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Comparative Analysis of Safety Management Systems and Safety Culture in Aircraft Maintenance

by

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Thesis submitted for the Degree of Doctor of Philosophy (Ph.D.),
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October 2002

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Signature of candidate Siobhán Corrigan

Acknowledgements

This thesis has taken many more years than I originally anticipated but among the great joys of finishing a thesis is the pleasure of thanking those who made it possible.

Firstly I am very grateful to my colleagues in the Aerospace Psychology Research Group (APRG) for their enthusiasm, unending support and encouragement. In particular I am very grateful to Marie Ward, my office buddy, for reviewing this thesis in its entirety and for all those words of wisdom. I would also like to thank my supervisor, Dr. Nick McDonald. This thesis was his travelling companion from Brussels to Milan and from Paris to Boston!! I would like to thank Nick for his perceptive insights, direction and guidance into the overall study.

A special word of thanks to the four aircraft maintenance organisations who took part in this study, and for all of those who took the time to complete the surveys, partake in interviews and observations studies and for their patience in answering endless questions and queries. I would also like to thank the partners from the ADAMS project; it was a pleasure working with them all.

Last but not least I would like to thank Aidan for all his love, patience, understanding and for always being there for me.

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Summary

The overall objective of the thesis was on developing a deeper understanding of the organisational processes of safety management systems and how they are embedded in the culture of aircraft maintenance organisations. The thesis has developed and validated a comprehensive model of safety management that is linked to the wider cultural context of organisations. The model highlights the ability of organisations to establish strategies, goals and internal standards; to plan and organise production to an optimal standard; to determine what actually happens in practice; to monitor and adjust systems and procedures and to learn from recommendations.

A comparative and empirical study of four aircraft maintenance organisations was undertaken: including analysis of company documentation; management interviews; surveys of safety climate and safety attitudes; surveys of procedure compliance and expected response to incident involvement. The data from the management interviews, the incident survey and safety climate survey exhibited a large measure of agreement in differentiating between the safety management systems and safety culture of the four organisations. However the measures of compliance with task procedures and safety attitudes did not differentiate between the four organisations (though one organisation did differ from the others in safety attitudes). This suggests a strong, relatively homogeneous professional sub-culture of aircraft engineers spanning the different organisations.

The overall findings from the study offer significant insights into the complexity of managing the human and organisational aspects of safety and reliability. One of the key findings from this study is that fundamental aspects of the system or systems for ensuring safety and reliability do not work as they are supposed to do because:

- There is a double standard of task performance in aircraft maintenance – an official way and the way in which work is actually done. One conclusion of this study is that it is the reliance on the informal systems of control and safety performance and the professional subculture of the aircraft engineers that compensates for the deficiencies in the more formal systems.

- Quality Systems do not systematically address how work is carried out, and there is little evidence that organisations are learning effectively from the incidents they have had.
- Planning systems do not always work effectively. Planning systems lacks the flexibility to address the pressures and requirements of production.
- The role of the regulator needs to be seen to support the aircraft maintenance organisation in their efforts to address organisational aspects of safety.

The overall thesis is structured around 8 chapters. Chapter 1 provides an overview of the literature, objectives of the study and a description of key functions in aircraft maintenance. Chapter 2 presents the initial model and the range of methodologies adopted in this study. The findings from the management interviews and documentation examination were analysed together as the overall organisational descriptions (Chapter 3). The survey of procedure compliance and the ergonomic assessment were analysed together as a reflection of normal operational practice (Chapter 4); and the survey of safety attitudes, safety climate and incident consequences were analysed together as a quantitative measure of the safety culture of each organisation (Chapter 5). The final three chapters focus on the implications of the findings: key issues and problems in effectively managing safety and the revised safety management model (Chapter 6); the further analysis of the revised elements of the model (Chapter 7); and the overall conclusions on the utility of the model, the methodologies, and the theoretical and practical implications of this study (Chapter 8).

Chapter 1 - Introduction and Literature Review

Introduction

Over the past number of years a series of high profile incidents and accidents across a number of domains have highlighted that failures cannot be described in technical or behavioural terms alone but that organisational and management causes must be addressed and understood. This need to understand organisational and management factors has been accepted over the past number of years, one only has to look at the plethora of literature on the subject, exhaustive inquiries, keynote speeches, organisational mission statements, accident reports and media coverage. However, incidents and accidents are still occurring across all domains. The underlying causes deeply rooted, for example, in internal and external processes of communication, decision-making, monitoring and feedback, planning, violation of procedures and regulatory failures all of which are embedded in the organisation over a long period of time before they cause an accident.

What is significant about the extensive inquiries and incident and accident reports (e.g., explosion of the Space Shuttle Challenger; the explosion at Chernobyl; King's Cross Underground Station fire; the sinking of the Herald of Free Enterprise; the British Midland Boeing 737-400 incident, near Daventry) is that the all came up with much the same conclusions. Contributory factors were identified as system failures, organisational failures, management failures, communication, design and maintenance failures and lack of an effective 'safety culture'. However, the immediate post-Chernobyl discussions of safety culture, for example, can be criticised for their reduction to a combination of administrative procedures and individual attitudes to safety, at the expense of the wider organisational issues (e.g., Pidgeon & 'O Leary, 2000). Indeed Gephart (1984) argues that few disasters result in effective change, it is argued that the few changes that do emerge are likely to involve formalisation of procedures already known to be inadequate. This raises two questions, (i) whether all the analysis and theories of past incidents and accidents tell us anything useful at all for designing effective safety management systems, (ii) what can the analysis of normal organisational practice as opposed to accident analysis contribute to our understanding for designing and maintaining effective safety management systems?

The overall objectives of this chapter are threefold:

- To provide an overview of the key theoretical and empirical contributions in understanding the human and organisational aspects of managing safety in 'safety critical industries'.
- To outline the research objectives of this thesis.
- To provide a descriptive overview of the aircraft maintenance industry (where this research took place).

Literature Review

A number of theoretical approaches have been advanced in the literature concerning the organisational dynamics that come into play in establishing an effective safety management system. But how far do they provide an analysis of normal organisational and management practice and the underlying cultural, political and social influences in advancing both the practical and theoretical considerations of safety management systems?

As a result of analyses such as those of Turner (1976, 1978), Turner & Pidgeon, (1997), Perrow (1984), Reason (1990), Toft & Reynolds (1997) and many others, explanations of accidents based upon individual operator performance ("human error") are now accepted to be inadequate as accounts of the accident generating process. Kletz (1985) reported that accidents, mostly from the chemical and oil industries were due to 'human failing'. However, these human errors, while often classified as the root causes of accidents/failures, were influenced by larger organisational issues. The shift of focus has been driven by the awareness that organisational, managerial and human factors rather than purely technical failures are prime causes of accidents in high reliability organisations (Weick et al., 1999). This awareness has been brought about primarily by the many inquiries and academic research into a range of high profile accidents across a number of sectors (e.g. Daventry, Herald of Free Enterprise, Kings Cross, Chernobyl, Clapham Junction, Bhopal).

The difficulty in finding an organisational account of safety failures is that organisations are highly complex dynamic entities, and safety is just one aspect of their functioning. This raises the question: what is the most appropriate level at which to analyse the

safety aspects of an organisation? Organisational analyses of safety have advanced a number of lines of research with distinct explanatory frameworks.

The first comprehensive analysis of organisational preconditions in large-scale technological systems was by Turner (1978), who argued that disasters arise from an interaction between the human and organisational arrangements of the sociotechnical systems set up to manage complex and ill-structured risk problems. Turner also introduced the notion of a 'disaster incubation period' to explain that the propensity for disaster could lie dormant in an organisation for years, awaiting only the appropriate conjunction of circumstances to realise this potential in an actual disaster. He proposed that the critical features present during the incubation period of a major accident (based on analysis of 84 British accident reports) were rigid perceptions, decoy problems, organisational exclusivity, information difficulties, violations, and failure to recognise emergent danger (Pidgeon & 'O Leary, 2000). It is not entirely clear how exactly these have been extracted from the cases studied, however one implication of the theory is that both culture and institutional design are central to the safety question. Similar factors were also discovered by subsequent qualitative analyses of organisational accidents (e.g., Perrow, 1984, Vaughan, 1996, Reason, 1995), which revealed cultures characterised by management complacency, role ambiguity, poor communication, and low prioritisation of safety against high pressures for performance (Cox & Flin, 1998). So if one accepts that there are identifiable factors or preconditions of accidents and incidents, then how can these be effectively analysed, monitored, and adjusted to enhance safety before the occurrence of an accident?

The Individual in the Organisation

A particular issue at the individual level of analysis concerns the pattern of attitudes of the employees. In other words, are the employees motivated to think about safety and to act in a safe way (e.g., Donald & Canter, 1994)? It was strongly argued by a number of authors during the 1980's that negative attitudes among workers were the precursors of unsafe behaviour and their origins, in turn, in defective management attitudes and practices (Jonson, 1982; Beck & Feldman, 1983; Sheedy & Chapman, 1984; 1987, Griffiths; 1985, Allen, 1986; Lee, 1998). While organisations rely on detailed procedures to control and organise work, they cannot always control the attitude and

motivation of the employees using these procedures. The motivation to perform a job in a safe manner is a function of both the individual's own concern with safety as well as management's expressed concern for safety (Zohar, 1980).

Weick (1987) argues that accidents occur because the humans who operate and manage complex systems are themselves not sufficiently complex to anticipate the problems generated by those systems. This is a problem of "requiste variety" – as the variety that exists in the system to be managed exceeds the variety in the people that must regulate it. Therefore if the issues of accidents are posed in this way, then there should be fewer accidents if there is a better match between system complexity and human complexity. The focus here is on the individual becoming more complex. The basic idea is that a system that values stories, storytellers, vicarious experiences etc will be more reliable than a system that derogates these substitutes for trial and error. In this way people will know more about their system, know more about potential errors, and how to handle those errors.

Although individual safety related attitudes and individual behaviours are certainly important and no doubt need to be addressed by the organisation, there are clearly larger organisational variables that impact safety performance (Hoffman & Stetzer 1996). Weick argues that humans need to be become more complex in order to deal with system problems, but the flip side of that argument is that it is the individuals and their professional practices that compensate for both the complexity and the deficiencies of the overall system (e.g., regulatory complexity, commercial complexity). Rather than making the human more complex in isolation to improving the system, surely a more desirable objective is to further understand and develop both the role of individual and the wider organisational system.

Safety Information System

Reason (1995) in his discussion of latent and active errors mirrors Turner's analysis. Active failures have an immediate and direct impact, whereas latent failures may lie dormant for long periods, sometimes many years before they combine with active failures and local triggering events to breach the system's defences (Reason et al., 1995). According to Reason all productive systems have five basic elements where potential problems can occur; (i) high level decision makers (fallible decisions); (ii) line management (line management deficiencies); (iii) preconditions (a well trained and motivated work-force as well as appropriate technology and equipment) (iv) productive activities (unsafe acts) and (v) defences (inadequate defences). Reason's basic premise is that "systems accidents have their primary origins in fallible decisions made by designers and high-level (corporate or plant) managerial decision-makers", which are at the first stage of defence against accidents. However the role of the organisational system within which fallible decisions are taken and through which the consequences of such decisions are taken forward are not developed in a systematic way, though Reason (1997) does emphasise the critical importance of an effective safety information system through the adoption of an effective reporting culture, a just culture, a flexible culture and a learning culture. Following from Weick's (1991) discussion that 'safety is an non-event', in the sense that safe outcomes can lead to the perception that, since no errors have occurred, there is nothing to learn from the system, Reason argues that the best way to instigate and then support a 'state of intelligent and respectful vigilance' is to gather the right kinds of data. This means creating a safety information system that collects, analyses and disseminates information from incidents and near misses, as well as regular checks on the system's vital signs – informed culture. Therefore Reason maintains a safe culture can be equated to an informed culture.

It appears that Reason's (1997) analysis is largely based on the assessment of two aviation-reporting programmes, NASA's Aviation Safety Reporting System (ASRS) and the British Airways Safety Information System (BASIS). Reason also refers to the findings of the research from the High Reliability Group (Berkeley Research Group). From these three primary sources Reason abstracts the 'best practices' for achieving an effective reporting culture (e.g., just culture, flexible culture, learning culture). While he does discuss the various dilemmas surrounding violations, negligence and blame, the

approach does not offer any significant insights into how an organisation can 'engineer a learning culture' or what are the real and potential barriers for effective learning.

Organisational Structure

Organisational structure theorists have focused on the importance of decoupling tightly coupled interdependent systems to allow local control and autonomy. Investigations into high reliability organisations, for example, have focused on how the organisational structure promotes (or inhibits) the co-ordination and execution of complex processes.

Perrow (1984) has described organisational systems in terms of two dimensions - complexity and coupling. This conceptualisation explains how in complex systems (with many interacting processes) with tight coupling (with strong causal and temporal interrelationships between these processes) it was possible for relatively small apparently isolated events to have large and ramifying consequences, sometimes disastrous. The model was developed from an analysis of a large number of official public inquiry reports. Perrow believes that the characteristics of tight system coupling (e.g., limited control options to cope with unanticipated events) restricts the "operator's opportunity to respond flexibly to unfolding and unexpected events". Perrow has pointed out that tight coupling of technical systems limits the possibilities for decentralised regulation of a system. If strong interdependencies exist between parts of the system so that changes in one subsystem will have wide ranging and locally foreseeable effects in other subsystems, regulation should be centralised (Grote & Kunzler, 1996). While Perrow's work offers many theoretical insights into the structural influences of organisational systems, the focus is primarily on the mechanistic and technological relationships between different parts and processes in the system, and does not adequately represent the range of social and organisational factors relevant to safety management.

Observations in so called 'high reliability' organisations indicate one possible solution to the dilemma of structural modifications and decentralised regulation of the system. The group has conducted field research in a number of 'highly complex, technology-intensive organisations' (e.g., air traffic control, naval air operations at sea) that must operate, as far as possible, to an error-free standard at all times. Flexibility is one of the defining aspects of the 'high reliability' approach. La Porte & Consolini (1991)

described how these organisations could switch between different forms of regulation depending on the requirements of the situation. Under 'normal' conditions, high levels of formalised, hierarchical control were found, whereas in states of increased alertness due to emerging threats a more team-like co-operation with local control was established where technical expertise surpassed hierarchical rank and authority patterns shift to a basis of functional skill. These organisations were characterised by demanding activities with a very low error rate and an almost complete absence of catastrophic failure over a number of years. Arguably the absence of an accident to date, however, does not prove that these are safe organisations, low accident can be a reflection of low reporting rates (Cox & Flin, 1998). In fact Sagan (1993) points out that many of these so-called safe organisations have a track record of concealed accidents and safety breaches.

Nevertheless on the face of it there is convincing evidence that an organisation's ability to adjust from a normal bureaucratic, centralised operation to a more decentralised operation is an important determinant of safety and reliability. So how do these organisations adjust between these two paradoxical modes of control? The importance of cultural factors in being able to perform these switches was emphasised by Weick (1987) who feels that the real trick in high reliability systems is somehow to achieve simultaneous centralisation and decentralisation. Before you 'decentralise you have to centralise so that people are socialised to use similar decision premises and assumptions so that when they operate their own units, those decentralised operations are equivalent and co-ordinated'. He argues that this creates a homogenous set of assumptions and decision premises so that when they operate in their own units, these decentralised units are equivalent and coordinated. Other factors deemed critical for the design and maintenance of such safe operations include safety as a primary goal, organisational learning, and senior management commitment.

However, the empirical studies by the high reliability researchers are very specific in terms of both institutional structures (typically military style organisation) and task demands (highly dynamic real time systems), raising questions about the transferability of their findings (Pidgeon, 1998). In the military, for example, the disciplined approach to working, following rules and procedures, and a familiarity and respect with the ways

of rank-based structures would all help to forge the shared values about safety and reliability required for effective decentralised operations when the situation demands it.

Organisational Politics

Turner (1976) argued that disaster events culminated in a full cultural adjustment and presumably organisational learning. However it could be argued that in fact very little cultural or structural adjustments occur following an accident. Sagan (1993) points to the many facets of organisational politics which corrupt the possibilities for learning; such as conflicts over parochial interests leading to faulty reporting of incidents, secrecy, normalisation of errors in the face of external accountability and the reinterpretation of failure as success (Rijpma, 1997).

Perrow (1984) highlights how organisational learning often takes place in extremely political environments in which efforts to determine the cause of accidents are not designed to promote learning, but rather to protect the interests of the most powerful members. However, while Perrow's work implies a political basis for the post onset interpretation of disasters, his discussion of political features remains largely implicit. Gephart (1984) also argues that the 'disaster incubation model' underemphasises the political processes and power relationships inherent in the daily life of managing risk, to the regulator-regulated relationship (Vaughan, 1990), or to society more widely (Shrivasta, 1987).

Gephart argues that a political sense-making model of reality better demonstrates why some versions of an event become accepted as legitimate within an organisation. Sense making refers to the processes whereby individuals reflect on and interpret the meaning of phenomena by constructing accounts (Leiter, 1980). The sense making perspective assumes that realities as we know them are descriptions, that is as Gephart explains, we know the world through the descriptive practices which make them visible. Given that there is a social distribution of interests, motives, and knowledge, it is likely that different descriptions of the same event will emerge (Molotch & Lester, 1975). Thus, sense making is inherently political: it involves the production of 'accounts as grounds for future action in the face of alternative descriptions' (Gephart, 1984). That is, politics may make the symbolic 'discovery' of the emergent incubation period (system

vulnerability) problematic both before and even after a serious visible near miss or accident has become manifest, as interest groups argue over what the turn of events signifies: as Shrivastava (1987) puts it, was Bhopal a 'technical incident' as claimed by Union Carbide, or a 'catastrophe' as claimed by the victims?

Sense making thus offers a perspective for viewing the way organisational members discuss, describe, and produce social realities, and it is a political process which can be linked to culturally and organisationally based interests and motives (Pidgeon & 'O Leary, 2000). Therefore processes of organisational and cultural learning may often become disrupted by political in-fighting and organised cover-up. The political sense-making model offers a very interesting and alternative perspective to explaining the occurrences of disasters or accidents. No doubt various political agendas and strategies are characteristic of almost every organisation, but political agendas are usually intrinsically motivated (e.g., individual promotion) and quite subtle. So while a government agency or a corporation may be politically motivated to cover up an accident, in the normal everyday situation one could argue that a political sense-making model does not adequately account for individual motivations, rather it focuses on the more social, group or corporate based political motivations.

Communication

Failed communication has also been discussed at great lengths in the literature. For example, Wright (1986), through his detailed analysis of the accident reports in the oil industry, discovered two underlying themes in all of the accidents: (i) an emphasis on 'speeding-up' the work processes, and (ii) failed communication.

Westrum (1995) has examined three distinct patterns of communication "styles" used by aviation organisations; pathological, bureaucratic, and generative. Each style, Westrum claims, differentiates high reliability organisations from organisations which can manage routine situations but not emergencies, and "conflicted organisations" where information is treated as a political weapon. The shift is from regarding individuals as a source of problems for an otherwise perfect organisation to one in which organisations can cause and cure their own problems by using the people who make them up.

Table 1. Westrum (1995) Patterns of Communication

Pathological	Bureaucratic	Generative
Information is personal power	Information is routine	Information seen as key resource
Responsibility is shirked	Responsibility is compartmentalised	Responsibility is shared
Messengers are shot	Listened to if they arrive	Messengers are trained
Bridging is discouraged	Bridging is tolerated	Bridging is rewarded
Failure is punished or covered up	Organisation is just and fair	Failure leads to inquiry/learning
New ideas are actively crushed	New ideas present problems	New ideas are welcomed

All of the above provide an overview of some of the different approaches to analysing safety. Other approaches include analysis at the level of decision making both operational and managerial (Halpern, 1989), human-computer interface (Grabowski & Roberts, 1996; Rochlin, 1986, 1989), role of team working (Weick, 1979), and organisational design (Grote & Kunzler, 2000; Jacobs and Haber, 1994) to name but a few. All of these analyses contribute in many ways to our level of understanding of the dynamics of managing safety. Implicit in all of these analyses, which have originated from consideration of organisational and management systems, is the theoretical notions of safety climate and culture in order to explain the organisational factors which underlie a predisposition towards safety failures.

Organisational Climate and Culture

The focus on safety culture and safety climate in understanding safety systems, also indicates a shift in emphasis from individual and directly accident related factors to organisational and latent factors. The idea of safety climate and safety culture is based on a substantial body of research into organisational climate and safety, where culture embodies values, beliefs and underlying assumptions, and climate is a descriptive measure reflecting the work-force's perceptions of the organisational atmosphere (Gonzalez-Roma et al., 1999).

Organisational climate has been a central concept in organisational research in characterising employee perceptions of their organisations. However there are many conflicting definitions of climate, inconsistencies in operationalisations, and little

theoretical integration (Rousseau, 1988). Dimensions of climate perceptions have varied widely, including, for example, communication characteristics (Bass et al, 1975), leadership style (Payne & Mansfield, 1973) and organisational effectiveness (Schneider & Shrivastava, 1988).

A number of attempts have also been made to map the main features or levels of organisational culture, including those of Schein (1985), Deal and Kennedy (1986), Graves (1986), Cooke and Rousseau (1988) and Williams et al (1989), Hofstede (1980, 1981). By and large a degree of concurrence exists between espoused models. In analysing the content of organisational culture, Glendon and Stanton (2000) developed a three-level classification embodying relatively accessible, intermediate and deep levels (see table 2).

Table 2. Comparison of three models of organisational culture

Originator	**Most accessible**	**Intermediate**	**Deepest**
Schien (1985)	Behaviours and artefacts	Beliefs and values	Underlying assumptions
Rosseau (1988, 1990)	Observable artefacts	Behavioural norms, which can be inferred from observed behaviours; values, as expressed consciously by organisation members	Fundamental assumptions – core values that may not be articulated
Deal and Kennedy (1986); Lundberg (1990)	Manifest level – symbolic artefacts, language, stories, rituals, normative behaviours	Strategic level – strategic beliefs	Core level – ideologies, values, assumptions

(adapted from Glendon & Stanton, 2000).

The most accessible level refers to observable behaviours and associated norms. Attitudes and perceptions exist at the intermediate level, these may not be directly observable but may be inferred from behaviours assessed through questioning. At the deepest level are core values, which are much less amenable to assessment and for whose investigation more ethnographic methods are likely to be required.

Cooke and Rousseau (1988) suggest that any culture has two key attributes pertinent to its assessment: 'direction' and 'intensity'. Direction refers to the actual content or substance of the culture, for example, what values, behavioural norms and thinking styles it emphasises. Intensity is the strength of this emphasis. Cultures varying in direction support different behavioural norms and thinking styles. Cultures varying in intensity have different degrees of influence on organisational members. The direction or content of the culture is the way in which members enact their environment and it can be described in different ways. Cooke and Rousseau present it as 'individual cognitions regarding appropriate ways of thinking and behaving within an organisational unit'. They see this as distinct from measures of individual perceptions of organisational characteristics and attributes, which constitute surveys of climate. Therefore they believe that climate reflects perceptions of organisational structures and how it feels to be a member of an organisation. Culture involves beliefs about how to behave within an organisational unit.

Arguably one of the more loose terms in current usage in that of 'culture'. Any definition that attempts to capture the essence of organisational culture is inadequate because each of its manifestations are extensive, complex and intangible (Lee & Harrison, 2000). Martin's (1992) approach goes some way to clarify some of the complexities of organisational culture. Martin defines three perspectives on culture: integration, differentiation, and fragmentation.

The integration perspective has three defining characteristics: all cultural manifestations are interpreted as consistently reinforcing the same themes, all members of the organisation are said to share in organisation-wide consensus, and the culture is described as a domain where all is clear and ambiguity is excluded. In contrast, the differentiation perspective describes cultural manifestations as sometimes inconsistent. Consensus occurs only within the boundaries of sub-cultures, which often conflict with each other. Ambiguity is channelled, so that it does not intrude on the clarity, which exists within these subculture's boundaries. The Fragmentation perspective focuses on ambiguity as the essence of organisational culture. Consensus and conflict are issue-specific and constantly fluctuating. No stable organisation-wide or sub-cultural consensus exists. Clear consistencies and clear inconsistencies are rare. Martin asserts that any cultural context contains elements that can be understood only if all three

perspectives are utilised. Nevertheless she underlines how "it is essential to keep each perspective separate ... as pressures toward assimilation would undermine a perspective's inherently oppositional stance toward other viewpoints, threatening its conceptual and political identity."

Comparing organisational culture and climate

Quite a longstanding debate has ensued within organisational theory regarding the nature, supremacy and applicability of culture versus climate. Schneider and Gunnarson (1991) make a clear distinction between culture and climate although they acknowledge that they are strongly inter-related. They define climate as the 'visible practices, procedures and rewarded behaviours that characterise an organisation and the themes or imperatives that employees believe describe their organisations. Culture, on the other hand, focuses on the assumptions, values and philosophies that give meaning or interpretation to what happens. These assumptions, values and philosophies tend to be broadly focused and concern wide-ranging issues such as the nature of human beings and the role of work in life. Table 3 presents a summary of the basic differences between organisational climate and organisational culture.

Table 3. Contrasting Organisational Culture and Organisational Climate

Differences	**Culture Literature**	**Climate Literature**
Epistemology	Contextualised & idiographic	Comparative & nomothetic
Methodology	Qualitative field observation	Quantitative survey data
Level of Analysis	Underlying values and assumptions	Surface-level manifestations
Temporal Orientation	Historical evolution	Ahistorical snapshot
Theoretical Foundations	Social construction; critical theory	Lewinian field theory
Discipline	Sociology & anthropology	Psychology

Adapted from Denison, 1996.

