inadvertent action by one crewmember was leading to an altitude violation. Cross-checking mitigated the consequences of the error.

- 'Autopilot disengaged unintentionally by FO, A/C lost 300' before CA caught error. Potential violation, ATC called them to check altitude.'

Error Exacerbation. An error of omission by the FO was later denied. The failure to verify the ILS could have had extremely serious consequences, but luck intervened.

- "CA specifically asked the FO if he ID'd the ILS, FO said yes, when in fact he did not. This goes down as one of the most unprofessional acts I have been witness to in my aviation experience.'

As part of the Flight Safety Foundation's efforts to reduce approach and landing accidents (ALAR-Approach and Landing Accident Reduction), we are also relating the presence or absence of markers from the LLC to crew behaviour in a world wide accident database.

We are also developing a new checklist to capture more information on the human factors aspects of incidents reported to ASAP. Neither BASIS nor the current ASAP form elicits systematic, quantitative information on human factors issues. The form is derived from one used successfully by Captain Sharon Jones of our group to obtain controller reports of operational errors (Jones, in press). In addition to demographics and environmental conditions the form allows the respondent to indicate positive and negative behaviours and circumstances that influenced the outcome. It also elicits information on triggers of the event, defences, and countermeasures. Additional ratings evaluate time criticality of the event and potential severity of outcomes. Reporters are asked to suggest organisational actions to prevent recurrence of the event.

One of our tasks will be to develop statistical methods to combine data from surveys, audits, training, and ASAP reports to achieve a more valid representation of system safety and problems.

We feel that embedding EMCRM in a more comprehensive safety effort can increase its impact as well as the overall effectiveness of the aviation system. Error management is a concept that should receive universal acceptance and presents a means of overcoming cultural resistance at the national and organisational levels.

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