While Denison (1996) does contrast the basic differences between organisational culture and climate, he does conclude that these two 'research traditions should be viewed as differences in interpretation rather than differences in phenomenon' and therefore there should be more integration of the two concepts. He observed that although on the surface the distinction between culture and climate may appear to be clear, at the deeper levels this distinction becomes uncertain.

For example, he refers to the 'multilayered' nature of both culture and climate. In culture research, for example, there is a frequent distinction made between the overt, surface manifestations of a culture such as artefacts, structures, symbols, rituals or practices and the underlying assumptions of values that those manifestations exemplify. In climate research, a similar debate exists surrounding the quasi-objective 'set of conditions' that exist in an organisational system and the subjective perception of those conditions by organisational members (Denison, 1996). Some theorists argue that the set of conditions is the climate, whereas others argue that the climate is in fact the selective perceptions (Glick, 1988; James, Joyce & Slocum, 1988).

Denison argues that the most significant differences lie not in the nature of the phenomenon or the methods used to study them, but in the theoretical traditions. The climate literature has its roots in the field of Kurt Lewin (1951), whereas the culture literature is grounded in the symbolic interaction and social construction perspectives developed by Mead (1934). From Lewin's perspective, the person must be analytically separate from the social context and must assume that individuals are either subjects or agents of a social system. In contrast, the social construction perspective assumes that the individual cannot be analytically separated from the environment and that the members of social systems are best regarded as being agents and subjects simultaneously. Thus, social context is regarded as both the medium and outcome of social interaction (Giddens, 1979).

Denison 1996 also highlights that differences of perspective also tend to be become confused with differences of phenomenon. He refers to Martin's discussion of three different perspectives on culture (Integration, Differentiation, Fragmentation), describing them as though they were three different phenomena. While these three perspectives provided a useful and insightful overview of the culture literature, issues of integration were generally overlooked. Thus the impression is that the field deals with three distinct phenomena, rather than the single phenomenon of organisational context, viewed from three different perspectives (Denison, 1996).

Reichers and Schneider (1990) have also analysed the two concepts and concluded that 'culture exists at a higher level of abstraction than climate, and climate is a

manifestation of culture. The idea that culture and climate are closely related phenomena is also advocated by Schneider & Gunnarson (1991), Cox & Flin (1998) HSE (1999) where safety climate can be regarded as the surface features of the safety culture discerned from the work-force's attitudes and perceptions at a given point in time.

Organisational Subcultures

In developing the idea of organisational culture, organisational subcultures are also implicitly addressed. Most organisations are characterised by subcultures, which form around different roles, functions, and levels (Hampden-Turner, 1990). Cooke and Rousseau (1998) also highlight the importance of organisational subculture, something which has been noted in studies of safety culture. If culture is related to implicit assumptions, value philosophies, behavioural norms and expectations then it is not unreasonable to assume that these might vary across organisational levels – regarding seniority and occupation. Thus beliefs, attitudes or values may or may not be common to all members. Guest et al., (1994) assert that a sub-culture can be conceived of in three rather different ways. Firstly it can be an extension of the organisational culture to a local or departmental level, taking on features of that department or function (e.g., Quality Department Vs Line Maintenance). Secondly, sub-culture can refer to a specific dimension of culture, such as safety or quality. Thirdly, it can refer to a distinctive local culture which is, in some important respects, different from, and possibly almost in opposition to, the dominant organisational culture.

Safety Climate and Safety Culture

Many of the conceptualisations, definitions and measures' developed for safety climate and culture has been derived from the more general notion of organisational culture and climate.

Analyses, which have started from the point of view of individual cognitions and attitudes, have developed the theoretical notion of safety climate in order to explain the organisational factors which underlie a predisposition towards safety failures. Typically organisational climate is described as a concept that describes aspects of an organisation's current state. Zohar's (1980) model of safety climate discriminated

organisations in terms of their accident rate. According to Zohar (1980) safety climate consists of the following dimensions: safety training programmes, management studies towards safety work, effects of safe conduct on promotion and on social status, level of risk at the place of work, priorities of work tempo versus safety and status of safety officers and of safety committees. Brown and Holmes (1986) reduced this model to a three-factor model consisting of management concerns, management activities and employee risk perception. Dedobbeleer and Beland (1991) tested Brown and Holmes safety climate model and reduced it to a two-factor model consisting of management commitment and worker's involvement.

There appears to be no agreement on the key dimension of safety climate except for management attitudes towards safety (Zohar, 1980; Cabrera et al., 1997; Cooper & Philips, 1994; DeDobbeleer & Beland, 1991). Perceived level of risk (Glennon, 1982; Lee 1996; Cabrera et al., 1997), communication (Glendon et al., 1994; Ostrom et al., 1993; Berends, 1996), training (Lee 1996; Coyle at al., 1995, Cabrera et al., 1997) and company procedures/policy (Coyle at al., 1995; Ostrom et al., 1993) have also been identified as other dimensions in measuring safety climate.

The term safety culture arose from the Chernobyl nuclear disaster in 1986, in which cause was attributed to a breakdown in the organisation's safety culture (International Atomic Energy Agency, 1986; Toft, 1992). As with the concept of organisational culture, a range of meanings has been attached to safety culture.

A range of definitions of safety culture have been put forward in the literature ranging from "the way we do things around here" (CBI, 1990); a reflection of the attitudes, beliefs, perceptions, and values that employees share in relation to safety (Cox & Cox 1991) and 'the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety' (Committee of Safety in Nuclear Industry (ACSNI).

Turner and Pidgeon have also developed the notion of safety culture (Turner et al., 1989, Pidgeon & O'Leary 1994). Turner et al., (1989) define safety culture as "the set of beliefs, norms, attitudes, roles and social and technical practices within an organisation

which are concerned with minimising the exposure of individuals both within and outside an organisation to conditions which are considered to be dangerous".

Overall while climate concerns a perception of the organisation, safety culture is a more global concept. Safety climate measures (e.g., Cox & Cheyne, 1998, Mearns et al., 1997) tend to focus on current perceptions and attitudes to management and supervisors, risk taking, safety policies and practices, and social aspects of the work situation such as trust, openness, discipline and team support. They do not usually claim to assess fundamental value systems or the organisation's philosophy of management.

Longstanding debates as to the nature, supremacy and applicability of culture versus climate in organisational theory are also echoed by safety researchers in relation to safety climate and safety culture (Clarke,1999; Denison, 1996; Cox & Flin, 1998; Reichers & Schneider, 1990). Cox and Flin's (1998) review of some of the arguments on safety culture vs safety climate concluded that safety climate can be regarded as a surface feature of safety culture discerned from the work-force's attitudes and perceptions at a given point in time.

Perhaps in relation to safety the possible differences between the two concepts are insufficient to support their independence, one of the other. Perhaps there is but one. If there is, as Lee (1993) has argued that safety culture is a more appropriate name than safety climate, because it highlights 'a quintessential feature, which is that the social system is independent of the people who comprise it – it consists of all that has been acquired and then passes on, it endures'. On the other hand Means et al., (1997) propose that safety climate is a more appropriate term of the questionnaire-based surveys, as these are only capable of sensing surface features discerned from the work-force's attitudes and perceptions at a given point in time – a snapshot of the prevailing state of safety.

Culture in general, and safety culture in particular, is often characterised as an enduring aspect of the organisation with trait like properties and which is not easily changed. Climate, on the other hand can be conceived of as a manifestation of organisational culture (Schein, 1985) exhibiting more state-like properties. It therefore appears that

safety climate can only give an indication of the underlying safety culture. It cannot then capture the full richness of the organisation.

The Relationship between Safety Culture and Safety Management Systems

Safety culture is often cited as the most important factor in the ability of an organisation to implement a safety management system (Reason, 1997; Hale & Baram, 1998; Flin, 1998). However many of the safety culture definitions are very global and therefore highly implicit, so they don't really outline particular aspects or components of safety culture. Also the approach taken in many definitions implies that safety culture is conflict free and aligned with the objectives of a controlling function. So what is the relationship between a safety management system and safety culture?

While there appears to be a large degree of consensus in the literature regarding key elements of a safety management system, much of this seems to be based on the analysis of major accidents rather than a systematic comparative analysis across organisations. Waring (1996), for example, has referred to a number of high profile accidents and safety cases or incidents (e.g., Three Mile Island, Nuclear Power Station Incident; Ferrybridge cooling towers collapse; Kings Cross) in relation to highlighting the importance of the various key elements of safety management. Likewise Pybus (1996) also refers to the causes of major accidents (from Clapham Junction to Zeebrugge) to highlight the important elements of a safety management system. Although a number of dominant themes in relation to safety management and safety culture have also recently emerged from a more prospective analysis from off shore studies, nuclear processing studies and other high reliability industries (e.g., military, ATC etc).

In the UK, regulatory bodies, such as the HSE, have also encouraged companies to develop a 'positive safety culture' as a means to successful health and safety management. It is now generally well accepted that any well-designed safety management system should possess the following elements (e.g., Waring, 1996; HSE, 1991):

- Clear policy, strategy and objectives.
- Clear responsibilities, accountabilities and authority of individuals.
- Adequate means of organising, planning, resourcing and decision making.

- Clear set of operational and safety procedures.
- Adequate means of implementing plans and decisions.
- A coherent and adequate set of measures of performance.
- Adequate means of monitoring, assessing, auditing and reviewing both the quality of the system itself and how it functions.
- Adequate numbers and allocation of competent well-led people.
- Flow of adequate information to all those who require it.

It is evident that in addition to these systematic requirements, the organisation also needs to understand the underlying culture of the organisation in order to develop and sustain an effective safety management system. In understanding the underlying culture of safety management a number of aspects have been highlighted, including the role played by safety attitudes, normal behaviour, safety climate and perceptions of management commitment, as well as the role of operational procedures, decentralised authority, organisational learning and effective communication to name but a few.

The definitions of safety culture indicate the key elements of a safety culture are underpinned by the beliefs and attitudes of individual employees, that these underlying beliefs are shared among employees, and that it is expressed in the normative practices and day-to-day behaviour of employees. Research in this area has focused largely on employee's attitudes and perceptions. Therefore understanding the underlying culture requires an assessment of both the key safety rules, practices and processes as well as the less visible norms, attitudes, values, beliefs and assumptions towards the overall system itself.

The central role that employee (staff as opposed to management) attitudes play in relation to safety culture has been widely discussed. As already mentioned, it was strongly argued by a number of researchers that negative attitudes among workers are the precursors of unsafe behaviour and their origins, in turn, are in defective management attitudes and practices (Jonson, 1982; Beck & Feldman, 1983; Sheedy and Chapman, 1984, 1987; Griffiths, 1985; Allen, 1986; Lee, 1998). Van Vuuren (2000) also found in their study of cultural influences on risk in a number of medical settings that the majority of cultural failure factors were related to the attitudes of employees towards the importance of safety.

Norms of attitudes and behaviour are also important to safety culture as well as individual responses (Lee & Harrisson, 2000). This is not only because norms are, by definition, shared attitudes and behaviour but also because both are powerfully controlled by conformity to norms – a process that generally acts as a condition of acceptance by social groups. Attitude change and behaviour modification also depend on this process and improvements are greatly facilitated if mediated through the influence of the group. It is 'implicit' or 'informal' norms that rule and there is extensive evidence, going back to the Hawthorne studies that these are different from formal rules. Despite their widespread use, it has long been demonstrated that sets of procedures, for example, cannot automatically prevent an incident from occurring. Beneath the formal rules and formal structures lies an informal structure, where informalities, adjustments, and micro-deviations are constantly improvised and dealt with by members of the organisation in order to get the job done (Bourrier, 1997). However at the same time, accident analyses provide ample evidence that incremental 'normalisation of deviance' and the habit of working outside prescribed boundaries lead to error and accident proneness. Mearns et al., (1997) have made the comment that despite the obvious relevance of norms to safety culture, researchers have not addressed them directly.

The importance of management commitment and, in particular, the perceived priority accorded to safety matters, has been repeatedly highlighted (Cox & Flin, 1998). It is hardly surprising that the role of management in determining the safety climate or culture of the work-place appears so frequently, although an understanding of the processes relating to management behaviours, their perception by the work-force and any resulting impact on work-force behaviours is rather less well established. Safety climate can be regarded as a surface feature of the safety culture discerned from the work-force's attitudes and perceptions at a given point in time (Schneider & Gunnarson, 1991; Cox & Flin, 1998) and the perception of management commitment towards safety has been measured in all empirical studies as a key dimension of safety climate.

Measuring safety climate and safety attitudes usually involves quantitative methods (e.g., self-reported surveys) which purport to describe a snapshot of the state of safety providing an indicator of the underlying safety culture of a work, group etc. However is

a quantitative approach to measuring safety attitudes, norms of behaviour and safety climate sufficient for capturing aspects of the underlying culture? There has been considerable debate concerning the lack of theoretical and methodological instruments for an adequate analysis of safety culture. In the early days studying culture involved qualitative research methods and an appreciation of the unique aspects of individual social settings (Denison, 1996). Meyerson (1991) noted, 'culture was the code word for the subjective side of organisational life...its study represented an ontological rebellion against the dominant functionalist or 'scientific' paradigm. However in recent years survey methods have been applied to study comparative 'dimensions' of culture in a way that appears to contradict the ethnographic foundations of cultural research even though it has been argued that this type of research runs the risk of reducing culture to 'just another variable in existing models of organisational performance' (Siehl & Martin, 1991).

The difficulties linked to the diagnosis of culture as a phenomenon not directly observable, but to be inferred from a variety of indicators requiring a profound knowledge of an organisation, have been described by a number of authors (Shien, 1985, 1992; Schneider and Shrivasta, 1988). In most cases a multiple measurement approach has been adapted when assessing safety culture and safety management. This multiple measurement approach usually incorporates questionnaires in measuring safety climate and attitudes, interviews, focus groups, observations and audits, as well as documentation analysis, and analysis of reported accidents and incidents which provide primary insights into the structure and functioning of the safety management system. Assessing the deeper levels of culture and core values are much less amenable to assessment and usually require more ethnographic and longitudinal methods.

Objectives of the Study

The literature review above provides an overview of the major approaches to safety systems and safety culture. Many of these theoretical approaches have contributed a lot to our understanding of safety management and safety culture, for example the seminal contribution (almost twenty five years ago) of Turner's man-made disaster theory. It is a tribute to the insight of Turner's thinking that his theories and research methods have retained their relevance and continue to provide a serious challenge for organisational research and design. In many ways this work prepared the theoretical ground for

subsequent work on safety management. Likewise the work of the 'high reliability' group has advanced a number of interesting ideas regarding the introduction of more flexible control systems during 'crisis' periods.

While all the empirical work and theories have contributed to our current understanding of safety management systems and there is almost total agreement on the importance of safety culture, there does not appear to be any consideration of how safety culture is embedded in the organisation's safety management system. Much of the literature on safety culture focuses around definitions, its applicability and its comparison with safety climate. Most of these definitions are quite global with little or no reference to key components of safety culture. Reason (1997) has outlined a number of components of a safety culture but these are largely generalised prescriptions of how to 'engineer safety culture', rather than a systematic analysis of the underlying organisational processes that make the system work effectively. In many ways organisational processes are fundamental to both the man-made disaster theory and Reason's theory in that they reveal that there are many preconditions to any major system failure, some originating years prior to the actual event. However these underlying processes have to be analysed in a more prospective way rather than rely on accident analyses and inquiry reports. The current literature provides little understanding or guidance on the normal organisational and cultural processes required for effective safety management. Therefore this study was designed to further explore the organisational processes of safety management systems and how they are embedded in the culture of an organisation.

The overall objective of this study was to describe and compare the organisational aspects of safety management systems and the underlying safety culture in the domain of European aircraft maintenance. The objective was not to treat safety culture as a separate and distinct category from safety management or the safety climate, but rather to begin to explore the relationship between a safety management system and safety culture. An element missing in many publications on safety culture is an explicit, theoretical model outlining the manner in which safety culture is thought to be embedded in the organisation's safety management practices. Therefore the first objectives were to develop a model outlining key aspects of safety management and safety culture and use this model as a framework to systematically describe and compare safety management and culture across four aircraft maintenance organisations.

For the sake of conceptual clarity the following definitions were adopted in order to distinguish between a safety management system, safety culture and safety climate. A safety management system comprises the explicit organisational processes (policies, structures, procedures, roles, practices etc), which influence the overall safety operation. A safety management system is integrated in a company philosophy or culture which includes the behaviour, attitudes, values, perceptions, and accumulated experience and expectations of the members of the organisation. Therefore management concepts and practices, rewards and pay systems, organisational work and design, procedures, training, quality assurance etc are all deeply rooted and influenced by the organisation's culture. Safety climate, on the other hand, is peoples' perception of their company's commitment to safety and it can also best be seen as a more manifest component of the overall safety culture in an organisation.

Much of the research on safety management and safety culture has focused on the nuclear industry (Lee, 1998; Ostrom et al., 1993), military (Bourrier, LaPorte & Consolini, 1991), petroleum (Cox & Cox, 1991; Mearns et al., 1997) and chemical industries (Donald & Canter, 1994; Budworth, 1997). Studies on aircraft ground handling staff (Cabrera et al., 1997; McDonald, 1997) appear to be the only empirical studies assessing safety management and culture in the aviation domain.

Aircraft maintenance is a critical component of the overall system for ensuring safety in aviation. Twelve per cent of major aviation accidents have been attributed to maintenance and inspection deficiencies (Marx & Graeber, 1994). A FAA Report on Error Investigation and Analysis Systems states that nearly 50,000 times a year, aircraft are dispatched in an unairworthy condition. One aircraft manufacturer claims that up to 30% of engine in-flight shut downs and up to 50% of engine-related delays are caused by maintenance error (Bartron, 1999). It has also been reported that the number of maintenance related accidents is on the increase and that over the preceding 10 years, whilst the number of flights had increased by 55%, the number of 'maintenance concern' accidents had increased by 100% (King, 1998). The human and organisational factor is the critical component of these accidents. Extensive analysis of aircraft accidents and incidents has shown that these were not simply a consequence of direct technical failure or operator tasks which were carried out incorrectly. The underlying

causes were deeply rooted in organisational and management factors. The safety management system in aviation maintenance is therefore an appropriate domain in which to further explore organisational and cultural factors that influence the overall safety of the operation.

The analyses of aircraft accidents and incidents have highlighted key deficiencies in safety management systems. The objective of this thesis, however, was to systematically describe and compare the safety management system and the underlying culture in the normal everyday situation rather than from the more reactive accident analyses. Therefore this study provides a prospective analysis rather than a retrospective study based on accident and incidents. Too often, organisational analyses are carried out only after a catastrophe has occurred. While very interesting, this perspective has serious limitations. It is more essential to understand the mechanism of the 'normal' functioning of high risk organisations, because having a correct perception of their 'normal' operation can help to prevent future dysfunctions and possible errors (Bourrier, 1997). Furthermore in recent years there has been a movement away from safety measures purely based on retrospective data or 'lagging indicators' such as fatalities, lost time accident rates and incidents, towards so called 'leading indicators' such as safety audits or measurement of safety climate. It can be argued that these are predictive measures enabling safety condition monitoring (Flin, 1998), which may reduce the need to wait for the system to fail in order to identify weaknesses and to take corrective action.

Another objective of the thesis was to develop a standard set of methodologies to explore all key elements of the proposed model. It has been suggested by many (e.g., Jick, 1979) that organisational researchers and practitioners can improve the accuracy of their judgements by both utilising multiple methods and collecting different kinds of data bearing on the same phenomenon. Bearing in mind the diversity of the notion of safety culture, the objective was to develop a variety of methodologies to reflect different aspects of the organisation, including the formal aspects of safety management, attitudes, expectations, and behavioural norms and to test whether the conclusions drawn from the different sources were compatible and 'told the same story'.

In exploring the relationship of different organisational aspects of safety, through the deployment of different research measures and methods, the next objective was to describe and compare safety management systems across different aircraft maintenance organisations and to evaluate the model in accounting for the organisational and cultural aspects of safety. In comparing and differentiating between different organisation's safety management systems this should also enable an evaluation of the strengths and weaknesses of different real operational systems therefore identifying theoretical and practical implications for current safety management practices. In addition the aviation industry has been one of the leading industries in recognising the important role of human factors in ensuring the highest level of safety, therefore another particular emphasis of the study was to assess the impact of human factor initiatives in aircraft maintenance safety systems.

The overall objectives can be summarised as follows:

- Develop a model focusing on the organisational aspects of safety management and culture in aircraft maintenance.
- Develop a set of methodologies to explore the elements of the model.
- Use the model and the methodology as a framework to systematically describe and compare safety management and culture.
- Evaluate the utility of the model and the methodologies in facilitating a clear description of organisational systems.
- Assess the impact the role of human factors initiatives has made on aircraft maintenance safety.
- Identify key theoretical and practical implications for current safety management practices in aircraft maintenance.

Descriptive Overview of the Aircraft Maintenance System and The Role of Human Factors

Aircraft maintenance is a highly dynamic and regulated industry characterised, for example, by complex and interdependent systems and technologies, detailed and legally binding task procedures and documentation, highly publicised accident rates and highly regulated management systems to ensure reliability, efficiency and safety at all times. Aircraft accidents always attract a great deal of media attention and maintenance related error has contributed in no small way to the number of major aviation accidents, and

indeed maintenance deficiencies can often be found as a contributory factor in accidents. Table 4 provides an overview of some the high profile maintenance related accidents in recent years.

Table 4. Maintenance Related Incidents and Accidents

Date	Referred to as:	Accident/Incident	Event	Direct Maintenance Cause
1988	Aloha Airlines 737	Aloha Airlines, Flight 243, Boeing 737-200	In flight structural break up, upper fuselage detached during flight	Inspection failure, e.g., cracks escaped detection
1989	Sioux City DC10	United Airlines, Flight 232, McDonnell Douglas DC10	Engine disk failure	Inspection failure
1990	BAC 1-11	British Airways, BAC 1-11	Cockpit windscreen blow out	Replacement windscreen refitted with the wrong size bolts
1991	Continental Express	Continental Express, Flight 2574, Embraer 120	In flight structural break up	Screws attaching left leading edge of the horizontal stabiliser not re-installed after maintenance
1993	Excalibur A320	Excalibur A320	Pilot could not turn left	Wing spoilers left in the wrong position
1994	Boeing New Tokyo	Boeing 747	Engine and pylon broke loose during landing	Fuse pin retainers were not re-installed after maintenance
1995	British Midland	British Midland, Boeing 737-400	Rapid loss of engine oil	Oil caps on both engine sumps not re-installed after maintenance

(adapted from Bacchi et al., 1997)

Understanding and addressing these maintenance errors and more importantly the organisational and management shortcomings that contribute to these errors is essential to improving flight safety, reducing the accident and incident rate, and enhancing maintenance resources and the maintenance environment.

Core Functions in Aircraft Maintenance

The following provides a generic description of the core functions in aircraft maintenance. It should be noted that any two maintenance organisations although operating under very similar regulatory and operating conditions could differ in many ways both in their organisation of maintenance tasks and in their terms of reference used. The aircraft system is also affected by a variety of geographically dispersed entities ranging from large international carriers, repair, and maintenance facilities through regional and commuter airlines to the fixed-based operators associated with general aviation (Drury et al., 1990). Therefore the following description is meant as a

general descriptive overview and therefore may not be an exact description of any one organisation.

Aircraft Maintenance Activities

Task analysis has revealed aircraft maintenance activity to be a complex sociotechnical system requiring sustained co-ordination, communication and co-operation between different work-groups and teams including aircraft engineers, supervisors, inspectors and shift managers; various other subsystems such as planning, stores, quality and engineering; and external bodies, such as the regulators, the manufacturer, the customer and the airline in order to ensure efficient and effective operations (McDonald, 1998; Drury et al., 1990; Gramopadhye & Kelkar, 1999). Figure 1 provides a simple schematic outline of some of the key functions within the aircraft maintenance system.

The diagram presents four of the key aspects of aircraft maintenance (i) the regulations – aircraft maintenance is a highly regulated industry where maintenance organisations are continually subjected to audits and approvals by aviation authorities covering both quality and operational requirements (ii) other external bodies – the manufacturer, customers, vendors and the airline also play a key role in influencing operational matters. For example the manufacturer and vendors provide the necessary task procedure documentation in order to carry out maintenance tasks, all of which are specified in extensive manuals and there is a legal requirement that performance of maintenance operations is signed off according to these manuals (iii) internal functions – a number of key functions continually support pre-check aspects of aircraft maintenance (e.g., contract negotiation, personnel selection, personnel training etc) and (iv) maintenance production system - this is where the work is actually carried out either aircraft overhaul or line maintenance, all of which is continually supported by engineering, planning and quality departments.

Every newly acquired aircraft will have a National Aviation Authority (NAA) approved Aircraft Maintenance Programme (AMP), otherwise referred to as the Approved Maintenance Schedule (AMS). This document lays down the mandatory minimum maintenance program and is produced by a Maintenance Review Board (MRB) consisting of the manufacturers and the aviation authorities, in consultation with the airlines and maintenance organisations to ensure the continuous maintenance needs of

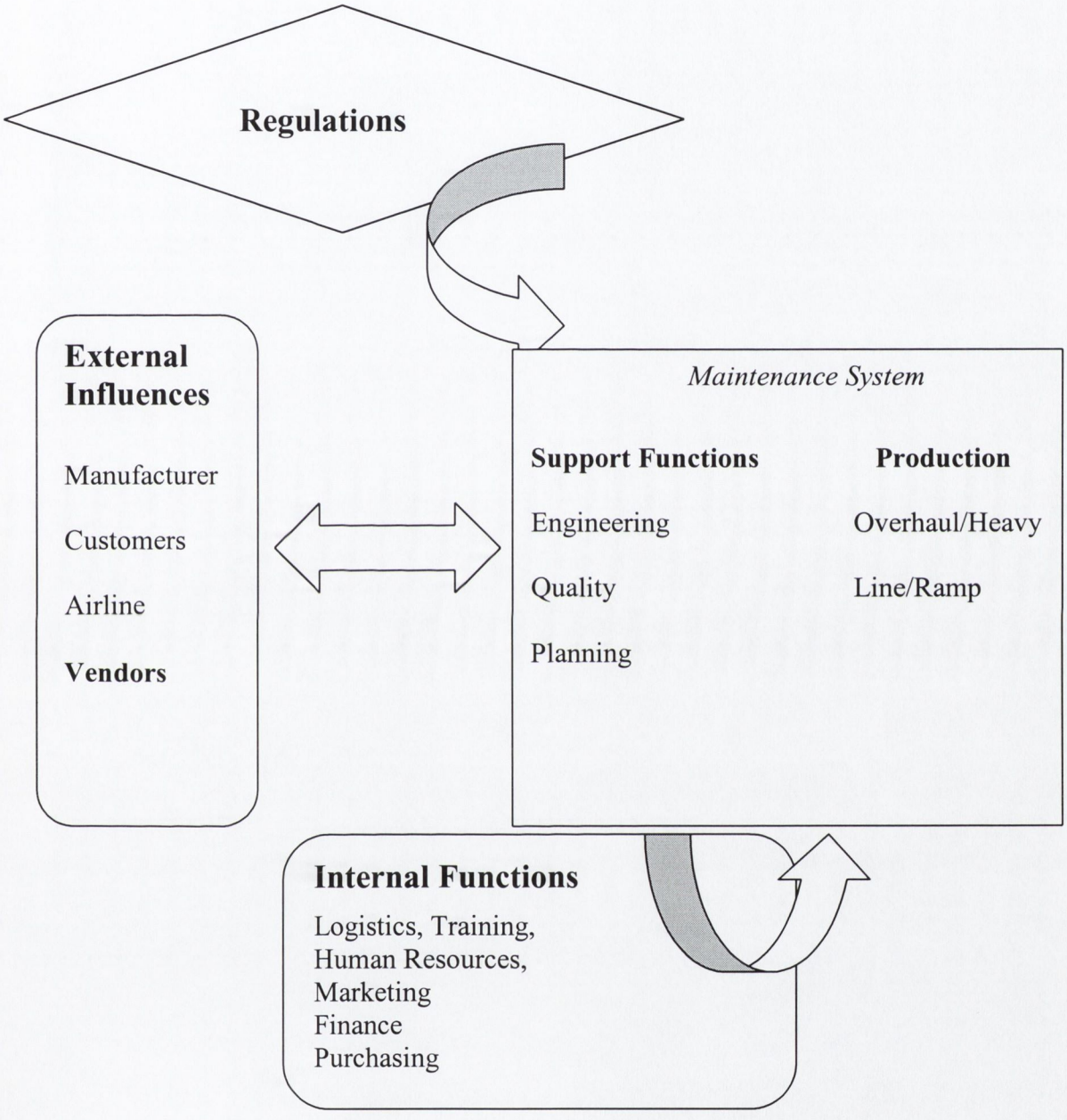
the aircraft are met. The AMS is modified by the maintenance organisation in order to suit individual organisational requirements as well as meeting all the legal requirements.

Usually the AMS is broken down into checks at various intervals, designated as either line checks, over night checks, and A, B, C, D (the heaviest checks). The objective of these is to conduct both routine and non-routine maintenance of the aircraft. This maintenance includes scheduling the repair of known problems; replacing items after a certain air time, number of cycles, or calendar time; repairing defects discovered previously from reports logged by pilots and crews or items deferred from previous maintenance; and performing scheduling repairs or inspections (Gramopadhye & Drury, 2000).

Once maintenance and inspection are scheduled for an aircraft, they are translated into a set of job cards or work cards giving the instructions for the aircraft maintenance personnel to carry out the different tasks on the aircraft. A major check (e.g., C or D check) may have as many as 5,000 – 10,000 job cards. Each card will include a description of the task and contain information pertaining to the type of aircraft. As the information on the job cards initially comes from task cards within the aircraft manufacturer's Maintenance Manuals (MM), all tasks will also have a reference to the relevant section of this manual. The work-card is also a legal document that when properly executed provides "proof" of work accomplishment and it exacts accountability from the aircraft maintenance engineer/inspector signing off the card.

A critical aspect of the workload is dependent on recognising and identifying defects during maintenance and inspection activities. In particular there is pressure to identify critical defects that necessitate lengthy follow-up maintenance and additional logistical support early in the inspection process. Therefore there is usually a heavy inspection workload at the commencement of each check. During inspection each defect is written up as a Non-Routine Work Card (NRC) and re-assigned to maintenance personnel for completion and sign-off.

Figure 1. Overview of Aircraft Maintenance



After the inspection activities and identification of defects, maintenance planning and management can provide a more accurate estimate of the expected maintenance workload, order replacement parts, assess manpower levels, assess additional technical support, and re-schedule maintenance items.

Much of the maintenance activity is organised around shifts and accomplished through different teams dedicated to different zones on the aircraft. During the entire maintenance process maintenance personnel work with their colleagues from the same shift and the next one as well as with personnel from engineering, quality, planning, stores etc to ensure task completion. The maintenance activities are also supported by technical training, HR, marketing, finance, purchasing departments etc. Operational maintenance also relies a great deal on the logistical support departments based around the hangar floor (e.g., stores, materials, component workshops etc).

The following description focuses primarily on the actual production activities that play a role in influencing how maintenance operations are planned, carried out and monitored. This section also provides an overview of the regulatory framework that the maintenance system must operate within.

Aircraft maintenance activities in Europe tend to be divided into three main types.

- Ramp or Line maintenance
- Minor or Light maintenance
- Major or Heavy maintenance.

Line Maintenance

Line maintenance is the term used for the day to day maintenance checks and repairs carried out on the ramp or terminal gate. Typically an aircraft will come to the gate and the passengers and baggage will be disembarked, and other ramp functions (fuel checks, tyre pressure checks etc) will be performed. The line maintenance engineer assigned to the aircraft will board, retrieve the technical log of the aircraft and investigate any problems that have arisen on the flight. The technical log details the physical state of

the aircraft at that moment in time. The flight captain records in the technical log any unusual occurrences, readings or technical problems occurring during the flight.

The line maintenance engineer will attempt to rectify all of these problems before the aircraft is due to depart. If a problem occurs that cannot be fixed the Minimum Equipment List is consulted to determine if the aircraft can carry the problem until such a time as it can be rectified. If this is allowable the problem will be deferred, (for a length of time specified in the maintenance manual) otherwise it must be rectified immediately or it could result in 'grounding the aircraft'. The line maintenance engineer also performs a series of inspections of varying detail during aircraft 'turnaround'. Finally, in conjunction with the captain for the next flight, the line maintenance engineer will sign the aircraft as 'released for service', that is that the aircraft is in an acceptable airworthy condition. (It should be noted that the Captain can refuse to accept the aircraft, as in Europe the pilot has the final say and responsibility for dispatching the aircraft, however in the United States the aircraft engineer signing the release is seen to have 50% responsibility).

Minor or Light Maintenance

Light maintenance consists of scheduled maintenance checks (or letter checks) usually every 500 flight hours but up to every 5000 and take anything from 10-24 hours to complete. These include the maintenance service checks often referred to as letter checks A or B and are planned in a similar way to Heavy maintenance tasks discussed below. Minor maintenance would also include overnight hangar work that does not receive the same level of advance planning. Tasks might include clearing of the Technical Log, completion of Airworthiness Directives, Alerts, Service Bulletins, Free Routine Tasks etc.

Heavy Maintenance

Heavy maintenance refers to checks which take many more person hours to perform and are carried out less frequently (e.g., anything from every 5000 - 20,000 flight hours and taking more than 48 hours in the hangar to complete). Like minor maintenance it consists of scheduled tasks from the Aircraft Maintenance Schedule, the plan of all maintenance tasks to be carried out over the life span of the aircraft. Usually around 40 per cent of tasks can be scheduled. The remaining 60 per cent are unscheduled defect

items discovered or raised during maintenance activities. When compared with Light Maintenance it typically involves more thorough dismantling and checking of aircraft systems, as the longer time span would suggest.

Maintenance Training

In general maintenance production personnel begin their careers with a three to four year course to qualify as Basic Aircraft Engineers. During this time they will gain experience in all areas of aircraft maintenance completing relatively simple tasks such as component replacement or minor repair. They are unauthorised at this stage so all their work must be co-signed by a supervisor. The next stage is to receive specialised training on specific aircraft or engine types to become an authorised aircraft engineer. Training is usually provided in-house and varies in length from 2-13 weeks, followed by written and oral examination on all aspects of the job from task completion to legal issues. Having successfully completed their training they receive a Personnel Authorisation Certificate, which specifies the aircraft, engine type, and subsystem they are licensed to work on. A typical aircraft engineer in line maintenance would have certification for a variety of tasks but for a more restricted range of types, whereas a typical maintenance engineer in heavy maintenance would be more specialised to a particular subsystem for many aircraft types.

Internal Support Functions

The maintenance engineering, planning and quality departments as well as the manufacturer are responsible for the production of all information and documentation critical for the planning and the execution of aircraft maintenance tasks. This information and documentation is available in varying formats at the different levels in different organisations.

Engineering Department

Personnel in engineering departments typically consist of graduate engineers and engineering managers who usually do not have a hands-on role working on the aircraft. In general engineering departments have ultimate responsibility for the receipt, control, approval and distribution of airworthiness data. Their primary role is to provide technical support and back-up to both Line and Heavy Maintenance. Typically this

support will include responding to technical queries, examining additional manuals and liasing with other internal departments and external organisations (manufacturer, airline etc). Engineering departments are also responsible for developing maintenance schedules based on the AMS. For Airbus aircraft, for example, the starting point for a maintenance program is the Maintenance Planning Document (MPD) which gives guidelines as to exactly what tasks should be done and at what intervals. However, these guidelines are just a starting point. Engineering departments can add or remove tasks from the schedule and/or intervals of checks extended or reduced. Based upon the MPD the Engineering department develops a Maintenance Schedule (MS) that is passed on to the planning department.

Planning Department

Most organisations have a planning department and also have personnel dedicated to planning activities on the shop floor. Personnel in the planning departments usually do not have a technical background, but are trained in administrative and clerical activities. Personnel dedicated to planning activities on the shop floor usually do have a technical background. From the information on the maintenance schedule the planning department will plan which particular aircraft is due for which check and prepare and produce all job cards and documentation necessary to complete the check. The Planning Department issues in card form (or in Check Sheet form in the case of minor checks) the inspection and work requirements for each maintenance check. The inspection and work items on the cards (or check sheets) are written strictly in accordance with the relevant item in the approved Maintenance Schedule for the appropriate aircraft type. The package of cards for each check contains all the items relevant to the particular check.

The planners in the production area are responsible for supplying all the paperwork and documentation both prior to and during a check. Production planners could receive 3,000 - 5,000 pieces of paper per check from either the planning department or from the customer and as a result receive a lot of queries on paperwork. The production planners receive the Aircraft Work packs from the Planning Department or directly from the Customer Airline Planning department and further break the packs down into more controllable work units. As each work card is completed and signed, the applicable card number or reference is marked off on the appropriate control cards as an indication that

the card has been completed. The schedulers audit the work-packs and check that all work cards have a signature of Certificate of Release into Service (CRS). The work packs are then sent back to the internal planning department or to the Customer planning department.

Quality Department

The Quality system is responsible for monitoring all operational activities primarily through regular audits, and assuring the company management that standards of safety are being complied with. Their role includes direct auditing, on-site inspection, routine visits to component workshops, statistical trend analysis, quality investigations, incident investigation, disciplinary measures and production of quality reports etc. Quality is responsible for ensuring that a satisfactory system of sampling checks is carried out on the documentation and facilities in order to ensure compliance with the regulations. These sampling checks (audits) culminate in an audit report which each area receives and each of the general managers receives a summary report of the primary findings. Company procedures are usually also compiled by quality personnel and are available in Quality departments. Quality also has sole responsibility for writing and amending the Maintenance Exposition Document (MOE), Quality Inspectors Procedures, CAA Design Approval, and the Approvals Manual.

Regulatory Framework

Aircraft maintenance is a highly regulated industry – new civil aircraft undergo an extensive certification process that includes all maintenance aspects. Maintenance organisations are subject to audit and approval by aviation authorities covering both operational and quality requirements. All maintenance tasks and procedures are specified in extensive manuals and other documentation and there is a legal requirement that performance of maintenance operations is signed off by appropriately certified staff.

The JAA Committee (JAAC), which is comprised of one representative from each member country, runs the present structure of the JAA. In general the representative is the person responsible in their country for all the safety and regulatory functions covered by the JAA. The JAA carries out its tasks of approval, certification and safety

monitoring using staff of the national aviation authorities (NAA), who also retain the responsibility for the legal findings of granting licences and certificates, etc. The Central JAA is responsible for the process of rulemaking, harmonisation and standardisation, (using specialist staff from the national authorities), the decision-making system, the "infrastructure" and various related tasks. There are 4 primary JAA codes which, concern aircraft maintenance: JAR 21 – Certification Procedures for aircraft and related products: JAR 65/66 for Certifying maintenance staff; JAR 145 for Approved Maintenance Organisations; JAR 147 for Training Schools.

The framework for the JAR 145 regulations is built around the philosophy of granting approval to maintenance organisations that have an adequate management system to ensure safe operations. Thus the regulator only indirectly regulates the safety of the operation – the responsibility is on operational and quality management to ensure safety. JAR 145 prescribes that 'no aircraft when used for Commercial Air Transport may fly unless a certificate of release to service has been issued by an organisation for maintenance carried out on the aircraft or an aircraft component intended for fitment to such an aircraft' (JAR 145.1a). The certificate of release to service can only be issued if the organisation is approved with the JAR 145 document. All JAR 145 approved organisations must provide a maintenance organisation exposition document (MOE) and JAR 145 approval renewal is dependent upon a continual monitoring process in which all functions are checked at least once during a two-year period.

All the regulatory bodies have to be informed if an incident compromises airworthiness and the airline has to have a system in place in order to inform the regulatory body. *JAR 145.60 Reporting of unairworthy conditions;* (a) The JAR –145 approved maintenance organisation must report to the Authority and the aircraft design organisation any condition identified by the JAR-145 approved maintenance organisation of the aircraft or aircraft component that could seriously hazard the aircraft; (b) Reports must be made on a form and in a manner prescribed by the Authority and contain all pertinent information about the condition known to the JAR-145 approved maintenance organisation.

Every national aviation authority also has an implicit or explicit policy in relation to prosecution. In the United States the FAA has a statutory obligation to prosecute

violations and it has been very difficult to achieve a policy which will encourage frank disclosure of violations. In Europe it is very rare for a National Aviation Authority to prosecute an approved maintenance organisation. The tradition has been for the authorities to seek to influence maintenance organisations through the weight of their authority, as part of an ongoing relationship and with a graded set of sanctions, which can be threatened and imposed, with prosecution being considered as a last resort.

A new regulatory environment for aircraft maintenance is developing in Europe and the United States which is placing increasing requirements on maintenance organisations to manage the human aspect of their business with the same level of excellence as has traditionally been accorded to the technical aspects. New regulations, especially JAR 66, are demanding that approved maintenance organisations address human factors issues, in this case through the training of certifying technicians. This requirement is stimulating many maintenance organisations to develop human factors programmes, often centred on training.

Human Factor Initiatives in Aircraft Maintenance

Aircraft maintenance organisations are changing rapidly largely because of economic considerations rather than purely safety or quality considerations. Many are reorganising, or re-engineering their internal structures and processes. Some are downsizing, or taking over or being taken over by other companies. Many are becoming independent subsidiaries of their parent organisations and there is a growth in 'repair shop' organisations. Aircraft maintenance technologies are also being transformed through new aircraft systems, diagnostic tools and information technologies. Accompanying these changes are new concepts of training, changes in the apprenticeship system, shortages in key qualified staff, and a growth in contract labour. All of these changes have an impact on the way in which aircraft maintenance operations are organised, managed and performed. In order to manage these changes more effectively many organisations are turning to 'human-factors' programmes to help them manage the 'people side' of their organisations, in order to ensure that standards of safety, reliability and productivity are maintained and preferably enhanced.

The term 'human-factor' or managing 'human factors ' refers to developing an understanding of the human and organisational issues that affect the performance of overall maintenance operations. A range of factors can affect the individual as he carries out his individual tasks and there are also a wide range of factors which potentially affect the performance of maintenance operations but which are not specific to the task being done. Some of these relate to the management of time at work. These include the arrangement of working hours and rosters, overtime, shift work and the hand-over of incomplete tasks from one shift to another, as well as time pressure within any particular shift. A second set of factors concerns the technology of aircraft maintenance - the aircraft, parts tools, documentation and equipment used. And finally there is the environment in which the work is done, either in the hangar or on the airport ramp.

An extended programme to promote human factors in aircraft maintenance was developed by the FAA with the industry (airlines and manufacturer) from the mid-1980s to address these issues (FAA, 1995). This involved

- Importing 'crew resource management' training concepts which had been developed for flight crew and adapting these as maintenance resource management (MRM), and implementing and evaluating these in several airline maintenance organisations (Taylor & Robertson, 1994).
- Developing incident analysis techniques (for example, MEDA – Maintenance Error Decision Aid), in order to promote cross-organisational and international sharing of incident data.
- Specific intervention strategies: documentation design, inspection practices.
- Planning for human factors requirements in regulations (FAR 145, FAR 66).
- Incorporating anthropometric principles in CAD tools for aircraft design.

After fifteen years of development effort the evidence of the success of this programme has been of small local successes, but overall of failure to meet objectives and increasing disillusion (Taylor & Robertson, 1994; Taylor & Patankar, 1999; and Goglia, 1999). In particular

- MRM programmes have been shown to have some short-term impact on trends in attitudes and performance, however the wider long term impact within the

maintenance industry, which may result from a sustained human factors initiative, has yet to be established.

- Few organisations do thorough human factors analyses of their own incidents.
- The programme to incorporate human factors requirements in US regulations has been completely stalled.

The objective of assessing human factor initiatives in this study was to get a better understanding of how these initiatives are built into all aspects of the production and management system of aircraft maintenance.

Overall Summary

Chapter 1 presented an overview of the key approaches in the literature to understanding the human and organisational aspects of managing safety. While the various approaches have contributed a great deal to current knowledge and understanding of safety management and safety culture, it was felt that much of this was highly reliant on accident analyses and inquiry reports, rather than on an assessment of normal operational practice. Many of the approaches also agreed on the importance of cultural aspects in understanding safety management, however there did not appear to be any systematic or comparative analysis of how safety culture is embedded in an organisation's safety management practices. Therefore the primary objective of this study was to develop a model outlining the key aspects of safety management and safety culture and use this model as a framework to systematically describe and compare safety management and safety culture across four aircraft maintenance organisations. A descriptive overview of the aircraft maintenance system and the role of human factors were also presented in this chapter in order to provide some context for the key findings of the study. The description of aircraft maintenance focused on the key operational functions with responsibility for organising maintenance activities and ensuring safety. The role of the regulatory body was also put forward as well as a brief overview of the role of human factors in aviation. This brief overview painted a somewhat negative picture of the impact human factor initiatives have had to date in improving safety operations; therefore another objective of this thesis was to assess how these initiatives are built into aspects of the production and management systems of aircraft maintenance (if at all) and how successful they have been in improving overall safety and reliability.

Chapter 2 - Overview of Safety Management System Model and Methodology

Introduction

The study presented here was part of a major European funded project in human factors in Aircraft Dispatch and Maintenance Safety (ADAMS). The ADAMS project was a three-year basic research project funded by the EU Fourth Framework RTD programme Brite-EuRam II. The project consortium comprised of four European aircraft maintenance organisations, three research institutes, and one university.

The overall goal of the project was to address in a comprehensive manner the human factors aspects of safety in aircraft maintenance in order to provide the basis for the development of new initiatives in the area of human factors guidelines, training, incident and accident investigation and analysis, and safety management systems. The project's work programme can be summarised under the following headings:

Accident And Incident Data

The aim of this strand of research was to provide a detailed understanding of the extent, nature and causes of errors in aircraft maintenance and dispatch. There were two distinct objectives: (i) investigation of the requirements for an error tool with a sound theoretical basis, which allows practical understanding of human error in maintenance and which could be usable by the maintenance organisations in the ADAMS consortium; (ii) generation of recommendations and strategies for error reduction.

Technology

The overall aim of the technology strand was to accomplish a study of all the information support systems available to support the aircraft maintenance engineer in completing his task. One objective of the study was to examine the feasibility of integrating current and future data management systems used in the area of aircraft maintenance and dispatch into an integrated information management system (IIMS).

Procedures And Operational Requirements

There were two key objectives to this strand of the project: (i) systematically assess the range of human factors issues in maintenance organisations which could be impediments to safe and effective production; (ii) further assess the issue of non-conformance with task procedures in aircraft maintenance.

Organisational And Management Systems

The overall aim of the organisational strand was to further explore human factor issues in managing safety in aircraft maintenance. The objective was to develop a model of a safety management system incorporating the notion of safety culture.

The study reported here focused on the findings from the organisational and management strand and from selected findings from the procedural and operational strand of the ADAMS project.

This chapter focuses on the first two objectives of the thesis:

- Development of a model focusing on the organisational aspects of safety management and culture in aircraft maintenance.
- Development of a set of methodologies to explore the elements of the model.

This chapter introduces the Safety Management System Model, which includes a schematic presentation of the model and a descriptive overview of each element of the model. The overall design of the study is explained and the range of methodologies developed and applied in the study is also put forward.

Overview of Safety Management System Model

In order to begin to explore the relationship between a safety management system and safety culture, a preliminary hybrid model was developed drawing both from the analysis of safety culture of Pidgeon & O'Leary (1994), and also from the rather more pragmatic and managerial focus of the Health and Safety Executive's 'Successful Health and Safety Management' (Health and Safety Executive, 1991[1]). The Pidgeon and O 'Leary model was primarily based upon Turner's *man-made disasters* and the

[1] Now recognised as HS (G) 65 'Successful Health and Safety Management', 1997. Also forms the basis for chapter 4 COMAH SRAM regulations (Control of Major Accident Hazards)

high reliability organisational theory, while the 'Successful Health and Safety Management' model was largely a practical guide, both well grounded in the safety management literature, and which has been influential on some aviation regulatory activities (e.g., UK CAA's CAP642).

The Health and Safety Executive (HSE, 1991) analysis focuses on five organisational functions, which are essential to effective safety management. These are:

- Policy: its development and implementation.
- Organisation: the development of the organisation to sustain effective communications, the promotion of competence at all levels and leadership to maintain a common culture supportive of health and safety.
- Planning to minimise risks and setting performance standards.
- Measuring performance.
- Auditing and reviewing performance: all aspects of the organisational safety system are subject to audit and auditing and review activities provide feedback to all levels of the system.

Pidgeon and O'Leary (1994) define safety culture as "the set of beliefs, norms, attitudes, roles and social and technical practices within an organisation which are concerned with minimising the exposure of individuals both within and outside an organisation to conditions which are considered to be dangerous". In this analysis the characteristics of a good safety culture are proposed as:

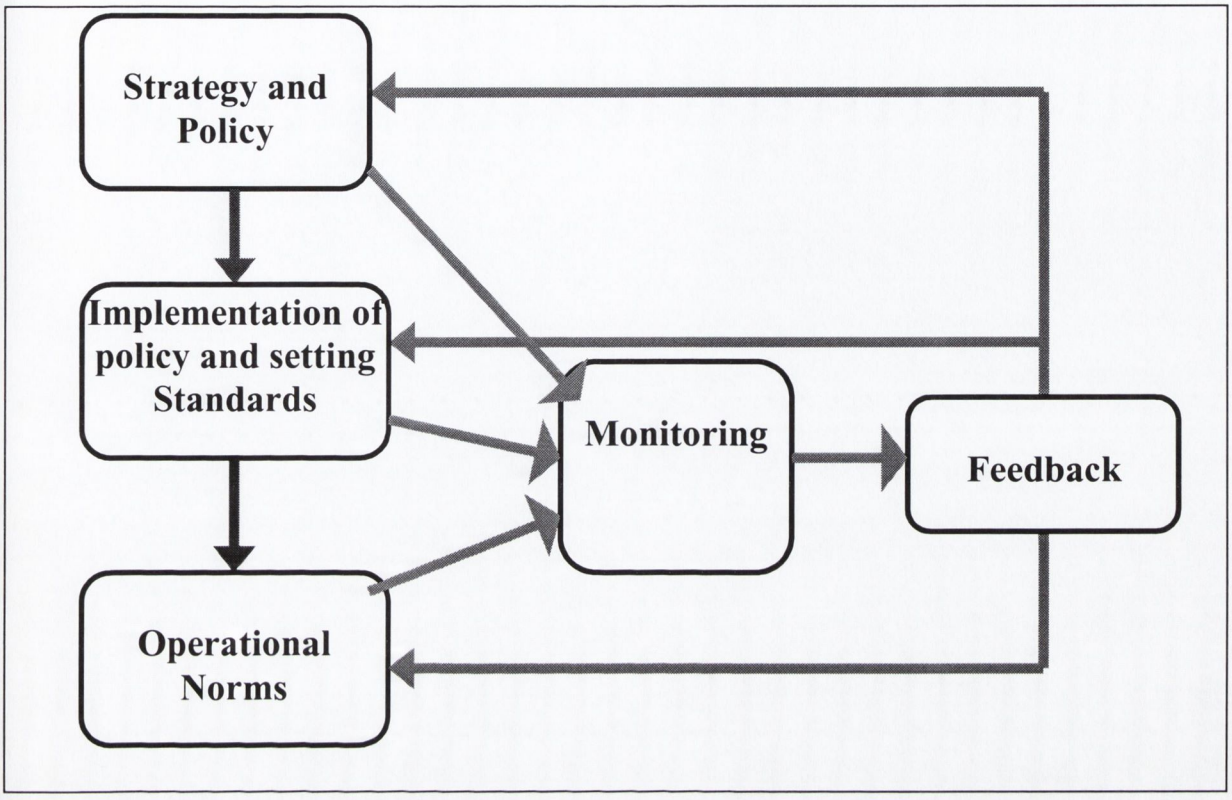
- Senior management commitment to safety.
- Attitudes of shared care and concern for hazards throughout all levels of an organisation.
- Norms and rules that permits a flexible approach to dealing with both well-defined and ill-defined hazardous conditions.
- Reflection on practice (or organisational learning) through such things as monitoring, incident analysis and feedback systems.

A difficulty in this analysis arises from broad theoretical definitions. Pidgeon and O'Leary's definition of culture is in terms of 'systems of meaning'. This leads them to emphasise that one major drawback to their characterisation of safety culture is that a clear link to risk and safety management practice does not become immediately visible.

On the other hand, they also state that some understanding of existing cultures must be gained before risk and safety management efforts, such as new training, reporting systems, procedural frameworks and resource management programmes, are designed and initiated. In drawing these conclusions, Pidgeon and O'Leary make a distinction between "safety culture" on the one hand and "risk management practices" on the other, although "social and technical practices" are explicitly included in their definition of safety culture. This raises some of the issues concerning the definitions and boundaries of culture discussed by Martin (1992). If there is an apparent conflict here, part of the problem may be due to vagueness in the definition of culture and part may reflect different measures and methods for studying cultural phenomena. On the face of it there appears to be considerable overlap between the two approaches of the HSE and Pidgeon and O Leary although the language and theoretical background are divergent. This overlap encouraged the proposal of a composite model, which sought to encompass the main elements of both.

The model proposed at the initiation of this research consisted of five fundamental elements: strategy and policy; implementation of policy and setting standards; operational norms; monitoring; and feedback. The model is outlined in Figure 2

Figure 2. Safety Management System Model Overview.



The model is quite hierarchical in nature in that the first process is concerned with how safety is represented and perceived as an organisation's overall goal and what is the organisational strategy for achieving its safety goal. This should feed into the next level, which is concerned on how the strategy and policy is translated and implemented into the organisation of work and how effective the overall implementation is when compared to safety standards. The overall goals of strategy and policy and their implementation should also guide what actually happens in practice. For the purposes of this study one particular aspect of operational norms was assessed, in particular the level of non-compliance with aircraft maintenance manual procedures, as evidence has implicated that non-conformance of procedures is relatively wide-spread not only in aviation but across all domains. The objective of a monitoring function in any organisation is to review the effectiveness of current policy and practice at all the different levels within the organisation and effectively feedback outcomes in order to initiate change and improvement as required. Therefore monitoring and feedback should play a pivotal role in both maintaining and improving a self-regulatory safety

management system. The following section provides a descriptive overview on each of the five elements of the model.

Safety Policy and Strategy

Pidgeon and O'Leary's emphasis on location of responsibility for safety at a strategic management level suggested that a strong emphasis should be put on how safety features in the strategic priorities of senior management and how this priority is manifest in policy.

Organisations with a strong safety culture enjoy a close fit between the formal statements and practices and what actually happen in practice (Waring, 1996). Many organisations proclaim in their safety policy and mission statements that 'safety is the first priority'. However the manifest level of their culture often tells a different story.

The first necessary condition for the development of a safety culture is that responsibility for safety should not only reside at a purely operational level, but be an issue at strategic management level also. Safety should be managed like any other company function with clearly articulated policies that influence their activities and decisions, including for example, safety goals (both occupational and operational); policies to do with the allocation of resources, dissemination of information, compliance with regulatory requirements and the design and operation of working systems.

Implementation of policy and setting standards

The model was also concerned to establish how such policy priorities are implemented in practice and in particular, where it would be possible to identify standards against which the successful implementation of policy could be judged.

The practical realities of implementing safety policy highlight the iterative links between organising, planning, resourcing, implementing, monitoring and reviewing. In addition the overall business policy, goals and strategies will also have implication for the safety management system.

Once the policies and strategies are established the policy objectives need to be implemented throughout the organisation. The implementation of strategy and policy

involves, for example the development of the organisational infrastructure, programmes of work, organisational procedures, training and human resource programmes.

Safety performance may also be measured against pre-determined standards. Various standards have been drawn up for management systems (e.g., ISO 9000 series for quality management systems, BS8750 Guide to Occupational Health and Safety Management) with the objective of seeking to achieve success through continuous improvement based primarily on the Deming problem solving principles. Adequate standards should reveal when and where action is needed to improve performance based on a variety of indicators of safety performance, which lead to the identification of standards, which are the subject of monitoring.

Operational Norms

Pidgeon and O'Leary's focus on appropriate norms and rules for handling hazards suggested that it would be important to seek to record or measure important aspects of behaviour, what happens in practice, and to compare this with the rules and prescriptive norms of work. This concern was particularly motivated by the evidence implicating failure to follow procedures as contributory factors in incident and accident occurrence and measures of the normative level of procedure violations, for example in aviation maintenance: Wooton (1998), Kanki et al., (1998), Daly, Corrigan, McDonald (1997); in other areas of aviation: McDonald et al., (1994), Lautman and Gallimore (1988); in the nuclear industry: Bourrier, (1997), Marsden, (1996); in the rail transport industry, Lawton (1998) and in the petrochemical industry, Embrey (1998). Accident reports also suggest that violations of procedures are relatively widespread, and are not being identified and/or rectified under present systems.

Therefore the objective of this element was to identify the extent of deviations from official maintenance manual procedures and also to assess the adequacy of the technology (most notably CD-ROM and Microfilm Reader Printers) in supporting procedure compliance.

Monitoring

Both Pidgeon and O'Leary and the HSE model prioritised, in different terms, processes of monitoring, review and reflection. Therefore monitoring and feedback were included

as components of the model. All levels of the organisation are potentially subject to monitoring from the level of policy and it's implementation through to the procedures and behavioural norms of operational practice.

Strategy and policy should drive the monitoring and review functions, the outcomes of which should be fed back into the overall strategy and policy. Mintzberg argues that strategy takes two forms, which operate at the same time, a deliberate plan and emergent action over time. In other words, strategy is not only what management says should happen but also what is actually happening. As various studies have shown (e.g., Johnson, 1987; Waring, 1993), strategy in action does not remain static but migrates as a result of changes in context. Whereas strategy is often assumed to be an expression of rational decision-making and a stable embodiment of intended action, in practice strategy is ambiguous and dynamic. It should be expected therefore that safety strategy on the ground will gradually drift away from what the official policy and/or strategy documents state.

The monitoring function should continually extract information from the overall effectiveness of policy implementation and the pre-determined standards and also from what actually happens in practice. This information is obtained for example from internal and external audits, quality investigation reports, incident reports, and analysis of trends in incident and quality indicators. Learning from all the relevant information obtained and from experience and actively applying the lessons learned should be important elements in an effective safety management system.

Review and Feedback

In reviewing the overall safety management system, the organisation needs to address the key safety components and their interrelationships. The monitoring function can initiate a feedback and review loop needed to enable the organisation to maintain and develop policy goals. Effective feedback can be described as a vehicle to facilitate organisational learning. For example Turner and Toft (1988) discuss requirements for organisational learning from disasters as: (i) investigation; (ii) techniques for deriving lessons; and (iii) effective information transfer. The last of these is not only appropriate after a major accident or incident, but is desirable as an inherent system characteristic. Effective feedback should influence all levels of the system from strategy and policy,

the mechanisms for the implementation of policy and setting standards to the behavioural norms of the operation.

Finally, Pidgeon and O'Leary's criterion of distributed attitudes of care and concern throughout an organisation was thought to be best represented in measures of safety attitudes and climate at all appropriate levels of the organisation. Thus, it is not distinguished as a separate component of the model.

Overall the model is primarily a descriptive or empirical model, which attempts to systematically describe and compare safety management systems and culture across aircraft maintenance organisations. It is defined in terms of those explicit organisational processes, which have an impact on safety. The model was kept conceptually simple in order to facilitate mapping onto diverse organisations. While the framework adopted is applicable to all aspects of safety, a particular emphasis was placed on how the human and organisational aspects of safety were managed.

Design of Study

Following the development of the model, a set of methodologies was developed in order to assess each element of the model. Table 5 provides an overview of the set of assessment methodologies applied to each element of the model. Four different surveys were developed and administered as part of this study, including a survey of procedure compliance, a survey of safety attitudes and safety climate, and a survey assessing the perceived consequences of incident involvement. A management interview schedule was developed and conducted as well a number of supplementary interviews with other personnel in the maintenance domain. A number of general observations, analysis of documentation and ergonomic assessments were also conducted.

Table 5. Methodologies applied to each element of the model

Methodologies	*Analysis of Documentation*	*Interview*	*Survey*	*Observation/ Ergonomic Ass.*
Strategy and Policy	√	√	√	
Implementing policy	√	√	√	√
Operational Norms	√	√	√	√
Monitoring	√	√	√	√
Feedback		√	√	

The model and the methodologies empirically assessed and compared safety management systems and culture across four European aircraft maintenance organisations. For the purposes of confidentiality each of the four organisations have been de-identified and are referred throughout this report as Company A, Company B, Company C and Company D.

Each of the organisations was part of the ADAMS project consortium and they were representative of the aircraft maintenance industry in Europe. Geographically they were quite dispersed (e.g., Northern, Central and Western Europe). At the time of the research two of the organisations were wholly owned maintenance subsidiaries of two European airlines (Company B and D) and two were the maintenance engineering divisions of European airlines (Company A and C). Both line and overhaul maintenance were represented in Companies B and D. However, due to access restrictions in Companies A and C line maintenance activities were not systematically analysed. Each of the organisations was going through various stages of change and development at the time of the research.

Four different site visits were organised across each of the organisations at various stages of the research. As far as it was possible, similar population samples, company documentation, and research procedures were applied across the organisations in order to ensure an effective comparison.

Site Visit 1 – Exploratory Study

An initial three-day visit was organised to each of the organisations as an exploratory study. The primary focus of this study was on the assessment of key company documentation as a starting point in outlining the key structural features of each organisation and the roles and responsibilities of each key manager and their departments.

Site Visit 2 – Administration of Survey and Ergonomic Assessment

Following the exploratory study a survey assessing maintenance manual procedure compliance and an ergonomic assessment of supporting technology was developed. Between five and seven days were spent in each of the organisations administering the survey, observing the various task support mechanisms and the aircraft engineers at work.

Site Visit 3 – Management Interviews and Administration of Survey

A management interview schedule was developed from a review of the literature and from information gleaned from the first two site visits. The schedule was structured around the five elements of the model. Key managers across each of the four organisations were interviewed. A parallel activity involved the adaptation of safety attitude and safety climate scales and the development of a survey assessing perceived consequences of incident involvement. Between 7 and 10 days were spent in each of the organisations conducting management interviews, administering surveys and conducting general observations.

Following the collection and analysis of all the information across all the different methods, the safety management system model was revised and a fourth site visit was arranged in order to further explore the revised elements of the model.

Site Visit 4 – Case Studies

The revised elements of the model were further explored and compared as case studies across two of the four organisations. Seven days were spent in each organisation conducting interviews, analysing documentation and conducting general observations.

For the purposes of reporting the findings, the management interviews and documentation examination were analysed together as the overall organisational descriptions (Chapter 3). The survey of procedure compliance and the ergonomic assessment were analysed together as a reflection of normal operational practice (Chapter 4); and the survey of safety attitudes, safety climate and incident consequences were analysed together as a quantitative measure of the safety culture of each organisation (Chapter 5). The final three chapters focus on the implications of the findings, key issues and problems in effectively managing safety and the revised safety management model (Chapter 6); the further analysis of the revised elements of the model (Chapter 7); and the overall conclusions on the utility of the model, the methodologies, the role of human factor orientated policies in addressing safety management shortcomings and future developments are put forward in the final chapter (Chapter 8).

Methodology Development

The model identified a number of key elements for a safety management system cultural framework. Bearing in mind the diversity of the notion of safety culture a number of levels of analysis were undertaken in order to systematically address the different aspects of the maintenance organisation.

All elements of the model were addressed through the analysis of the official documentation and from information elicited from the management interviews. A safety incident survey addressed the perceived consequences of incident involvement, which is a key issue in the co-ordination, and management of information about critical incidents and overall monitoring. The safety incident survey also quantified the perceived modalities of feedback about safety incidents (two versions of this survey were used, one where the scenarios led to a serious flight incident, and one that did not).

A particular aspect of operational norms was directly addressed in a procedural and operational survey and ergonomic assessment on CD-ROM and Microfilm Reader Printers. Finally a survey of safety attitudes and climate provided quantification of perceptions of the overall safety management system across all five elements.

Analysis of Company Documentation

An analysis of company documentation was the starting point in outlining the key features of each organisation's safety management system. The primary objective of reviewing company and regulatory documentation was to obtain an overview of the formal procedures, roles, responsibilities and overall structures of each of the organisations.

Exploratory visits to each of the organisations were undertaken in order to identify and assess key organisational documentation. The starting point in each of the organisations was their 'Maintenance Exposition Document'. The 'Maintenance Exposition Document' (MOE) is compiled in compliance with the regulations of the European Joint Aviation Authorities governing maintenance organisations (JAR 145). For example the document contains information on the following aspects:

- Organisational charts
- Management Procedures (e.g., corporate commitment by the accountable manager, manpower resources, duties and responsibilities of management personnel
- General descriptions of facilities
- Quality System Procedures (e.g., certifying staff records, duties of audit personnel and inspectors etc)
- Line Maintenance Procedures (e.g., control of aircraft components, completion of the technical log, servicing/fuelling/de-icing etc)
- Aircraft Overhaul procedures (acceptance of tools and equipment, release to service procedure, cleanliness standards of maintenance facilities etc).

The information from the MOE allowed for a formal overview of each of the organisations. Based on this information other key documents were identified and reviewed including:

- Safety Policy and Objectives Statements
- Health and Safety Legislation
- Aircraft Maintenance Manuals
- Engineering Manuals
- Quality Reports
- Incident Investigation Reports
- Documentation on current human factor initiatives and proposed new change programmes.

In each of the four organisations a supplementary interview was also conducted with a quality manager with the objective of clarifying any queries, responding to questions and providing additional information on the organisation's procedures, policies and structures. In addition to obtaining an overview of each of the organisations, the documentation analysis was also valuable in developing the management interview schedule and planning the research activities (e.g., research interviews, observational studies and survey administration).

Management interviews

The primary objective of conducting management interviews in each of the organisations was to obtain a more in-depth insight into the key functions, procedures, and roles in a safety management system, and to establish what role, if any, human factors play in their safety systems.

A semi-structured interview schedule was developed (see Appendix 1) focusing on the different elements outlined in the model. This interview schedule was developed from a review of the relevant literature and from information from the initial visits to each of the organisations. The following aspects were covered in the interview:

- Safety policy and strategy
- Flow of safety information

- Quality systems
- Auditing
- Reporting and investigation systems
- Human factors
- Incident Management
- Management training
- Relationship with external agencies.

Key management were identified from the documentation analysis and the researcher was given the authorisation within each of the organisations to contact key managers to request their participation in the interview. Each of the managers was briefed on the project objectives prior to the researcher contacting them by one of the ADAMS project representatives within the organisation. A total of 33 individual semi-structured interviews (approximately lasting between 1 and 1.5 hours each) were conducted with a cross section of management (that were directly responsible for production) across the four organisations. Table 6 outlines the personnel and the number interviewed across the 4 organisations.

Table 6. Number of Personnel interviewed across the 4 organisations

	A	B	C	D
Chief Executive		1		1
Line Maintenance Manager		1		1
Aircraft Overhaul Manager	1	1	2	2
Training Department			1	1
Quality Department	2	3	1	2
Shift Manager	2	2	2	2
Senior Technical Managers	1	1	1	
Human Factors Department	2			
Total	8	9	7	9

Some personnel (e.g., chief executive, human factors personnel) were not interviewed across all of the organisations. This was due to a number of factors, including lack of availability and operational demands at the time of interview and no clear specified role

(e.g., human factors personnel). However it was felt that this lack of strict comparability would not cause problems in the analysis as a range of key personnel representative of operational management were included from each of the four organisations.

At the beginning of each interview the participants were briefed on the objectives of the research and the aims of the management interviews. Interviewees were also assured that their views would be completely confidential and non-attributable and that they would each receive a draft synopsis of the interview for their comments/confirmation.

Safety Attitude, Safety Climate and Incident Survey

In parallel with the management interviews a safety attitude and safety climate survey along with a survey assessing perceived consequences of incident involvement was administered across the four organisations as one overall survey. Describing and comparing the key functions of safety systems cannot provide all the necessary information to evaluate safety systems or the underlying culture. The perceptions and attributions, which members of the organisation have of organisational practices, also have a strong influence on safety as well as the practices themselves. These perceptions may not reflect objective and precise descriptions of the organisational environment, they are rather how employees (including managers) interpret and assign meaning to organisational characteristics, giving as a result a 'collective schema of meaning' or a 'collective attitude' (Poole & McPhee, 1983). In addition the determination of safety climate has been put forward by some authors as an alternative indicator to safety performance compared to the more retrospective analysis of accidents and incidents. The inclusion of the incident survey provided a quantitative assessment of the overall incident management system in each of the organisations that complemented the relevant aspects of the management interviews.

Safety Attitude and Safety Climate

Perceptions of safety attitudes and safety climate were measured by two separate scales and administered as one survey. The survey was adapted from scales developed by Cabrera et al., (1997) measuring safety attitudes and climate in ground handling organisations.

The initial version of the safety attitude scale included 39 items on a 1-5-response scale (absolutely agree – absolutely disagree). The attitude indicators were taken from two sources: (i) content analysis of relevant literature on the subject; (ii) statements resulting from a brain storming session involving ground handling and ramp personnel. The initial version of the safety climate survey included 45 items across 5 dimensions, *with* a 2-point response (agree –disagree) in order to evaluate the participant's agreement with each item. The 5 dimensions included:

- Strategy/Company policy towards safety matters; budget, information channel, importance of training, evaluation of performance etc.
- Company global philosophy; emphasis on productivity versus safety.
- Individual/group attitude: significance perceived, compliance with safety standards, levels of co-operation within groups etc.
- Safety attitude and behaviour perceived in supervisors/management.
- Level of risk and safety perceived.

In the development of the original safety attitude and climate scales, a pilot study of 60 participants from three-airport ground handling companies from Tenerife South airport was carried out (see Cabrera et al., 1997). Once the results from the reliability analysis and the item frequency distribution study of both the attitude and climate scales were obtained, the items in a low correlation with the scale total, as well as those with a non-normal distribution were deleted (cf. Tabachnik & Fidell, 1989). In relation to the attitude scale, six items had both low correlation and inadequate distribution, while five items was omitted due to inadequate distribution. In relation to the climate scale, five items were eliminated due to low reliability.

The internal consistency of the attitude scale reached a Conbach's Alpha value of 0.87. It included 29 items, 11 of which were positive and 18 of which were negative. The internal consistency of the safety climate scale reached a Conbach's Alpha value of 0.90. It included 40 items, 25 of which were positive and 15 of which were negative (Cabrera et al., 1997).

This scale was adapted for this study. Items for the adapted scale were selected using a two-step process. Firstly, a Factor Analysis (via principal components analysis with

varimax rotation of factors) was conducted on a sample (n=1304) of ground operations personnel as part of the SCARF□ project. Secondly the number of items in each factor was reduced. This was carried out by eliminating items that showed one or more of the following characteristics:

- Were not applicable to the maintenance environment
- Had a high number of missing values
- Produced particularly skewed or homogeneous responses
- Had a low loading on the factor
- Had considerable semantic overlap with other items in a factor.

In total 16 items from the original safety attitude scale were retained (including the statement – 'how difficult is it for you to understand this questionnaire') and 20 items from the safety climate scale were retained. Some adaptation of terminology across some of the items was necessary as the sample in this study was from aircraft maintenance as opposed to aircraft ground handling.

The Safety Attitude & Climate Safety Survey used in this study consisted of 4 main sections.

Section 1 – Objectives of the study

The first section provided a brief description of the objectives of the study, and instructions on how to complete the survey. The fact that the survey was completely confidential and that access to the completed questionnaires would be restricted to the researcher was also highlighted.

Section 2 – Background details

Participants were asked for a number of background details including time in the company, time in current job, level of education/training to date, job title, usual place of work and present job situation. Participants were also asked for some form of identification (i.e., staff/employee/roll number) as it was planned to administer the survey to the same people at a later date so that changes (if any) in the safety climate and attitudes could be measured. Requesting some form of identification did not cause

[1] SCARF – Safety Courses for Aircraft Ramp Functions – COMETT Programme, 1994-1997

any major problems across any of the organisations in relation to this particular survey. Inevitably a number of the participants decided not to give any form of identification, as they preferred to remain anonymous but were still willing to participate in the survey.

Section 3 - Safety Attitudes

This section contained sixteen statements measuring the participants attitude to safety. The respondents were required to respond on a 5-point scale ranging from Absolutely Agree to Absolutely Disagree. Examples of some of the statements included;

1. I think that reporting accidents and incidents is a better way of preventing them.
2. Those colleagues, who ignore safety procedures and standards, make me angry.

Section 4 – Safety Climate

This section contained twenty statements measuring perceptions of organisational safety climate. The respondents were required to indicate whether they agreed or disagreed with the statement. Examples of some of the statements included;

1. My Company regularly reminds the workforce about safety standards.
2. My co-workers respect safety standards and procedures.

Incident Survey

A survey assessing the perceived consequences of incident involvement and reporting was developed specifically for this study. The safety incident survey addressed the perceived consequences of incident involvement, which is a key issue in the co-ordination, and management of information about critical incidents and overall monitoring. The safety incident survey also quantified the perceived modalities of feedback about safety incidents (two versions of this survey were used, one where the scenarios led to a serious flight incident, and one that did not). This incident survey was attached to and administered with the Safety Attitude and Safety Climate Survey. Four brief incident scenarios were developed. One incident was taken from each of the four organisations and summarised by the researcher. Aircraft engineers (n= 8) validated the incident scenarios across the four organisations for their applicability and technical accuracy prior to their inclusion in the survey.

incident scenarios across the four organisations for their applicability and technical accuracy prior to their inclusion in the survey.

There were two versions of the incident scenarios. In one version the scenarios led to a reported flight incident, which could have led to the loss of the aircraft or the death of those on board; in the other version they did not lead to a flight incident. Including both these outcomes measured the degree of information dissemination and the organisation's actions in response to two conditions (i) the situation where the incident resulted in serious consequences and (ii) the situation where the incident did not result in any serious consequences. Both these versions were equally distributed throughout the samples in each of the organisations and participants were required to indicate their response from a range of possible answers.

The overall survey (safety attitude, climate and incident scenarios) took between 10 and 15 minutes to complete.

Overall Procedure

The sampling strategy involved identifying key areas in each of the organisations that played a role in the operational activities. The identification of the sample involved the analysis of company documentation and guidance from company personnel. The key areas identified included all operational staff, management and three primary areas of support: Quality; Planning; and Engineering. While all of the organisations had a health and safety infrastructure (safety reps and safety committees), this was a secondary aspect to their task whether they were in the personnel department or a technician at the production level. In the domain of aircraft maintenance there is a clear distinction made between safety airworthiness of the aircraft and operations and health and safety issues. The objective of the research was not to think of safety in terms of protective gear, personal injury, work procedures etc. Rather than focusing on health and safety issues, the objective of the research was to assess how overall safety operations were managed.

A number of steps were taken in order to ensure no bias in the sampling strategy: (i) researchers and key contact personnel in each organisation agreed on the most effective sampling strategy; (ii) the sample had to include a range of operational personnel across

different shifts and different areas of work (e.g., hangar 1, hangar 4, Line Maintenance); (iii) the sample had to include a range of management and support personnel across different areas of work; (iv) completed surveys were checked against sampling plan for each organisation to ensure a representative sample across the key areas.

The administration of the survey differed in each of the organisations.
In Company B and company D the researcher spent 2 to 3 days administering the survey throughout the organisation. Participants were recruited through two methods; (i) the researcher approached members of staff directly, outlined study aims and asked for their participation; (ii) the researcher telephoned members of staff, outlined study aims and asked for their participation. In almost all of the cases the researchers were available to respond to queries and questions regarding the survey.

In Company A one of their own personnel took responsibility for administering the survey. This involved approaching a contact person from the various Fleets, workshops and the Quality Department. Each person was briefed on the survey and asked to distribute and collect the surveys and to return them in the envelope to the Human Factors Co-ordinator. The managers in the organisations were contacted directly and the surveys were forwarded to them. The Human Factors Co-ordinator forwarded the completed survey to TCD.

In Company C the researcher briefed a contact person in each of the relevant areas outlined above. They were then asked if they would take responsibility for distributing and collecting the surveys and returning them to the Director of Administration who then forwarded them on to TCD. Everyone that was approached agreed to participate in the administration of the survey.

Survey Participants

The survey was administered across the four organisations and amongst four main groups of personnel; operational personnel (apprentices, aircraft technicians, certifying technicians), management with direct responsibility for production (from shift manager to the Chief Executive Level), quality personnel (auditors, inspectors, investigators, quality Managers,) and planning functions (planning, technical support). A total of 800

questionnaires were distributed across the four maintenance organisations and 669 surveys were completed and returned, this represented a response rate of 84%. In total 230 questionnaires were completed in Company A, 141 in Company B, 76 in Company C and 222 in Company D.

See Appendix 2 for Safety Attitude, Safety Climate and Incident Management Survey.

Survey of Compliance with Task Procedure

This thesis also provides an overview of some of the key findings of a study carried out as part of the ADAMS project - "Tasks Procedures in Aircraft Maintenance" (Daly, Corrigan & McDonald, 1997). A survey was developed as part of this study with the following objectives:

- Identify the extent to which deviations from official maintenance manual procedures occur.
- Identify the most common factors underlying these violations.
- Compare organisations to establish whether or not differences in organisational practice underlie differences in the way in which task cards are used.

The survey was developed from preliminary observational studies across the four organisations and piloted with a group of four aircraft engineers across two of the organisations (A and B). The final version of the survey was divided into 4 main sections.

Section 1 - Background information

Participants were asked for a number of background details. The background information included certification level, years of experience, job card number (from last job completed) and MM reference number. The job card number was required, as it would facilitate the retrieval of a copy of the card from the computer record system at a later date if it were felt that having the actual card would aid later analysis. The MM reference was also sought so that the manual could be queried at a later date.

Section 2 – Specific Task Information

In this section participants were asked a number of questions relating to the task they had just completed. These questions included, the source of their task card, assessment of the difficulty of the task and the quality of task support information (e.g., clarity of the task instruction, availability of the Maintenance Manual).

Section 3 – Consulting the Maintenance Manual

Section 3 dealt with whether the MM was actually consulted (regardless of whether it was followed). It was felt that consultation of the MM would promote conformance with the MM method, whereas performance of the task from memory, unavailability of the MM or other factors highlighted in the questionnaire might promote violations. This section also dealt with, regardless of consultation of the MM, whether the method was followed. Thirteen items attempted to establish, in the case of non-conformance, the reason(s) behind the reported violations.

Section 4 – Quality of Documentation Support

The final section focused on the quality of documentation support. It was hypothesised that perceptions of documentation support as inadequate would promote violations, so questions were asked as to what sources were used if any, and what the perceived quality was, e.g. too much detail. The final two parts were reserved for open comment on documentation and other aspects of the maintenance task respectively.

The survey took approximately 15 minutes to complete.

Procedure

The surveys were collected over the course of weeklong visits to each of the aircraft maintenance facilities (except in the case of Company B where a number of one day visits were carried out). The sampling strategy involved identifying key tasks across all shifts and across both line and hangar maintenance. The researchers and the relevant shift managers identified key tasks and the relevant personnel. The researchers administered the survey to a sample of aircraft engineers as they finished a task (e.g., either returning from the aircraft after a task like a push back or as they returned a card to the rack). The researcher was on hand to help with any problems and answer any queries in relation to the survey.

Participants

The survey was administered to aircraft technicians across the 4 organisations. A total of 286 surveys were completed.

See Appendix 3 for Procedure Compliance Survey.

Ergonomic Assessment (CD-ROM and Microfilm Reader Printer)

Based on current regulations and guidelines for standard and non-standard environments (Health and Safety - Display Screen Equipment, 1993), an ergonomic checklist was developed to assess the usability (i.e., efficiency, effectiveness, comfort etc.) of the CD-ROM and the reader printers. This complemented the later sections of the procedure survey that dealt with the quality of manuals and suggestions for improvements.

Procedure and Participants

A total of 12 aircraft engineers were observed carrying out maintenance tasks across the four organisations.

The researcher observed a total of 12 aircraft engineers (3 in each organisation) as they used the microfilm reader printer and/or CD-ROM while carrying out a task. This was then supplemented by a brief 10-minute interview where the researcher addressed any issues that arose during the observation. In all cases the supplementary interviews were conducted when the aircraft engineers had completed their tasks.

The location for the ergonomic assessment was based on the following criteria;

- Availability and access to both microfilm reader printers and CD-ROM
- Relatively busy location with a high degree of use of both technologies
- Similar location across organisations (e.g., hangar size, manpower levels)
- Unobtrusive means of observation
- Availability of aircraft engineers for short interview with the researcher.

For the observational study one location was chosen in each of the four organisations. In companies B and D observation studies were carried out on both the line and in one of the hangars. In companies A and C the observation focused on one hangar in each of the organisations. The observation and assessments lasted approximately 4/5 hours in each of the organisations. Each observation commenced half way through a shift and followed the shift until it finished.

See Appendix 4 for Ergonomic Checklist.

Observational Study

Throughout all of the site visits in each of the four organisations the researcher conducted general observations and walk-a-rounds in the various operational areas. Re-occurring issues that were emerging from the analysis of company documentation and the management interviews set the criteria for the observations. These observations were supplemented by a number of informal interviews primarily with operational staff (e.g., aircraft engineers, supervisors, apprentice etc) that further explored problem areas.

Overall Summary

A model was proposed which sought to integrate the main features of a safety management system, developed as a practical guide for management (HSE, 1991) and the main components of safety culture as outlined by Pidgeon and O'Leary (1994). The model consisted of five key elements; strategy and policy, implementation of policy and setting standards, operational norms, monitoring and feedback.

The five elements of the safety management system model were evaluated with a range of methodologies across four European aircraft maintenance organisations. The methodologies included analysis of company documentation, qualitative interviews, surveys of safety climate, safety attitudes, expected response to incidents, compliance with task procedures and an ergonomic based assessment of task support technology.

Analysis of company documentation was the starting point in providing an overview of each organisation, their management structure and key operational departments. The objective of the survey of procedure compliance and the ergonomic assessment was to

provide both a quantitative and qualitative estimation of the extent of procedure non-compliance and the utility of supporting technologies. The primary objective of the management interviews was to allow for a more in-depth insight into the way safety and human factors was managed within each organisation. Finally the survey on safety attitudes, climate and incident consequences provided a quantitative assessment of the organisation's perceptions on the effectiveness of their overall safety management system. All the findings and conclusions derived from the different methodologies were reviewed by each of the participating organisations. Summary documents outlining the key findings of each aspect of the study were forwarded to key personnel in each of the organisations, who recognised and confirmed the observations and interpretations offered.

Chapter 3 - Managing Safety; organisational descriptions

Introduction

The third objective of the thesis was to use the model and the methodologies as a framework to systematically compare safety management and culture across four aircraft maintenance organisations. Based on the analysis of the management interviews, company documentation and general observation this chapter provides a descriptive overview of each of the four organisations based on the key elements of the model: strategy and policy; implementation of policy and setting standards; operational norms; monitoring; and feed-back. Comparing and differentiating between different organisations' safety management systems should also enable an evaluation of the strengths and weaknesses of different real operational systems, thereby identifying theoretical and practical implications for current safety management practices. The overall objective of this chapter was to report on each of the four organisations and describe how safety is managed and what role human factor policies have on the overall strategy and actual operation of each organisation.

The management interviews, documentation analysis and general observations looked at three primary issues in relation to strategy and policy: (i) how is safety represented and perceived as an organisational goal? (ii) what is the organisational strategy for achieving its safety goal? (iii) what is the role of human factor initiatives in achieving overall safety policy goals?

The next levels of analysis focused on issues in each organisation that impacted the effective implementation of policy and setting standards and how these issues translated into normal operational practice. This analysis also looked at three primary issues: (i) what supporting mechanisms did the organisation adopt or were planning to adopt to realise their safety goals? (ii) what organisational issues impinged on effective implementation? (iii) do the organisations maintain coherent and adequate set of measures or standards of performance?

The Survey of Procedure Compliance and an Ergonomic Assessment of CD-ROM and Microfilm Reader Printers assessed the level of normal operational practice in the

model. The results of this analysis can be found in Chapter 4. Three key issues were addressed in relation to the overall monitoring and feedback systems in each organisation: (i) what monitoring functions are in place? (ii) how effective are they? (ii) do the outcomes feed back into key functions within the organisation and what are the feedback mechanisms and how effective are they?

A number of important differences emerged between the four organisations particularly in relation to their expressed commitment to safety; commitment to management training; commitment to human factor policies; effective quality reporting systems; quality audits; incident and accident investigations; dissemination of information; disciplinary action and relationships with their regulatory bodies. A number of similarities also emerged between the four organisations, most notably: compliance with JAR 145 as a major focus of safety policy; no system for routinely feeding back non-technical information; huge backlog of a range of quality reports with little or no follow up; the relationship between disciplinary actions and the reporting culture were not fully articulated and/or not fully understood by the organisations.

In the following four sections each of the organisation's safety management systems are described under each heading of the model. As indicated earlier for reasons of confidentiality the companies are de-identified and are referred to throughout as companies A, B, C and D.

Description of Company A

Background Information

At the time of this research Company A was a world-leading aviation maintenance organisation providing full technical and engineering support for their airline's aircraft fleets and for the aircraft of a number of customer airlines. The organisation employed approximately 9000 staff over 100 locations around the world. The company's core capabilities were centred on Boeing 737, 747, 757, 767, 777, and the Airbus A320. Company A had many years of experience within the component repair overhaul business and line maintenance operations. At the time of research the organisation was halfway through a major organisational change initiative.

Strategy and Policy

Compliance and Operational Safety

Company A like all organisations in the aviation industry existed in a regulatory environment that required compliance and could exert pressure to ensure compliance. This compliance with safety requirements set by regulatory bodies was a major area of concern in addressing safety policy and strategy. Strategy and policy were driven by a number of prevalent factors within the company. Firstly there was confidence at all levels in the company on the high professional standards in the operation of safety practice. It was believed that these safety standards were engrained throughout the organisation largely because of the influence of regulatory bodies and the influence of management in communicating the message to ensure safety compliance.

There was full disclosure of a number of reports (e.g., all Mandatory Occurrence Reports (MOR's), Audit reports and Quality Investigations Reports) to the national Aviation Authorities. In fact Company A notified the regulatory bodies of more events than many other airline organisations. For example the in-house development of an investigation tool (which helped to understand and address factors contributing to maintenance error) had uncovered many human factor issues that other operators did not address in a systematic manner. However some managers felt that the very success of the tool in highlighting human and organisational problems was causing the company problems by increasing its exposure to criticism particularly from the national Aviation Authority.

The company were also half way through a major organisational change programme. This "new world" advocated by the organisational change proposed for example, that safety would be at the front of all technical decisions; quality standards required for safe operation of customer aircraft would be set and communicated; and that solutions to the management of safety issues would be highlighted.

Human Factor Initiatives

It was reported that in response to a number of internal incidents, the company undertook a commitment to understand human factor issues and how they affected safety. Within the aviation industry the company had in many ways taken the leading role in the development and implementation of a human factor programme. Their human factors programme included the appointment of a human factors Manager, training and the distribution of a monthly human factors magazine, all of which went some way in creating awareness of the subject and its importance to the industry. In addition the development of a tool for identifying maintenance related errors and the investigation tool, each of which were fundamentally based upon different approaches to safety, also raised human factor awareness and understanding within the company.

Implementation of policy and setting standards

Organisational Change Programme

The organisation had been working on the implementation of a radical organisational change programme. The organisational change had been described "... as a systematic and structured approach to analysing, improving, controlling and managing processes with the aim of improving fundamental activities, such as manufacturing, marketing, communications, and other major elements of an organisations operation".

A number of reasons were put forward for introducing the new ways of working within the organisation. Primarily it was to reduce their reliance on the work from their own airline, by becoming more customer-focused and "building a loyal customer base". To do this, the company proposed to employ more flexible work patterns, with increased standardisation and reduced duplication of work across all organisational departments. It was also proposed that responsibilities would be devolved downwards (with greater self management) and that tasks would be fully engineered and resourced for the aircraft engineer before the commencement of a task.

A major change evident throughout the organisation was that work was now organised on a fleet basis. Each fleet/hangar has responsibility for the maintenance of certain aircraft types. For example, Fleet 1 - B767, B757, A320; Fleet 2 - B747, B777.

A fundamental aspect of the fleet principle was the Fully Engineered Task (FET), which was the complete package of man-hours, spares, tools, equipment and documentation required to complete a particular task. For example one of the biggest changes was the introduction of a new zonal toolkit system. The distinctive blue cupboards in each zone contained all the equipment staff on the shop floor were likely to need. Staff were also issued personal toolboxes and the company had introduced a 5-minute briefing to all staff at the beginning of each day in order to keep them abreast of 'anything new'. Team working was also a key element in the new fleet streams (flexibility between teams and flexibility between hangar and ramps, continuous improvement workshops etc), for example there was a core team for each fleet and for each shift. The core team consisted mainly of four personnel: Fleet Technical Engineer who defined the fleet maintenance programme; Fleet Material Controller who managed stock of material and tools; Fleet Planning Engineer who organised work-packages; and the Fleet Resource Controller who was responsible for manpower levels. A Satellite (support) team supplemented the core team. The satellite teams were physically located in the hangars and ramp areas. The satellite team worked shifts to match local production shift patterns and produced fully engineered, planned and resourced tasks to the production area: they had a similar workgroup to the Core team with the following roles; Fleet Technical Engineer who provided front-line technical backup to production; Fleet Planning Engineer who organised and issued work packs to production teams; Shift Manager who had overall responsibility for each shift and the Fleet Logistics Co-ordinator who was responsible for resourcing spares, parts, tools, etc for the fully engineered task kits.

A number of problems surfaced with the introduction of the organisational change programme. Many of the aircraft engineers felt they would have less "ownership over safety" as the Fully Engineered Task (FET) would deny them any self management or ownership for safety, as everything was pre-planned. While the zonal tool kits received positive feedback ('The guys don't have to go to Stores and queue – this saves a lot of time'), the personal toolboxes were felt to be 'too heavy to lug around, especially on and off aircraft. It was also felt (by both managers and aircraft engineers) that because of the "us and them" mentality between the different hangars and between the hangar and the line that much more "tangible" actions were needed to break down barriers in order to work as the "flexible team".

It was reported that some of the managers (particularly at the lower level) experienced problems as a result of role ambiguity. This role ambiguity was reported to be a result of the new positions created where responsibilities were not clearly defined. This "migration" (from the 'old world' to the 'new world') process was cited as a major cause of stress particularly as many managers had to re-apply for the new positions. Another problem area was that the change was not consistent across all areas. While the satellite teams had been implemented in some hangars the FET, for example, had not been introduced (lack of resources was cited as reason) so therefore production and support were not seen as going through the change process at an equal pace. As a result it was felt that safety management was compromised in this unsupportive climate.

Human Resource Planning

A number of problems were raised in relation to ineffective planning. One incident in particular provided an illustration of some of the deficiencies in human resource planning. The incident occurred as a Boeing747 was preparing for departure and the undercarriage collapsed;

Some contributory causes to the incident:

- Problems with spares procurement and additional work as a result of inspection meant that the original Estimated Time of Departure (ETD) was not going to be achievable.
- No contingency plan was available to resource this unexpected demand.
- Customer representative on site putting pressure for the aircraft to be released as schedule (would only allow a 24 hour delay when 48 hours were required).
- Several production managers adopted the role of technical team leaders. Several other managers who were not involved in the production process were also present at the aircraft. Chains of command broke down.
- Production management team were working for nearly 20 hours carrying out duties outside their normal roles.

The recommendations from the "human factor" investigation can be summarised as follows; (i) clear chains of command should be established as well as new procedures

introduced governing the control of the access of personnel to an aircraft; (ii) enhanced planning procedures should be put in place to illustrate more clearly the resource requirements for outstanding tasks; (iii) incident control procedures should be put in place to provide thinking time to prevent an incident turning into a potential disaster. (Account taken from Human Factors Magazine, No.9, 1996). The evidence indicated that none of the recommendations were implemented within the organisation as a result of this particular incident.

Training

There was a strong commitment to management training in the company. Most managers had undertaken short management courses ranging from Emergent Leadership courses to Stress Workshops and Human Factor Briefings. The human factors (0.5 day briefing) was only offered to the personnel seconded on the organisational change projects and was not offered organisation wide. The Emergent Leadership Course (9 days) for management addressed participation, collaboration, problem solving, shared values etc. and was linked with performance and efficiency but not linked with safety issues. Some positions in the "new world" received role training and attended stress and human factor workshops. However when management was asked about the effectiveness of the training courses, they indicated that many of the courses didn't have any real impact. It was felt that to be a success training courses needed to be continually supported (need buy in from the top). It was reported that ideally a human factors programme should be fully integrated with all other programmes and it should be viewed as a corporate issue. Therefore it was felt that human factors can't be seen as a separate department and that even though the human factors magazine had reasonable success it should be included in the staff magazine and not seen as something separate.

Monitoring

The Quality system was responsible for monitoring all operational activities through regular audits, Quality Discrepancy Reporting (QDR's), and incident investigations.

Auditing

Company A defined an audit as a documented process aimed specifically at managers to address both the underlying culture and systems that exist in a department and demonstrate how those systems are contributing to safe working. Quality staff assigned to specific areas carried out a programme of formal independent audits. The objective being "to ensure that the quality systems employed within the organisation are effective and that the standards set by the company are being met and maintained".

It was stated (Systems and Procedures for Ensuring Safety, p.13) that the 'auditing activity is comprehensive and the Quality staff undergo specialist training in auditing methods and the associated report writing. The products and processes of the specific areas were reviewed together with the adequacy of and compliance with relevant procedures and the work practices of the staff'. Audit findings should be discussed with the local management on-site and backed up by formal reports that detail the findings and highlight any discrepancies. This should enable the Quality group to obtain an overview of the effectiveness of the ongoing Quality Monitoring Procedures applied by the local management and staff of each area and judge the overall quality awareness. However it appeared that the primary focus of the auditing was on all relevant documentation and that the actual work was not directly monitored. There was the potential for audits to go much further in uncovering all of the important issues (e.g., the possibility that the softer issues gleaned from human factor investigations could be built into the audit reports).

Incident Investigation

The official stated goal of conducting Quality Investigations was to 'identify the root cause of the incident or discrepancy and put forward corrective actions to prevent any recurrence'. Quality investigations emanated from a variety of sources namely Air Safety Reports (ASRs), Quality Discrepancy Reports (QDRs) and Ground Occurrence Reports (GORs). They were collated and assessed for appropriate action by the Quality Department. If assessed as a Mandatory Occurrence Report (MOR) the national Aviation Authorities had to be informed and they could decide to carry out their own separate investigation.

A quality engineer is appointed to conduct an incident investigation. The investigator is required to establish the root cause and the appropriate action in order to prevent re-occurrence of the particular incident. Methods of investigation involved interviewing individual(s) involved in the incident and analysis of technical elements and documentation. Once the investigation has been completed and the entire criteria have been investigated a draft report is compiled covering all aspects of the incident and proposed recommendations. Representatives from the quality department and the department where the incident took place assess the draft report and implement the recommendations. A final version of the report is filed in quality records and it appeared that little or no follow-up on the effectiveness of the recommendations occurs. The final reports can be shared internally or externally (i.e., national CAA, customers).

Maintenance Error Investigation - MEI

Company A had also just recently introduced an investigation tool which had been described as "an event-driven aid which helps to gather the facts and provides a consistent method to help reduce organisational and individual errors by giving the front-line aircraft engineers and managers a tool to understand and address factors contributing to the error". In addition, the tool provided a standardised format for the reporting and tracking of data collected from each investigation. The reporting mechanism (GORs/QDRs/ASRs) flags up the need to carry out the investigation, depending on the significance of the incident. If the incident is considered to be significant then Quality has the responsibility to co-ordinate the investigation. For the less significant incidents, trained local area personnel can conduct the investigation, with assistance from Quality. However at the time of research (i.e. during the pilot stages) the tool was only being applied to the more serious incidents. The investigation tool was piloted over an 18-month period. It was seen to get to the root causes of incidents in a more consistent and structured way. The investigators underwent a 2 /3 hour training session in the principles and methodologies of the investigation system. A comprehensive user guide booklet was produced, which was designed to provide supplementary information when carrying out an interview.

The investigation interviews were conducted following guidelines from the handbook produced by Quality. On completion of the investigation the results should identify

- Operational event (how the incident was revealed)
- Maintenance error (causes of the incident)
- Contributing factors checklist
- Process errors
- Corrective actions

Two of the shift managers and a number of aircraft engineers reported that they were quite positive about the introduction of the new investigation tool. It appeared that some management did not have the same appreciation of the investigation tool, as they did not feel it productive taking the shift managers out of work in order for them to undergo training. Some managers reported that the tool was a finger pointing exercise where a lot of the blame was coming back to them. In addition they viewed the negative aspects of too much information especially with regard to the Air Accident Investigation Branch (AAIB) and the National Aviation Authority (NAA). They felt that more pressure was aimed at management by the national aviation authority to establish what they proposed to do with all the additional human factor information.

Quality Discrepancy Reporting

A quality discrepancy report could originate anywhere in the organisation. After the quality department assessment the report is re-directed to the relevant department or operational area that then has a 30-day time limit to feedback to the originator. In actual fact it was reported that it takes months to complete. A number of aircraft engineers reported, for example, 18 months between a QDR raised and an investigation closed. It was reported that one possible cause of this problem was the difficulty Quality found in identifying the responsible person/department. The system allowed the form to be redirected up to four times by departments who felt it was not their responsibility to deal with it.

When a response to a QDR has been achieved that response is fed back to the originator of the report. If the originator and the relevant actioning department/personnel cannot agree on adequate actions, the QDR usually arise as an agenda point on the Monthly Quality Forum. Recommendations from the Monthly Quality Forum are included in the report and it is sent back to the originator. Ideally a QDR cannot be closed until the

originator is satisfied with the response. It appeared that the company were doing very little with QDR's (receiving about 800 per year). For example there was not always thorough follow through in checking that things had been actioned or whether the QDR asked the right questions and there was no comparison or analysis over time. Therefore, as the system was not seen to react to the problem adequately or took too long to generate solutions, it was not surprising that many users were attempting to circumvent the system or indeed refusing to use it at all.

A separate investigation protocol existed for discipline related incidents, using a different reporting form. It was stated "it is not normally the policy of Company A to institute disciplinary proceedings in response to the reporting of any incident affecting safety" (Company Health and Safety Environment Manual, 1997). However in reality the relationship between disciplinary actions and the QDR/GOR reporting systems, as it existed was unclear. Dissatisfaction with this ambiguity was expressed at a number of levels.

Feedback

There was very open and comprehensive discussion of Company A's incidents and reviews of recently published maintenance error related incidents in the human factors magazine and engineering news. Both these magazines (even though both reported to be limited in their distribution) did go some way in increasing awareness of safety issues. The human factors magazine in particular was reported to be a very effective medium for disseminating information. There were also plans to introduce Health and Safety issues in the human factors magazine. It was proposed that these issues would include problems identified within the organisation and the lessons learnt as a result. It would also examine issues and incidents that had affected other areas of industry.

There was a formal structure of safety committees, which reviewed safety reports. However the safety committees did not see their role as going beyond monitoring trends. The method for analysis of the bulk of QDR/GOR's was a trend analysis system. In effect managers were being monitored to ensure that what over time had emerged as a consistent number of reports was maintained. If a department was seen to be raising fewer than normal reports, then it was assumed that they were failing to

report and pressure was exerted to increase reporting levels. This did result in a sudden upsurge in the number of reports as the pressure filtered down through the organisation often far above the average level of reports. The problem seemed to be that other reasons for the decline in reporting were never addressed. Also an artificial average level of reports was being maintained, as the principle goal at the senior management level, seemed to be to maintain a consistent level of reporting.

The negative aspects of too much information especially with regard to the AAIB and national aviation authority were also highlighted. Company A's management felt that more pressure was aimed at them by the national authority to establish what they proposed to do with all the human factor information. In addition it was also reported that in a number of incidents four separate investigations were been conducted simultaneously (i.e., local investigation, quality investigation, national authority investigation, AAIB investigation). This had led to a highly political situation as each investigation was wondering what the other had found. In particular it was felt that the AAIB's involvement "put the national authority's guard up". However it was felt that the AAIB probably appreciated the company problems much more than the national authority. The AAIB in a "non threatening manner were trying to get to the bottom of the problems".

A "proactive confidential computer based system which sought to encourage staff to comment on potential error provoking local and organisational factors.." was first introduced in Company A for field testing in 1993. This system was developed with the understanding of addressing safety from a proactive point of view, for diagnosis, and it was to be applied to everyday working situations with the objective of identifying, in very general terms, problematic factors within the system before they actually manifest themselves through an incident or accident.

There were problems of integrating this system within the culture of the company and during the time of research the trial implementation of the system within the company was suspended. While the overall philosophy and structure of the system was quite impressive, it was felt that inadequate training, lack of understanding and lack of management commitment all played a large part in the failure of the system to meet its original objectives. The aircraft engineers did not see it as a tool in their everyday work

as it dealt with perceptions of what might be therefore the users could not see the benefits. Initially the aircraft engineers were inputting potential problems into the system but as very little was actually done with this information and they were receiving no tangible improvements the system became largely overlooked and unused.

Overall it was felt that there was no ownership or commitment as it was imposed on everyone and there was no way or commitment to managing the information that it provided. The system was also seen as a 'policing role' as it was part of the analysis in the Quality System and there wasn't a clear policy on potential disciplinary outcomes. However it was felt that when the climate was more 'suitable' the company planned to re-introduce the system as part of their continuous improvement initiative.

Analysis

The safety policy and strategy within Company A was seen to be 'ingrained' and 'built-in' throughout the organisation. They had adopted an explicit policy and programme on human factors. The company had a well-developed human factor-based investigation tool and they were very open in disseminating human factor and safety issues especially through internal company magazines. However the company did appear to have difficulty in translating the human factor based information into change. It also appeared that the relationship with their regulatory authority was a little 'strained' and that the organisation was struggling with the implications of managing human factor issues arising from incident investigations.

It was reported that a major factor that inhibited the success of the "proactive IT-based reporting system" for example was the slow response, or lack of progress in resolving the problems identified and the lack of specific feedback to the users. The system may have identified and prioritised a number of human factor issues but a deeper analysis of the information and effective feedback was required in order for the organisation to benefit from all the safety information it generated.

The organisation was also embarking on a radical organisational change programme, however many of the changes were not fully realised (e.g., the Fully Engineered Task, FET). Extensive management training and human factor awareness training was carried out in the company, however it was not always rated very effectively. A range of

monitoring activities was conducted within the company. It appeared that the main focus of the audits was on documentation rather than actual work, the quality discrepancy reporting was used quite regularly but there was a huge backlog in responding to these reports.

Overall the analysis established a number of key issues in relation to the safety management system in Company A:

- Compliance with safety requirements set by regulatory bodies was a major area of concern in addressing safety policy and strategy.
- Safety policy and procedures were well disseminated and understood at all levels within the organisation.
- The company had taken a leading role in the industry in relation to human factor policy in addressing safety concerns.
- The company had embarked on a change initiative and while some progress was made problems were emerging in relation to effectively implementing the change across all levels in the organisation.
- There was a strong commitment to management training, however, there was mixed feelings about the effectiveness of the training.
- The quality system monitored all operational activities through regular audits, quality discrepancy reporting and incident investigations. While these monitoring functions adhered to the standards set by JAR 145 they were ineffective in feeding back outcomes through the organisation. Rather the system was characterised by huge backlogs, no effective follow-up of recommendations and no effective analysis of trends.
- Considering the importance of the relationship between disciplinary actions and the reporting culture it seemed undesirable that the relationship between these two were not fully articulated and/or understood by the organisation.
- The company encouraged a very open discussion of their incidents both through verbal briefings and internal magazines.
- Formal safety committees reviewed a range of safety and quality reports. It appeared the focus was on maintaining a standard level of reporting rather than investigating any variations in reporting.

Description of Company B

Background Information

At the time of this research Company B was a wholly owned maintenance subsidiary of a European airline. The company provided full support for their airline's aircraft fleet and for the aircraft of a number of customer airlines (3rd party maintenance organisation). The company employed approximately 1750 staff. The company's core capabilities were centred on Boeing 727, 737, 747, 757, 767 and the Airbus A300. The company had many years of experience within the component repair overhaul business and line maintenance operations. At the time of research the company had just undergone a series of industrial disputes and as a result the industrial relationship climate was not very positive.

Strategy and Policy

Compliance and Operational Safety

Compliance with safety requirements set by regulatory bodies was a major area of concern in policy. Company B had just completed amendments to their Maintenance Organisation Exposition document compiled in compliance with the requirements of JAR -145. This document comprised clearly articulated responsibilities of management, manpower resources (i.e., distribution of staff, manpower planning), maintenance procedures and quality system procedures etc. It appeared that the completion of the MOE required quite a bit of administrative effort and was a considerable 'drain' on resources within the company.

While the company documents emphasised safety as the number one priority, the verbally expressed policies towards safety differed. Some managers expressed that safety was the number one goal within the company, while others expressed that current priorities for company management was to get the 'economics back on track'. It was reported that this difference in the verbally expressed policies toward safety reflected the financial and industrial pressures the company had recently found themselves under.

A particular target for the company was to develop a procedures manual whereby every single task would have an accompanying safety procedure. Each area would only

require the safety procedures for the areas in which they worked, so that each single task would be systematically proceduralised. When this was in place it was planned to provide relevant training in order to ensure that the new procedures would be implemented organisation wide. The company safety procedures project was only at an early stage at the time of research but early indications did highlight a number of problems, particularly in relation to personnel resources. It was envisaged within the company that these safety procedures would be seen to be a separate aspect of the particular task rather than attempting to integrate the safety aspect with the operational aspect of the task. Arguably this approach could be seen to further exacerbate the impression that safety is seen as a 'secondary issue' or something that is 'bolted on'.

Human Factors

The company had no clear documented policy on addressing human factor issues although they were open to new ideas addressing these issues. They had embarked on a 1-day Human Factors Awareness Course for all staff in the organisation and had employed a MEDA based methodology for conducting their incident investigations.

Implementation of Policy and Setting Standards

Industrial Relations

Company B reached a crisis point two years previously when in the face of a company threat to close the business; its numerous trade unions twice rejected extensive changes to labour agreements before finally giving into a wage freeze, layoffs and work rule adjustments. The months of work disruptions created by the conflict cost the company several of its steady customers. There was also a strong impression by the company management that the industrial relations climate was inhibiting the effective mechanisms for the planning and organisation of work.

Human Resource Planning

There was a clear safety infrastructure outlined in the Maintenance Organisation Exposition document for objectives and strategies for Human Resource Planning. However a number of issues were highlighted in relation to human resource planning. One such issue was the change of company policy from a half an hour (verbal and

written) overlap between shifts to just a written hand-over. The company had operated a policy where there was a half an hour overlap between shifts so that the in-coming production staff could receive clarification on work completed and work outstanding. It was strongly felt that this written hand-over alone was insufficient and would inevitably lead to problems.

The heavy reliance on overtime was also highlighted. It was reported by some of the managers that if everything was effectively planned from the outset (i.e., resource requirements for outstanding tasks, manpower levels etc.) this would eliminate much of the overtime that was prevalent in the company. However it was also highlighted that overtime was considered a fact of life in this industry (and production staff accepted and encouraged overtime) as it was impossible to plan for every contingency in aircraft maintenance. Contrasting viewpoints were also evident between managers and aircraft engineers in relation to issues of manpower. A number of managers felt that the hangar and line were "over manned and over resourced". This can be compared to comments reported by aircraft engineers ("lack of manpower has caused endless problems"; "lack of usable equipment at peak demand creates frustration and stress"). Again this was reported to be a result of a number of factors. It was felt to be a reflection of the industrial relations reported to be prevalent in the company and in particular the "arms length posture" between management and operational staff. It was also reported to be a result of ineffective planning of the basic short-term and long-term processes.

Information Technology

Company B were planning to implement a fully integrated company wide ERP (Enterprise Resource Planning) system. It was envisaged that the new system would have significant new capabilities from quoting and estimating through to invoicing, while catering for technical records, aircraft and component configurations, planning, forecasting, certification and production control. It was proposed that the new system would gradually be introduced throughout the organisation in order to replace the eight different computer systems currently in place. It was reported that a challenge in the hand-over was convincing the various departments 'to hand over local control of their data' to a more centralised system.

Training

A lack of training on people management competencies was also reported. A small number of management, for example, had some form of training. This ranged from 1-week intensive courses; a range of training programmes when the company was set up, and other half-day leadership courses. The introductory management course when the company was set up addressed health and safety, cost saving etc. and was rated to be very effective. However most felt that the other management courses were not applicable, had no relevance to their everyday work and did not address human factor competencies.

A 1-day human factor awareness course was developed in order to introduce a proactive approach to addressing Quality and Airworthiness issues with a particular focus on human factors. The course was broken down into three modules. Module 1 concentrated on recent maintenance errors in the aviation industry (although not on internal company incidents and errors), and the cost and safety implications. Module 2 concentrated on the controls for JAR 145, FAR 145 and ISO 9002. Module 3 concentrated on human factors (i.e., individual pressure and peer pressure, meeting turnaround requirements and the importance of feedback).

It was planned that everyone in the organisation would undertake the training programme. At the time of research about one third of all staff had participated in the training course. The feedback from the 1-day human factor course appeared quite positive. While the managers and the rest of the work force were segregated for their actual training on the programme there was a session at the end of the programme where a manger was present to address any outstanding questions or issues. This was felt to meet the programme objectives to improve "quality performance"; "ability to participate in the feedback process" and " improvement in internal processes and resources".

Monitoring

The Quality Department were responsible for assuring the management that standards of safety were being compiled with. Their role included, direct auditing, on-site inspection, routine visits to component workshops, statistical trend analysis, incident

investigations and monitoring quality discrepancy reports (QDR's). The primary mechanisms for monitoring safety related aspects in Company B was through the use of audits, QDR's and incident investigation.

Audits

Quality audits included product audits (e.g., of aircraft or a component), facilities (e.g., tools, testing equipment), maintenance error audit (e.g., outcome of an incident investigation), aircraft zonal audit, paperwork and documentation audits etc. This could result in up to 200 audits per year. Around 90% of the audits were scheduled, the other 10% could result from an incident investigation, re-occurring problem or from a request from a responsible area manager or a customer. The company was also subject to a number of external audits including the annual national aviation authority audit and their customer audits.

An internal audit was scheduled between one or more months in advance. At the time of carrying out the audit, one quality inspector was usually assigned to conduct the audit and to manage the auditing process along its lifecycle, which included its verification and closure. Each audit had an accompanying set of procedures that the inspector followed when conducting the audit. Depending on the nature of the audit it could take anything between a few days and a few months. If any non-conformances were found the first task was to assess the gravity of non-compliance. For example:

Level 1 - must be rectified within 3 working days unless the non-conformance warrants an immediate close down of the area or activity
Level 2 – must be actioned within a maximum of 3 months
Level 3 – would be raised for items that are not of a regulatory nature.

Once the severity of non-conformance was assessed, the quality inspector contacted the appropriate area manager and would start the process of agreement of the date to solve the problems found. When the audit was complete a report was written in accordance with the procedures. All non-conformances were highlighted with accompanying recommendations. It was usually up to the responsible area manager to ensure that the recommendations were carried out. While a number of audits were carried out including

facilities, general housekeeping, documentation and product audits, it appeared that the primary focus of the auditing activities was on all relevant documentation.

Quality Discrepancy Reporting

Company B had just recently introduced a new reporting system - Quality Discrepancy Reporting (QDR). Within the company the QDR had been described as a "tool to alert management of a potential Airworthiness problem and once aware of the discrepancy, management are required to take or initiate corrective action within a prescribed time limit" (Company Procedures Manual, 1997).

It was stated that the QDR must be complete when any member of staff becomes aware of a discrepancy or a problem that has the potential of becoming a technical airworthiness issue. Examples include:

- Key procedures not correct or not available.
- Function or system test failure.
- Structural defect discovered not as a result of scheduled inspection.
- Critical in-service defect.

The Quality Assurance Department monitored the Quality Discrepancy Reports (QDR's). However it involved almost all departments and areas of work in relation to report initiation, recommending and implementing corrective actions. At the time of research the Quality Department were receiving approximately 2/3 QDR's per week. When a QDR was raised Quality assessed the report and assigned it to the relevant department who were expected to respond to the report within 30 days. If a response was not available within 30 days any outstanding QDR's were highlighted and addressed at the monthly Quality meeting. Even though there was a slow uptake in initiating QDR's and only a small number had been raised, more than half of these were still outstanding.

Two aircraft engineers reported that they had raised a QDR but were not satisfied with the response and the suggested corrective actions. One example quoted involved a QDR raised as a result of 'blatant display of unrecorded work'. The aircraft engineer claimed to have given a detailed account of the problem and it was investigated over a 2-month period. The suggestive corrective action consisted of 2 sentences ".... the

Quality Engineer assigned to the particular work area will monitor the situation more closely' . When the aircraft engineer was asked why he and his colleagues did not object to the corrective action, he replied '...what is the point of waiting another few months for an unsatisfactory outcome...anyhow I have too much other work to do'.

Half of the managers interviewed perceived the QDR's as very useful and realised that if they cannot respond to all the information that is coming in then the whole system would be counterproductive. It was also felt by the other half of management though that the QDR's were being used as a medium whereby the aircraft engineers were raising their own "snipes" (e.g., pay and conditions).

The fact the system was not completely anonymous seemed to have caused a number of problems as some aircraft engineers were reluctant to report something that they had been directly involved in as they were unsure how the QDR system was aligned with the disciplinary system. In addition it was also felt that many aircraft engineers were not fully informed of the objectives of the QDR's. This lack of dissemination of information on the QDR's was reported to raise a number of problems especially as very few of the aircraft engineers appeared to be actively using this tool.

Incident Investigations

The company had also developed a human factors based incident investigation approach (Quality Assurance Incident Checklist), which was based on Boeings' Maintenance Error Decision Aid tool (MEDA). The Incident Checklist developed in the company had a very similar layout to MEDA but also included a section where the name of the person under investigation was required, a section for witness to the incident (nobody has ever come forward), and a section reviewing the existing procedures, processes and policies currently in place to prevent the incident. Factors affecting individual performance were also addressed such as the job/task (i.e., complex task, repetitive task etc.), environmental factors (weather, lighting), physical health (fatigue, physical stress etc). Although it was developed over a year it appeared that very few of the quality inspectors were actually using the tool in carrying out investigations.

Following an incident the responsible area manager is notified. This usually involved a verbal account from the individual(s) implicated in the event or from a supervisor. The

responsible area manager has responsibility for completing the relevant reporting form and forwarding it to the Quality department. Once the Quality Department receive the report an assessment is conducted in order to assess the severity of the event. If the event is assessed to be of a serious nature, a decision would be made to notify the National Aviation Authorities and to commence a full investigation. If the event was assessed and had no serious or potential outcomes the relevant report is recorded and filed in Quality records.

When an incident investigation is called and the staff member involved is felt to be a danger to the safety of the operation then their approval is removed even prior to the investigation beginning. All the facts and details surrounding the incident are reviewed and assessed. This covers company procedures, regulations, manufacturer related documentation etc. The individual(s) implicated in the incident would usually undergo an interview with one or more of the quality investigators. The objective of this interview is for the individual to present his/her version of the events and defend any actions taken and for the quality investigator to assess all factual information from all relevant sources. Each person interviewed has the right to have their manager present at that interview if they so wish. Depending on the nature of the incident a customer representative can request to be present during the interviews. A representative from the national aviation authority could also be present or they could initiate an investigation of their own. All of the information and facts are assessed following the interview. This could result in requesting additional interviews either with the individual(s) implicated or other relevant parties. An interim report with recommendations can be drawn up at this stage with a number of recommendations including recommendation of a disciplinary nature.

The company reported that it operated a "no blame " policy. However a training programme for staff implicated in incidents had recently been introduced. This training programme was a half a day workshop where everyone involved in a particular incident were re-educated on safety issues, and company policy. This training seemed to be very effective and the feedback from the aircraft engineers was quite positive although some did insist that the company would never subscribe to a "no blame culture" and that the training programme is in fact viewed as a "blame and train" policy.

Disciplinary action usually involved a verbal reprimand and or approval withdrawal. If disciplinary action of a serious nature was not taken then the person involved would usually receive a verbal reprimand and if they have had their approval removed prior to the investigation, it would be re-instated following the training course. When a recommendation involved withdrawal of approval the individual(s) would still be allowed to carry out certain tasks for a specified time period and would then have their approvals renewed. Again re-training would be undertaken before returning fully to their job. The Quality department had the responsibility for implementing verbal reprimands and withdraw approvals.

Feedback

There were a number of both formal and informal management meetings within the company that reviewed the outcomes of the various quality monitoring functions. There were also a number of reports that were disseminated throughout the senior management grades. However there was a marked contrast between the amount of information that was processed upwards through the hierarchies of committees, and the amount of information that was disseminated horizontally and downwards to the staff as a whole.

Monthly Quality Reports were forwarded to all the General Managers and the Chief Executive. These reports provided a summary of all findings from the audits, QDR's and incident investigations. They also highlighted any outstanding audits or QDR's. This was all formally reviewed at a monthly Quality meeting and various other safety committees where responsible management were expected to explain any overdue QDR's or audits from their area. Even though outstanding QDR's and audits were reviewed at these monthly meetings there did not seem to be any accountability on the responsible managers to close any outstanding issues. There also did not seem to be any follow-up on the recommendations arising out of a QDR investigation. Both the managers and the Quality Department appeared to be satisfied once a report was closed rather than verifying that the recommendations actually solved the core issues.

At the time of research all incident and accident reports were highly confidential and only selected personnel had access to the reports. A number of reasons were put

forward to explain this. It was felt that reports should be kept confidential in order to protect the individual involved in the incident ("save face") and not expose the company to any unwanted publicity or blame from the media or from customers. For example, 'Quality Assurance Notices' displayed in the hangars did not refer to the particular incident that had occurred. The notice specified the correct procedure on "Robberies" for example but did not highlight that this reminder was due to an incident where the procedure on "Robberies" was not adhered to.

The primary means of communicating within the company was through verbal briefings rather than more formal or documented channels. The company frequently operated an information "cascading system" where certain information was verbally cascaded through management briefings from the top down through the various levels in the organisation. The aircraft engineers, for example were usually given this verbal briefing "in front of the aircraft". This verbal briefing usually involved a general summary of a particular incident and would outline changes that would occur as a result of the incident.

Once an incident signal was raised the national authority were automatically informed in writing. There was an agreed format for the full reports that were forwarded to the national authority in accordance with requirements. However they did not get the full internal reports unless they specifically requested a full report.

The company had plans to introduce an Aer Safety 2000 magazine including a maintenance section. It was reported that this magazine would not refer to incidents within Company B but rather take examples from other airlines as the company feared that in "...pinpointing the individual it may lose the message to the person and lose the cooperation of people to help prevent incidents in the future..."

Overall it was reported that the communication of information did not work very well in the company and that more emphasis should be placed on effective communication and feedback within the company.

Analysis

In company B it appeared that safety had to be made compatible with commercial survival and that compliance with JAR145 was a major commitment of effort. The industrial relations climate was also seen as a major constraint on planning and achieving organisational improvements. Management training was inconsistent but there has been an initiative to introduce human factor awareness training. While the human factor training received positive feedback, how sustainable it will be will depend on whether the feedback is used as an internal learning process throughout the company and the resources are made available to address all of the issues.

Like most aircraft maintenance organisations, auditing focused primarily on documentation. A quality reporting system had been introduced as well as a human factor based investigation tool. However it appeared that only a small number of quality investigators actively used the human factor investigation tool and even though there was a relatively small number of QDR's raised, the company were having difficulty in dealing with them. The company had also introduced a relatively new policy of a routine "retraining session" after incident involvement, but this was perceived as 'train and blame' policy. The primary means of communicating within the company was through verbal briefings rather than more formal or documented channels.

Overall the analysis established a number of key issues in relation to the safety management system in Company B:

- Compliance with JAR145 an administrative effort.
- Perceived incompatibility of safety and economic goals by company management.
- Climate of industrial unrest.
- No explicit policy on human factors but initiated human factors training and MEDA type investigation protocol.
- A degree of commitment to management training.
- Quality monitoring system not working optimally with much backlog of reports and inadequate follow up and analysis.
- Different perceptions from management and operational staff in relation to the disciplinary code.

- Formal hierarchical safety committees but little information formally disseminated down through the organisation.
- Cautious approach to disseminating outcomes from internal incidents.

Description of Company C

Background Information

Company C is one of the largest airlines in Europe. The company employed approximately 23,000 staff, 3,500 of which were employed in the maintenance division. The company's core capabilities were centred on the B767, B737, DC 8, 9 and 10 families, MD 80/90. The company had an excellent reputation in providing component repair and overhaul and line maintenance both to their own airline and to their third party customers.

Strategy and Policy

Compliance and Operational Safety

Strategy and policy were driven by a number of prevalent factors within Company C. The company had a very strong verbal commitment to safety. The company policy on "safety as number 1"was well disseminated at all levels in the company. It was consistently reported that the main priorities were safety, punctuality and quality of service. Only a " non failure rate" was acceptable when it came to safety, punctuality and service with the commitment that "...if we don't have safety we won't exist."

It appeared that not only was compliance with the safety requirements set by regulatory bodies a major area of concern in policy but there was also the commitment for forward thinking and to go beyond the regulation policy. The 'functional control' concept developed within the company in the seventies was the foundation for the 'Internal Control' concept as defined and issued by the regulatory authorities in the late eighties. The functional control concept clearly articulated what was required for effective internal management and control within the company. The company also introduced Total Quality Management (TQM) in the mid nineties following the European Foundation for Quality Management (EFQM). There seemed to be mixed response in relation to the success of the programme. A number of personnel that were responsible for implementing TQM in the company felt that it had not been an unqualified success as the company attempted too much too soon. They felt that the company set their target at winning the EFQM prize in a short time and did not allow for the processes to

change. It was strongly felt that if 'you wanted to change the company by changing the process, you have to be prepared to wait for the changes to occur gradually'. It was also felt that it was difficult to get management to work with TQM themselves, rather than just seeing it as merely a way of managing others as, the 'most successful agents of change are those who are role models rather than mere teachers'. However the perception from the aircraft engineers was that management were taking this initiative very seriously and that it was seen as much more than mere "tokenism".

Human Factors

Although there were no initiatives explicitly labelled as human factors, many of the their policies and initiatives were of a human centred nature. There was a strong focus on effective planning and provision of resources with considerable investment in facilities, management training, acceptable shift rosters and quality systems. The company had just adopted a policy of sending their quality auditors on a 2-day human factor-training course. It was recognised that the focus on human factor training should involve all areas in the organisation, particularly by the middle management grades, which for example are responsible for developing and implementing recommendations as a result of audits and other quality investigations. It was reported that human factors training for all staff was planned in the near future.

Implementation of Policy and Setting Standards

Functional Control Concept

The functional control concept consisted of the following activities: directing by establishing and maintaining procedures, routines and resources required for the fulfilment of assigned tasks; monitoring of the execution of work; analysis of observed deviations; adjustment/development according to observation and analysis.

By adequate and effective application of these four activities, the objective was that the analysed results of the monitoring activities would be applied to the directing part of the functional control (e.g., establishing and maintaining procedures, routines and resources). Thus, a continuous, dynamic process of adjustment and/or development was assured. To accomplish an adequate functional control, some practical activities were also advocated:

- Establish goals and safety standards for the operations and the flight safety standard.
- Establish the organisation. Define the functional description and responsibilities of each department. This includes an outline of what has to be done, who is authorised to do what and the allocation of resources. If these conditions are not fulfilled then senior management are accountable.
- Ensure follow up so that the goals and the flight safety standards are adhered to.
- Conduct systematic studies of incoming documentary information or inspection reports.
- Evaluate experience and review trends and goals.

This all should be a continuous process or a 'circle of control'. This 'circle of control' could be applied within a department, to a particular process or function or to the organisation as a whole. It was reported that the actual monitoring function could require varying degrees of specialisation and organisation. In its simplest form it could be performed by the individual himself as applied to his assigned work; at the other extreme the services of a specialised team could be required. The purpose of the monitoring function was to compare the actual result of an activity with the intended one and to present the result in a suitable manner to all parties involved.

Planning and Resources

The company also placed a strong focus on planning and on the provision of resources. Information Technology for planning and the organisation of work was strongly developed and embedded throughout the organisation. The facilities for the aircraft engineers both in the hangar and on the line were also of a very high standard. On walk a rounds within the company it was evident that there was considerable investment in the facilities. Many had access to CD ROM's, their staging equipment was in very good condition and shift work patterns were planned in order to allow flexibility in the every day work.

Job Card Production

Company C's routine job card production was an essential part of the company's attempts to plan and organise work. In general the quality of job cards was seen as very high, however some management and staff did feel that more aircraft engineer input was

necessary and one manager reported reorganising his department specifically to improve contact between job card production and the aircraft technicians.

Shift-work

Shifts were planned in order to match skills and number of personnel to every day work demands. This was recognised to be a difficult task especially in relation to unplanned work. One manager reported that he felt that the company was not particularly good at planning shift allocation but the system was improving all the time. Comments regarding the shift system from aircraft engineers were very positive. Two of the aircraft engineers reported that they had no problems in arranging their shift patterns to "suit their social and family life.." In addition there also appeared to be very little overtime. This was felt to be a direct result of the thorough focus on planning throughout the organisation.

Information Technology

Information technology was strongly developed, integrated and embedded throughout the organisation. The company's technical information system appeared to be a sophisticated network with a wide range of capabilities including, for example:

- Check Scheduling tasks
- Creating and printing job cards
- Component Type data
- Engine Shop data
- Modifications
- Daily Technical Reports
- Manpower Reports
- Customer Orders
- Inventory Control
- Purchasing

All of these systems were integrated and were automatically updated. When, for example, a component was taken from a line station store, the information was inputted into the computer system, this automatically notified the responsible materials department that the spare has been used, therefore enabling the materials department to initiate the need for replenishment. An integrated IT based system was also used in the

co-ordination and monitoring of aircraft traffic on the line. This centre included all the vital technical services and control for aircraft during turnaround (i.e., catering, cleaning, refuelling etc.).

Training

There was a strong commitment to management training within the company; for example, middle management had received extensive leadership training. These courses did address human factor issues such as teamwork, leadership, communication and motivation.

Most company management had gone through a series of "Leadership" courses. The training focused specifically at middle management to impart the skills senior management felt were imperative in 'good people managers' as well as managers who could manage change in the organisation. The middle management levels were identified as the agents of change, as they were the link between the senior management vision and the imparting of that vision down through the organisation.
The time invested was much more considerable than similar management skills courses in other organisations. One manager spent approximately 60 days training over an 18 month period. Typical total course length for equivalent courses in other organisations was between 3-5 days. One interesting aspect of the more recent leadership courses was that "new leaders" were assigned a mentor in the company for a two-year period to offer help and advice through the first period of management. This was reported as being a very helpful way of supporting new management.

Union Relations

The level of co-operation with unions was reported to be very high. Monthly meetings were held to negotiate and organise changes in work practice. Information was not withheld from unions as management felt that 'unions were as interested in the survival and success of the company as they were'. The press were seen as a much more of a threat with sensitive information than the unions.

Monitoring

The overall objective of the Quality System was to ensure that planning, preparation and accomplishment of maintenance were performed in compliance with the authorities, the manufacturers and Company C's own requirements (Technical Operations Manual, 1998).

The stated purpose of the Quality Assurance System was to:

- Control the processes and tasks to ensure they are performed satisfactorily with continuous improvements, according to principles of Total Quality Management.
- Decrease the number of non-conformities to the established standards.
- Decrease the resulting costs for lack of quality.

The Quality Assurance System primarily involved quality reporting, investigation, audit, management evaluation and monitoring corrective actions.

In Company C there were also quality-inspectors who worked at the operational level. The quality inspector acted as an independent observer at the operational level alongside the aircraft engineers. The quality inspectors reported to the head of quality inspection who reported to production management. It was unclear in the company to what extent production could influence the decisions of the inspectors though there was a suggestion from one shift manager that he did have some level of influence over their decisions despite the inspector's independent role.

The quality inspectors inspected work to ensure it was carried out in accordance with official methods and procedures. They appeared to be viewed as a useful support to the operation in that they advised the aircraft engineers and provided support in trouble shooting and problem solving. It was reported that conflict does arise between inspectors and production managers on occasion. How this was resolved seemed to depend on the individuals involved but it appeared that the co-operative perception of the role of the inspector meant that these conflicts were never of a serious nature. The quality inspectors also took responsibility for the correcting Non-Conformance Reports (see section on Quality Reporting) within their own areas.

Auditing

One of the primary functions of the Quality department was to audit all areas and line stations according to official procedures. Generally the audit plan contained information on the area to be audited, scope of the audit, applicable documentation, responsible person to be notified, assessment of previous audits etc. Usually one-week's notice was given to the relevant area prior to commencing the audit. Depending on the type of the planned audit and the area concerned an audit team was established. The team could be made up of engineers, planners, production personnel as well as quality personnel. As a rule personnel in the team did not belong to the area currently under audit. Before participation in an audit personnel usually received in-house training on the basics of auditing.

The auditing process usually involved an assessment of relevant paper work and documentation, informal interviews, checks on training records and certification levels, checks on manpower, serviceable equipment, tooling, housekeeping etc.

Company C carried out what they called both system and process audits. Process audits followed a particular process from initiation to completion (e.g., modification on a component). Therefore they dealt with an actual work practice and documentation. Process audits were carried out in a frequent and systematic manner. A system audit in comparison had the organisation and the infrastructure as its main subject. System audits were less common and were reported to deliver more difficult problems that required longer-term solutions. It appeared that the system audits were largely based on the functional control concept.

In the words of one senior auditor "We feel that 20% of all mistakes are the responsibility of operations, 80% are the responsibility of management and the organisation. Process audits look at the nuts and bolts of the operation and problems at this level are easily identified. System audits are much more difficult as management mistakes and organisational shortcomings can exist within a company for years".

Following the completion of an audit, post-audit meetings were held in order to present the findings to the management. All responsible area managers are given full feedback

and all discrepancies are addressed with responsible parties in order to (i) acknowledge that the discrepancy actually exists and (ii) to agree an action and set of recommendations and timelines. The effectiveness of these recommendations should then be subject to review at the next scheduled audit. It was noted that only the management get the final audit report and little feedback filters to the ground level, it was felt that "operational departments have a lot of things to do, the audit reports would just add to the load."

Quality Investigations

The stated purpose of a Quality Investigation was to determine the chain of events of a particular event or incident, identify and analyse the prime causes, and recommend the actions to be taken to avoid a recurrence of an incident (Technical Department Handbook, 1994).

An investigation required a study of all available information regarding the incident. Each of the involved departments or persons were asked to give an account of their view of the incident through an interview with a quality inspector. These statements were evaluated and integrated into the preparation of the Quality Investigation Report (QIR). The QIR was distributed to the relevant organisational departments, which had been involved in the investigation. The report included recommendations related to the factors contributing to the incident. For each recommendation the organisational department responsible for the action was named. These responsible departments were expected to suggest and implement the preventive actions required. When all recommendations had been accomplished, verified and documented, the Quality Assurance department officially closed the QIR.

The company's Accident and Incident Investigation Team was an internal group specialising in the investigation of more serious accidents and incidents. Expertise within the team was broadly technical and was made up from personnel from various departments including quality, safety and production. All team members had undertaken rigorous incident and accident investigator's courses. Team members for a particular investigation were chosen both pragmatically and on the basis of necessary expertise. Following the investigation recommendations were further explored by relevant area managers to assess their feasibility and plan a course of action. Two

investigation reports were examined and while the investigations were very thorough the recommendations were very broad and were categorised as either 'mandatory' or for 'serious consideration'. It appeared that while there was verification in assessing the development and implementation of the recommendations there appeared to be no follow-up in evaluating their effectiveness. In both types of investigation the company policy was to deal with personnel implicated in the incident and accident through discussion rather than punitively; in the case of serious incidents the issue of suspension of approval could arise but nothing would be decided without consultation with the union.

Quality Reporting

The quality reporting system was part of the functional control system that had the purpose of keeping the company management and other functions informed on performance in the flight operational and maintenance fields. A Non-Conformance Report (NCR) was a written report from any employee within the Technical Division that reported on incorrect methods, deviation from approved procedures and/or airworthiness data, the incorrect handling of documentation, incorrect component, and installations (Technical Department handbook, 1994). When a NCR was raised it was sent to the responsible Quality Assurance Inspector who would decide on the appropriate action and decide what other departments needed to be involved. The cause of the non-conformance was determined and recorded. It was the responsibility of the Quality Inspection Manager to process all non-conformance reports to a conclusion. Therefore it appeared to have similar objectives to the Quality Discrepancy Reports that the other two organisations used, except the quality inspector designated to different areas took responsibility for the NCR rather than a central Quality Department. In addition a cost analysis was also carried out in connection with the non-conformance.

Every 3 months each Quality Inspection Unit compiled a report with the following information:

- Total number of non-conformance reports with the period
- Cause detection trends
- Total number of recurrences
- Quality Cost
- The purpose/scope of the analysis.

Based on the analysis of the non-conformance and Quality Cost Reports, the respective production managers were responsible for the implementation of corrective actions in order to reduce and minimise the total quality cost. It was the procedure within the company that the initiator received a response to their report within 3 weeks. If it was not possible to meet that requirement the Quality Inspection Manager of the NCR-initiating maintenance unit would be informed and a revised date would be agreed.

A large number of reporting systems specific to departments and particular situations articulated in company documentation appeared defunct or were rarely used. It was reported that there was very little difference between these various reports and sometimes it is difficult to know which one to report what on.

At least two distinct forms of non-conformance reporting systems were in actual operation. The paper-based NCR system in operation was reported as log jammed with reports, which has resulted in a lack of confidence in the system. As a result the company were conducting a pilot scheme on the introduction of an IT based Non Conformance Reporting system (available on the company data network) in one of the hangars. This appeared to work efficiently due to the fact that the recipients viewed it in a positive light and were very receptive to the system. The fact that a manager as well as a quality inspector had been specifically delegated to action all NCR's directed in one department was also reported to have added to the success of the reporting system.

It was stated in the Airline Production Manual that the "established follow-up procedures aim to identify failures and deviations from standards in each process of the operation, therefore, firm procedures regarding analysis and remedial or corrective actions must be established and adhered to in a disciplined way". However it was reported that many of the reports (generating all sorts of information) were just filed away with no "related analysis".

Management Evaluation

The company had just recently introduced a management evaluation with the objective to review the suitability and effectiveness of the Quality System. It was the

responsibility of the Quality Manager and other relevant managers to perform a management evaluation at least twice a year. The areas under review involved previous decisions and tasks, performance according to objectives and standards, trends in NCR's, conclusions from Quality Audits, evaluation of management functions, quality system training. The objective of this review was to develop both preventative and corrective actions in order to improve the overall quality monitoring system. At the time of research the initiative was only just introduced and it was therefore too early too comment on it effectiveness.

Feedback

There did not appear to be any formal hierarchy of committees that met and discussed the outcomes of the various monitoring functions, unless there had been a very serious incident or accident. All outcomes from the audit reports were discussed at a local management level and all quality investigation reports were distributed to the relevant departmental managers, which had been involved in the investigation. Although there did not seem to be a systematic approach to dissemination of information on incident/accident reports beyond distribution to relevant managers, they were available if anyone wished to find out information. A summary version of these reports could be requested from the quality department; these versions would not contain any names of personnel implicated in the incident or accident.

Safety information was widely transmitted through Safety Bulletins that were posted on common notice boards at points of congregation all around the organisation. The company made very good use of effective and colourful posters in relaying the safety message. In many instances these posters explicitly referred to internal incidents and were placed alongside punctuality charts and projections for future punctuality performance.

Company C management considered themselves very open in relation to dissemination of safety information. One manifestation of the openness was in the treatment of aircraft engineers involved or implicated in an incident. The preferred method was discussion, or in the words of the manager for this section "a serious talk" but no removal of licensing or other official disciplinary proceedings. There did not appear to be knowledge of an actual company rule on the matter. Reports varied between feeling

that there should be more stringent sanctions and feeling that official sanction would remove management flexibility to deal with situations fairly. In addition, following an incident or serious accident, the relevant area manager would facilitate an informal and open discussion with his team of aircraft engineers and supervisors in order to inform what actually happened and to receive feedback on the recommended actions or further suggestions to prevent similar occurrences.

The company had a very open relationship with their regulatory authority and the latter had open access to all information sources within the company. The highly collaborative nature with the unions was also reported as a positive factor in disseminating and communicating information throughout all levels in the organisation.

Analysis

The company policy on "safety as No.1" was well understood and disseminated throughout the organisation. While the company did not have an explicit human factor programme, human and organisational concerns were built into their training, Total Quality Management (TQM) initiatives and other company initiatives. They had also developed their own internal safety standard, which was well embedded in the management systems. The company had a strong commitment to the planning and the organisation of work and had invested heavily in IT to support this function. It was reported that even though the company adopted a self-assessment model this did not always translate into improved processes in the workplace. However it was also felt that the company was moving in the right direction because of the continual monitoring of key functions and processes within the organisation.

It was also reported that there was a strong commitment to providing comprehensive and effective management training. It appeared that the company seem to go beyond auditing the documentation but also carried out substantial system and process audits. However it appeared that the reporting systems within the company were not being used as a tool for improvement. For example, an assessment of a number of the recommendations derived from quality investigation reports was found to be quite broad with no guidelines for preventative action. When it was asked how they would deal with such recommendations it was reported that it was up to the discretion of the

individual manager on what actions, if any should be taken. Overall feedback of information was very open and disseminated at all levels within the organisation.

Overall the analysis established a number of key issues in relation to the safety management system in Company C:

- A consistent safety message was disseminated and understood at all levels within the organisation.
- Proactive approach in managing beyond JAR145 (e.g., functional control concept, management evaluation).
- No explicit policy on human factors but adopted such an approach in various management areas.
- Commitment to investing resources for effective planning and organisation of work (e.g., IT systems).
- Highly collaborative working relationship with unions and regulators.
- Strong commitment to management training.
- The feedback from the various monitoring functions was not always apparent in relation to organisational improvement and learning.
- Quality inspectors played a key and complementary role at the operational level (e.g., inspecting work, dealing with NCR's).
- Development of a specialised team for serious incident and accidents rather than relying on quality investigators.
- Discussion preferred over more serious disciplinary actions.
- Open approach to disseminating information on accidents and incidents.

Description of Company D

Background

Company D was a wholly owned maintenance subsidiary of a European airline. The company was a provider of line & light, heavy maintenance, component and engineering services covering a wide range of aircraft. 35 percent of their work was with their airline and 65 percent was with third parties. The company employed approximately 2000 employees. The company's core capabilities were centred on Boeing 707, 727, 737, 747, 757, 767 and the Airbus 320, 310, 330, 340, and 300.

Strategy and Policy

Compliance and Operational Safety

The verbally expressed policies towards safety differed at the various levels in Company D. At the management levels economic goals, particularly cost and punctuality, were seen to have to be balanced against safety. However it was also pointed out that safety was a precondition before addressing the important goals of punctuality and cost and should not be compromised in anyway. At the operational level safety was expressed as a clear priority. Aircraft engineers reported that despite management's focus on punctuality, safety was still their number one priority and they never allowed performance parameters to approach too closely to unsafe practice. Overall it appeared that the safety policy was not clearly articulated throughout the organisation. In addition it was felt that this emphasis on punctuality had a bearing on a number of recent incidents within the company.

In response to these recent incidents there were strong signals from senior management that the disciplinary code should be enforced completely (e.g., docking wages, written warnings of varying degrees or the threat of dismissal). In some parts of the company this had been interpreted as the adoption of a "blame culture", whereas at more senior management, this was seen as a reaction to serious negligence. One manager reported that the 'lack of disciplinary sanctions and the lack of motivation is why this company is loosing money'.

It had also led to bad feeling between the management and staff at the operational level, particularly in one location where quite severe disciplinary sanctions were used on one of the aircraft engineers involved in one of the recent incidents. The aircraft engineer was dismissed but was reinstated after an appeal through his union. The aircraft engineer reported that they felt under pressure to perform to punctuality goals and so it was inevitable incidents would occur. However it was also reported that not all managers adhered to the policy of enforcing the disciplinary code, completely opting instead for discussion on the events that led to the incident.

There were plans to introduce a number of initiatives to accomplish greater control and clarity on company and organisational procedures. It was felt that something was required within the company especially in light of the incidents that raised a number of problems. Most notably the problems that surfaced included:

- No clear accountability or responsibility for work
- Lack of clarity in procedures for organising work
- Work not always written up
- Incidents of signing off work without sufficient checking of work
- No clear procedures or standards for shift handover/transferring information.

At the time of research while the plans to introduce initiatives to improve the work procedure system was a priority it was not clear what specific action plans were to be put in place. However it was recognised that introducing such changes could be confounded by established IR practice and culture within the company.

Human Factors

There was no explicit human factors programme although a number of managers attended 1-week IATA courses in human factors. It was reported that these courses encouraged the "interweaving and building of human factors" across departments. This "lighter" approach to human factors was preferred within the company rather than for example implementing a MEDA programme. It was felt that the MEDA programme was predicated on the notion of a perfect workplace and that it wouldn't succeed in the company because "... the perfect workplace could not be achieved without great cost

and with a clarification of the alignment of such a programme and a disciplinary procedure…"

Implementation of policy and setting standards

Maintenance Operations Control Centre (MOCC)

The organisation's focus on punctuality could be seen to manifest itself in the development of the concept of the Maintenance Operations Control Centre (MOCC). This was an integrated IT based information system on line maintenance that communicated with and co-ordinated between the various ramp-based parties such as Flight Operations, Fuel, Transport Co-ordination etc., as well as light and heavy maintenance. The key personnel involved in the MOCC included:

- Co-ordinators – communicated with all line maintenance functions including the flight crew, stores, fuel, flight operations etc.
- Dispatchers – primarily involved in planning and delegating manpower according to flight schedule.
- Parts co-ordinators – responsible for the co-ordination of parts, materials and tools.
- Support group - provided backup for the co-ordinators. The support group include engineers and planning personnel. While quality personnel were not always physically located on the line they could be 'called in' at short notice.

The MOCC was in effect a short-term planning centre (between 1-4 days) in advance where its success depended on effective communication and planning between the various functions (e.g., Flight Operations, Planning, Transport Coordination etc.).

The MOCC system appeared to be a very effective system in co-ordinating in order to meet punctionality objectives. Some concerns were raised in relation to the various co-ordination activities between so many parties on the ramp. Meetings were held at 8.30 every morning where the focus was on analysing the previous day's delays and attempting to learn lessons, and for watching the overall trend of delays. There was some concern expressed at the way that punctuality was used as a measure of performance in that it was impossible to legislate for every eventuality and as such it was an overly random measure. One comment was: "you have a day when everything

is set up everywhere and still something can go wrong (e.g., ATC constrictions) you cannot predict your problems, you cannot cover every eventuality".

The MOCC, light and overhaul maintenance had a team of instructors (who were very experienced and qualified aircraft engineers). The role of these instructors was to provide technical support to all the other aircraft engineers in trouble-shooting and any task they had difficulties with. It appeared that instructors played a very important support role in the overall operation and they were the link between the operational problem and the engineering solution.

Industrial Relations

Three different unions played a huge influential role on everything that went on in the company. Weekly meetings were held on a formal basis with company management and also on a more informal basis on the shop floor. One of the managers reported that almost fifty percent of his time was spent negotiating with the unions. Therefore any new programme or initiative had to be fully accepted by all the unions before the company could embark on implementation.

Management Training

All managers within the company were recruited as graduate engineers. There was a "ceiling effect" for the aircraft engineers in that they could not earn promotion into the managerial grades. There was the perception from the top that while technically the aircraft engineers were excellent they did not have what it took for the higher echelons of the organisation. Two of the managers interviewed felt that this was a very unjust and demotivating policy, but could not see this policy changing. There had been some standard management training courses (1 to 3 days) in communication, team building and assertiveness. This was reported to be 'ad-hoc', 'unsystematic' and not very effective. Most of the managers felt that "a good technical background was sufficient' for effective management.

Human Factor Training

There was no policy on human factors training in the organisation although discussions had commenced regarding the JAR 66 requirements for Human Factors training.

Black-books

Black books are unofficial versions of task documentation. These 'black books' can be anything between photocopies of frequently used parts of the official manual to notebooks with a variety of details from the manuals, recorded for use as a memory aid (torque values for particular bolts, for example). Virtually every aircraft maintenance engineer will admit (informally) to having his own 'black book'. However these are illegal documents, as only the official maintenance manual may be used as a guide to task performance. As manuals are frequently updated and amended, the great danger of unofficial 'black book' documentation is that it contains information which is out-of-date or otherwise inaccurate, and which therefore leads to incorrect task execution

As a result of a number of problems highlighted in recent incidents there had been a drive to obtain more control over production. One manager reported that "company documentation needed a complete overhaul...as there was an ever widening gap between practice and official rules". This had resulted in an initiative to address company and organisational procedures with the objective of developing greater control over them. In addition the company were planning to review the use of 'black books' and assess the possibility of developing some sort of formal black book that the aircraft engineers could utilise.

Monitoring

Auditing

In Company D one team of quality inspectors (answerable to production) carried out inspections of the aircraft. There was also a team of quality inspectors (answerable to Quality) that carried out audits on the relevant documentation, components, zones of the aircraft, housekeeping etc. It was stated in the company policy that these audits should be conducted continually although it was reported that because of time constraints that this did not always happen.

The actual auditing process was very similar to the other organisations. A quality inspector was assigned to conduct the audit, if any non-conformances were discovered the severity was assessed to determine the time frame for implementing corrective actions (e.g., immediate action, 2/3 months or 12 months). A plan (including time frame) for implementing the corrective actions was then developed by the quality inspector and forwarded to the relevant area manager. If the corrective actions were implemented within the specified time frame, the relevant manager notified the Quality Department in writing. Before closing the audit it was the responsibility of the Quality inspector to follow up and verify the effective implementation of the corrective actions. This follow up was not always carried out because of 'time constraints' or 'additional problems'. If corrective action(s) were not completed within the specified time frame, the quality department sent out reminders to the relevant areas. If these reminders were not successful, overdue audits would be raised at the safety management committee. This committee consisted of personnel from engineering, quality, flight operations, training, production and line maintenance and usually met once every 2 months.

The auditing policy was driven by compliance with the regulations with the overall aim of ensuring safety and improving standards. However there appeared to be little or no trend analysis from the different audits, so reactive measures were adopted each time to deal with similar problems rather than taking a more preventative approach. For example in one area, poor housekeeping was highlighted in 4 different audits over the space of 1 year. The recommendations or corrective actions for each audit were the same even though they were aware that these recommendations were largely ineffective.

Quality Reporting

Company D had recently introduced Discrepancy Reports (DR's)/Non-Conforming Material Report's. The stated objective was that "each important defect or unnecessary difficulty affecting the quality of the products shall be reported". The ultimate purpose of the discrepancy report was to improve process, quality and efficiency. It was highlighted in their Aircraft and Light Maintenance Instructions Manual that " it shall never be used against individuals or to any other purpose than it was intended". When a discrepancy form was completed it was sent to the Quality Department who assessed the report and passed it on to the relevant department for a reply. In the other organisations an aircraft engineer could complete a discrepancy report, however in

Company D a quality inspector who had been notified of a particular problem could only complete a discrepancy report.

It was reported that the follow up from the discrepancy reports was largely ineffective until the Corrective Action Board was formed as an aid to process the reports. The Corrective Action Board was made up of a number of personnel from all operational and support areas in the organisation. The role of the Corrective Action Board was to decide on corrective actions if a satisfactorily reply had not been elicited beforehand. Copies of all discrepancy reports were also forwarded to the safety committee. However it was reported that the DR's were seldom used in the company and each time one was raised the relevant department took "it as an insult" as they felt the blame was coming back on them. It was also reported that many of the aircraft engineers on line maintenance were unaware of the existence or purpose of the discrepancy reports. It was also felt that the perceived 'culture of blame' had a very negative impact on the ability of quality to establish the discrepancy reports as a more effective reporting mechanism. Therefore the blame policy was compromising the ability to get an accurate picture of what actually happened.

Incident Investigation

Only the more serious incidents and accidents underwent a formal quality investigation in Company D. The 'minor' or less serious incidents (e.g., no technical damage, no injury etc) were dealt with at a local level that usually involved an informal discussion between the shift manager and the aircraft engineer(s) implicated in the incident. The quality department were notified of this less serious incident and a report was filed in their records. To control the less serious incident reporting system regular meetings (Airworthiness Commission) consisting of four people were organised. The four people included: Safety Officer Flight Operations; Training Manager Flight Operations, Engineering Manager and Technical Quality Manager. The Airworthiness Commission met every two months and reviewed all the past cases and checked that the root causes were identified and that appropriate recommendations were made. The commission could also request a further formal investigation by Quality if they were not satisfied with the initial set of recommendations.

The formal quality investigation for the more serious incidents and accidents was similar to the other organisations and involved an analysis of all available information regarding the incident and interviews with responsible personnel. The National Aviation Authority was also notified as well as customers, the manufacturer or anyone else deemed relevant. Following the investigation the quality investigator(s) would issue a report of their main findings and arrange a meeting with the relevant area manager to develop recommendations. These recommendations (including time frame) were written up by the relevant area manager and signed off by the Quality investigator(s). Human factor issues were not identified and not addressed in any of the quality investigations.

When someone was implicated in a serious incident their approval was usually removed during the investigation and they were required to undergo re-training before their approval was renewed and they could return to their job.

Feedback

It was well recognised by company management that the most important function for managing safety was to deal with problems and change the situation through effective communication and feedback channels. Overall, however, it was reported that the formal communication of information and feedback did not work very well in the organisation even though the company had a number of formal management meetings (e.g., safety committee, the corrective action board, airworthiness commission). There appeared to be no effective analysis or follow up of results following incidents, audits and quality discrepancy investigations.

The company had the motto "from every accident and incident we learn". Safety bulletins were posted on general notice boards concerning specific incidents, which had occurred in that or in other departments, or concerning industry issues Airworthiness Directives (AD's). There were also pigeonholes for each staff member so that each person could receive personal copies of information leaflets. A running light had also been installed broadcasting short relevant messages to the workers on issues to do with job performance.

It was felt that communications problems in Company D were closely related to the bureaucratic nature of the organisation and the legacy of fear of management in some areas of the company inhibited the effective flow of information. One manager reported that contact with staff was viewed as very negative, "in the past calling a foreman into your office meant blaming him for a delay". It would appear that this had greatly damaged effective communication links between management and the rest of the workforce.

It was reported that at least 50% of management time was spent negotiating with unions. The poor relations between union and management appeared to focus on the lower priority assigned to safety issues by company management. One supervisor reported that the 'management's neglect of safety had given the unions ammunition which they constantly used in all negotiations'.

There appeared to be a very open exchange of information between the company and their National Aviation Authority. It was reported that Company D did not hide anything from the CAA and they insisted on a completely open policy to reporting incidents. There was the feeling that the national CAA had confidence in the company's management system. However it was felt that the National Aviation Authority blocked the empowerment of the aircraft engineers as they insisted on dual inspection. The aircraft engineers felt, as they were trained professionals, they deserved more responsibility and that they might feel more valued if they had more responsibility and did not feel that inspectors would always highlight their mistakes.

Analysis

In Company D safety contrasted with other goals and there were inconsistent safety messages at the different levels within the organisation. Demarcations and industrial relations were seen to inhibit effective planning, organisation and communication. The company had little or no commitment to management training. The main focus on the audits was on the documentation rather than the actual work and while a quality reporting system was used they had difficulty in achieving systematic follow through. The company had no explicit human factor method for incident/accident investigation and had no plans to implement one. However all accident and incident information was openly distributed both within and outside the organisation.

Overall the analysis established a number of key issues in relation to the safety management system in Company D:

- Contradictory safety priorities between management and operational levels
- Disciplinary sanctions widely enforced
- Control by management edict
- Prevalent IR climate
- No explicit human factor policy
- Effective short-term planning centre (MOCC)
- Aircraft technicians cannot earn promotion into the managerial grades
- Proactive approach in developing 'formal black book'
- Quality inspection and assurance in operation
- Quality monitoring functions not always effective in systematically improving the safety system
- Ineffective communication and feedback channels.

Comparative Analysis Across Organisations: An Overview

A number of salient characteristics of safety management systems and culture were identified through observations, documentation and interview analysis across the four organisations. Chapter 6 provides a much more detailed comparative analysis and discussion on these issues and their implications both for safety management and for the proposed model and methodologies. This section provides an overview of the key differences and similarities across the organisations.

Safety Strategy and Policy

- Compliance with JAR 145 was identified as a major focus of safety policy.
- The perception of senior management's commitment to safety differed both within and between organisations.
- All organisations had explicit documentation on infrastructure for safety management and responsibilities for safety, however these documents were by and large ineffectively realised in practice.

- Companies appeared to be open to initiatives such as human factors programmes, however Company A was the only organisation to explicitly have an active human factors policy.

Implementation of Policy and Setting Standards

- Companies A and C had embarked on organisational change initiatives with varying degrees of success.
- Union and industrial relations had a huge influence in Companies B and D.
- Company C appeared to have the most comprehensive management-training programme. Short training courses were available to most managers in the other three companies however these were reported to be largely ineffective. The other three organisations appeared to value operational skills more highly than management skills.

Monitoring

- Quality reporting systems varied in sophistication both within and between organisations. Company A appeared to have the most established system, however this system was log-jammed with reports. Companies' B and D systems were both in the early stages of implementation, while Company C had a number of independent systems with varying degrees of success in their operation.
- Quality inspection existed in companies C and D alongside quality assurance.
- Serious incidents and accidents were investigated by a specialised team in Company C rather than by quality assurance inspectors.
- Quite similar auditing practices across the organisations with the exception of Company C who appeared to audit actual work as well as the documentation
- Disciplinary sanctions were routinely enforced in companies B and D.

Feedback

- No system for routinely feeding back non-technical information in order to improve the system either at a strategic or operational level.
- Accident and incident information was found to feed mostly upwards in the organisations and to a much lesser extent laterally or downwards.
- Company B had a much more judicious approach to sharing incident and accident information both internally and externally compared to the other three organisations.

One of the key elements of the model was to assess what standards are in place to ensure effective safety management and overall safety performance and to assess if aircraft maintenance organisations go beyond compliance with JAR 145 to develop their own independent, internal standard of safe performance. This issue of internal standards was not explicitly referred to in the preceding descriptions as this question proved quite a problematic issue for the research, largely because the study failed to adequately define exactly what was meant by developing an internal standard. However a number of interesting findings warrant comment at this stage. A more detailed discussion on the internal standard is offered in chapter 6.

It became apparent during the interviews that while compliance with safety requirements set by the regulatory bodies was a major area of concern in policy, there didn't appear to be any internal independent standard to measure the effectiveness of safety management practices and overall safety performance. Company C was the exception, in that they had adopted an independent internally generated standard for evaluating their safety performance. The "internal concept" of the company was built around setting an internal standard for performance which was monitored and against which performance was measured. However while the philosophy of this internal standard was clearly documented it was not clear precisely how achieving this standard was measured within the company.

It was very difficult to find examples of consistent and effective improvements or change in maintenance safety management operations (particularly in response to human factor issues). While the Quality Systems undertook a variety of indicators of safety performance (e.g., QDR's audits), these were largely ineffective in leading to the identification of safety standards or initiating improvements as a result of these indicators.

Overall this analysis has identified that while it is the responsibility of every approved maintenance organisation, under the JAA, to manage and to be accountable for the safety and reliability of their operations, there are a number of salient issues that need to be addressed to ensure optimal and reliable safety management systems.

The above analysis based on the proposed model and methodologies systematically differentiated between the safety management systems of four European maintenance organisations. Each manager that took part in the interview reviewed a draft report on the findings of each of their organisations. Overall the managers requested very few changes, however slight amendments were required in order to completely de-identify a particular organisation or to 'tone' down a particular negative aspect of their safety management system. Therefore the final representation was recognised as valid and accurate by the organisations. The analysis in this chapter focused on four elements of the model. The next step involved applying the survey of procedure compliance and the ergonomic assessment in order to assess the fifth element of the model - 'normal operational practice'.

Chapter 4 - Managing Safety; Normal Operational Practice

Introduction

The interviews in the previous chapter largely focused on the role of the various management and support functions in ensuring safety and airworthiness of the aircraft. Another particular focus of the model was to measure important aspects of behaviour in normal operational practice and to compare this with how work is formally planned, prescribed, supported and monitored. Pidgeon and O'Leary (1994), for example, highlighted the importance of measuring important aspects of behaviour, what happens in practice (i.e., in the normal operation), and to compare this with the procedures and prescriptive norms of work.

Aircraft maintenance operations is characterised by a formal procedural system where all aircraft maintenance tasks have to be performed correctly, in conformity with all the prescribed procedures. Most maintenance tasks are documented in a task or work card format. Under the JAA regulations, the mechanism for ensuring that these tasks are performed correctly is that each task is signed off. Therefore the work-card is a legal document that when signed provides not only verification of the completed task but also exacts accountability from the aircraft maintenance engineer/inspector signing off the card, that the task was carried out in accordance with the prescribed procedures. One of the critical aspects of documentation use is the quality of the documentation as presented to the user. In aircraft maintenance organisations, documentation from the manufacturer is most often made available to technicians undertaking maintenance work through microfilm reader-printers or more recently on computer screens from CD ROMs.

Therefore this formal procedural system represents how tasks must be carried out in everyday maintenance operations. However despite the extensive formal procedural system of overseeing of aircraft maintenance operations, it has long been recognised that beneath the formal rules, task procedures and organisational structures, lies an informal structure, where adjustments, and deviations are the norm. It has been found that task procedures are not always followed, and the way maintenance operations are planned does not always take into account operational realities. Accident reports, for example, suggest that violations of procedures are relatively widespread, and are not

being identified and/or rectified under present systems. Therefore the overall objective of this chapter was to provide an insight into the relationship between the role of aircraft maintenance procedures and actual normal operational performance and practice.

This chapter provides an overview of some of the key findings of a study carried out as part of the ADAMS project - "Tasks Procedures in Aircraft Maintenance" (Daly, Corrigan & McDonald, 1997). In this study aircraft maintenance personnel across the four maintenance organisations completed a Survey of Procedure Compliance. The primary objectives of this survey were twofold:

- Identify the extent to which deviations from official maintenance manual procedures actually occur in aircraft maintenance
- Identify the most common factors underlying these deviations.

The overall study provided an in-depth analysis of a wide range of factors pertaining to the actual survey sample, specific task information, reasons for consulting and not consulting the procedures as well as reasons for actually following and not following the maintenance manual procedure. The study was also interested in the overall usability of the supporting technologies (e.g., microfilm reader printers and CD-ROM) in supporting the aircraft engineer in completing maintenance tasks in accordance with the prescribed procedures. Therefore an ergonomic assessment of the supporting technologies across the four maintenance organisations was also carried out.

This chapter provides an overview of some of the key findings from the Survey of Procedure Compliance and the Ergonomic Assessment of microfilm reader printers and CD-ROM. In particular this chapter focuses on key differences in normal operational practice across the four maintenance organisations with the objective of assessing if different practices have any impact on the level of non-conformance with official task procedures.

Survey of Procedure Compliance

286 questionnaires were completed and returned by maintenance personnel across the four organisations after they had completed a task. Table 7 provides a breakdown of participants by organisation. Years of experience in the companies ranged from 46 years to 5 years with the average being 14.5 years.

Table 7. Breakdown of respondents by organisation

Organisation	Company A	Company B	Company C	Company D	Total
Number	48	94	71	73	286

A wide range of tasks was covered in the survey. The tasks were comparable across the organisations as they all maintained similar types of aircraft and all the aircraft technicians underwent similar training in carrying out aircraft maintenance operations. The more familiar and routine tasks as well as the more difficult tasks were sampled across different shifts and across line and hangar maintenance.

The terminology for the description of maintenance personnel varied between organisations. However it was possible to group maintenance personnel under 5 categories:

- Apprentice – in training to become an AME (Aircraft Maintenance Engineer)
- Operative – no technical qualifications (e.g., painter)
- AME – Aircraft Maintenance Engineer (e.g., avionics, sheet metal, mechanical etc)
- LAE– Licensed Aircraft Engineer (e.g., aircraft engineer with higher levels of certification. Supervisor, aircraft station engineer)
- Quality Inspector – companies C and D has dedicated quality inspectors at the operational level.

Table 8 provides a breakdown of these five categories of maintenance personnel across the four organisations.

Table 8. Breakdown of personnel across the four organisation

Job Category	Company A	Company B	Company C	Company D	*Total*
Apprentice		3			3
Operative	5				5
AME	30	66	21	46	163
LAE	13	5	46	26	90
Inspector	0		3		3
Total	48	74	70	72	264*

* 22 participants did not indicate their job title.

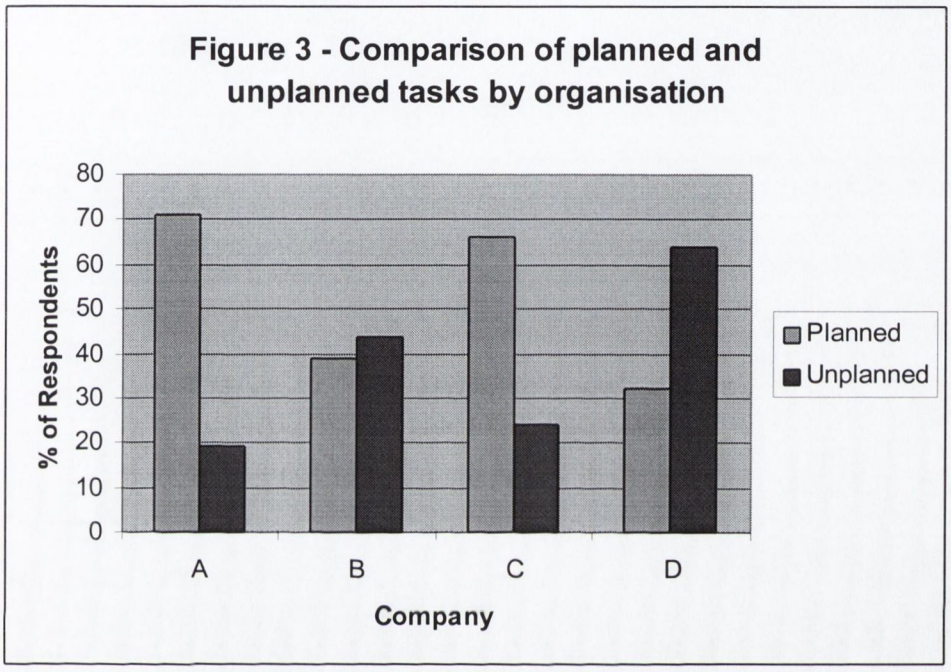
The aircraft maintenance engineers and the licensed aircraft engineers accounted for 96% of the overall sample. This was not surprising as both these categories are responsible for almost all maintenance tasks.

Planned Tasks

It is usually the case that only around 40% of aircraft maintenance tasks are scheduled or planned tasks and many more tasks are actually unscheduled or unplanned. This is because not all defects can be recognised or planned in advance and a critical aspect of the maintenance workload is dependent on recognising and identifying defects during maintenance and inspection activities (i.e., unplanned tasks). The survey was conducted with a guarantee of confidentiality. One of the consequences of this was that it was impossible to identify tasks, which had just been carried out, as this information could, in principle, be used to identify the aircraft engineer involved. Thus the opportunity to study in detail the characteristics of tasks and related documentation was not available.

Just under half (49%) of the tasks covered in this survey were reported to be planned or scheduled maintenance tasks. The amount of planned versus unplanned work differed significantly across the organisations (see figure 3). Higher levels of planned tasks were reported in companies A and C and Company D reported significantly higher levels of unplanned tasks compared to the other organisations ($\chi 2=42.858$, $p<.0001$). A number of reasons may account for the different levels of planned and unplanned tasks across the organisations. Depending on the type and stage of a check (e.g., inspection phase) it is inevitable that more unplanned tasks would be raised. While other aspects of the check (e.g., removal and installation) would be characterised by more planned tasks.

Unfortunately the survey was unable to discern either the type or stage of the check. One reason for higher levels of planned tasks in Companies A and C could be a result of more effective planning systems as the analysis of the management interviews in both these organisations did indicate a more effective and systematic approach to overall planning of maintenance operations.



Maintenance Manual Procedure

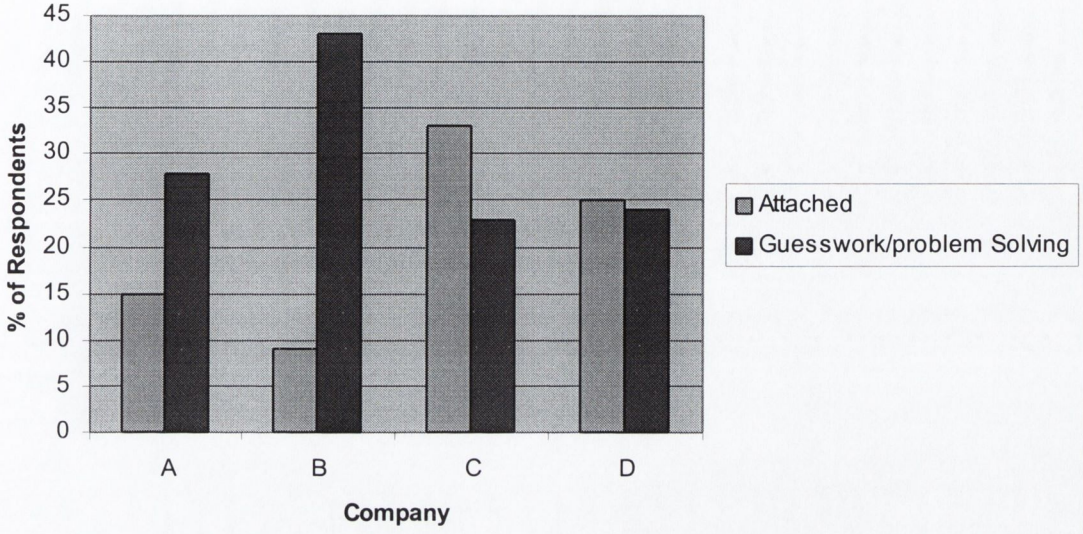
The task card is one of the most important documents both for aircraft maintenance personnel and for the overall maintenance operation as each planned maintenance task is documented on the task card. Therefore the clarity and adequacy of information on this task card is a very important support for the aircraft engineer. While in over ninety percent of tasks it was reported that it was clear from the task card what exactly the task was, nearly ten percent of the sample reported that the task card was not clear. When asked whether or not it was clear from the work card what steps had to be taken to complete the task, 17% replied that it was not clear. In addition 11% of the sample reported that it was necessary to defer certain items at the end of the task (i.e., the task could not be completed). Although the spread of results was not significant across the organisations, there did appear to be a trend towards higher levels of deferring tasks in Company D at 19% against an average over the other companies of 8%. A number of reasons for deferring tasks were reported across all of the organisations including: unable to identify the problem; unavailability of parts; and time pressure.

Overall 78% of the sample reported that a maintenance manual (MM) procedure existed for the task. It is often the case that in some maintenance organisations the relevant part of the maintenance manual is copied and attached to the actual work card. In this survey only 20% reported that the MM was attached. Companies C and D reported higher numbers of work-cards with the MM procedures attached than the other two organisations (see figure 4). Company C reported significantly higher numbers of work-cards with the MM attached ($\chi 2=15.450$, P<. 005) than Company B.

31% of the total sample felt that it was necessary to use guesswork, trial and error or problem solving skills in order to complete the task. Respondents in Company B were significantly more likely to agree with this statement at 44%, compared with the results from the other three organisations being relatively consistent at an average of 25% ($\chi 2=10.711$, $p<0.5$). Therefore almost half of the respondents in Company B reported using problem solving, guesswork or trial and error to complete a task. This raises questions to the adequacy of supporting documentation and technologies in Company B.

Looking at figure 4 it is interesting to note that those organisations (Companies C and D) that had the MM procedure attached were less likely to use problem solving, guesswork and trial and error to complete their task.

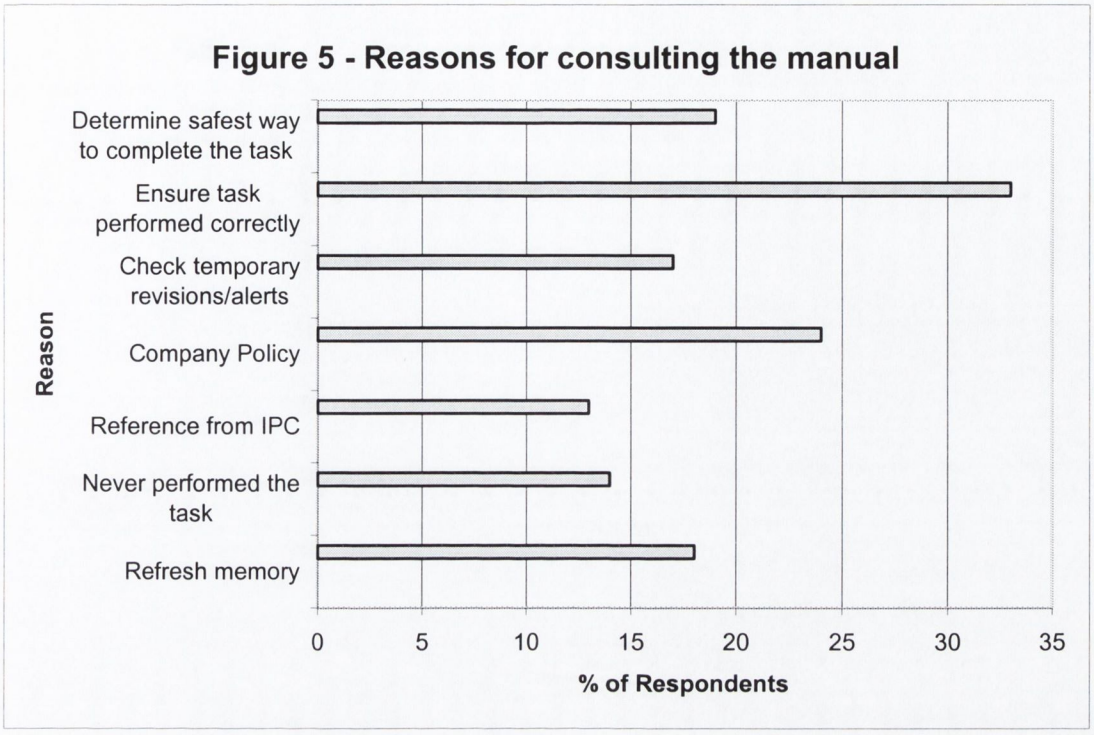
Figure 4 - Workcards with MM attached and the use of guesswork/problem solving across organisations



Consulting the Maintenance Manual

In total 44% of the sample reported that they did consult the maintenance manual procedure in order to complete the task (whether the MM was attached or not. There were no significant differences in consultation whether the MM procedure was attached or not). There was a significant difference in the spread of results across organisations ($\chi 2=14.311$, $p<0.005$). Company B reported the highest level of consultation (59%), followed by Company A (43%), and Company D (38%). Only 31% in Company C reported consulting the maintenance manual even though they were more likely than the other organisations to have the maintenance manual attached to the work card.

The most common reason for consulting the maintenance manual was to ensure that the task was performed correctly (34%). 25% of the respondents reported consulting the manual because it was company policy and 20% to determine the safest way to complete the task. These reasons were largely reflected within each of the individual organisations. Figure 5 outlines the range of reasons given for consulting the maintenance manual.

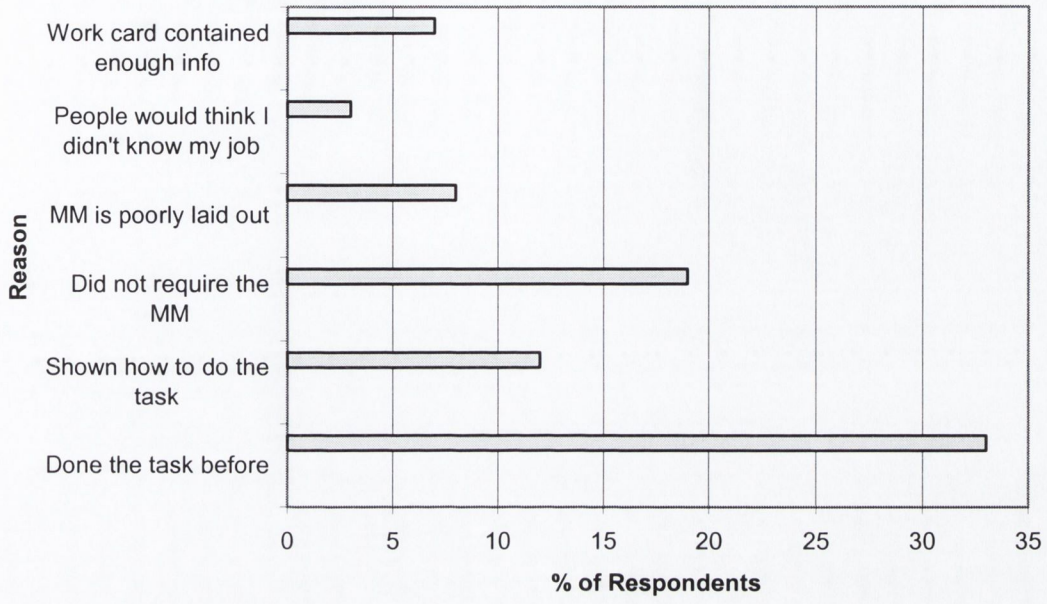


Not consulting the Maintenance Manual

The main reasons for not consulting the maintenance manuals included: 34% reported that they had done the task before and knew the correct procedure and therefore did not consult the manual; 19% reported that they did not require the MM to complete the task; and 12% reported that they received instruction from a colleague or supervisor. Figure 6 outlines six of the most common reasons for not consulting the maintenance manual.

Other reasons included: someone else was using the maintenance manual; the reader printer was unserviceable; the reader printers were in use, and other manuals were consulted. Many more respondents in Company C (30 compared to an average of 15 responses across the other organisations) reported that they had done the task before and knew the correct procedure. While this result was not found to be significant, this could explain why so few reported (31%) actually consulting the manual in Company C.

Figure 6 - Reasons for not consulting the manual

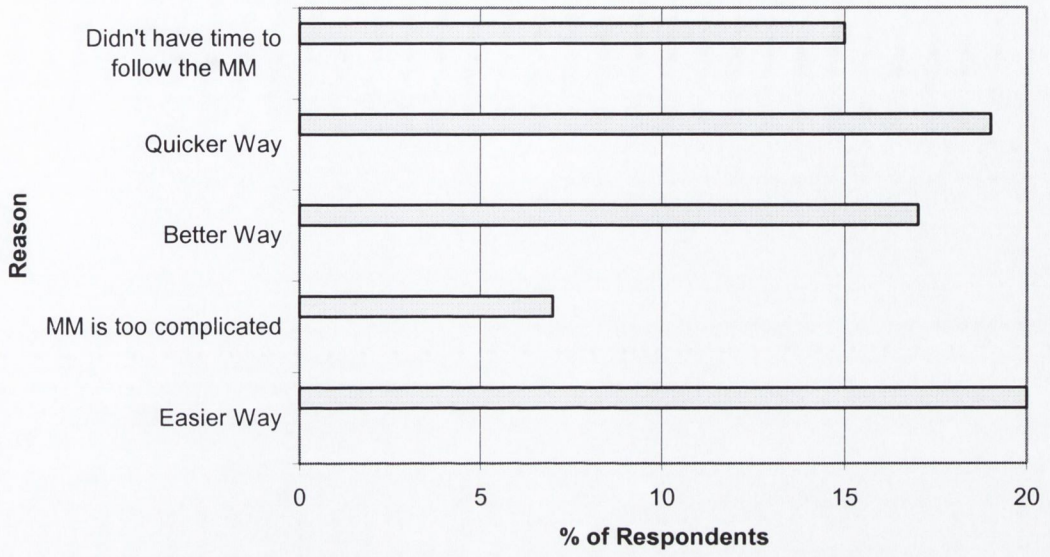


Following the Maintenance Manual Procedure

When asked the question "did you perform the method for performing this task exactly as laid down in the manual (whether or not you actually consulted it)?" In total 34% of the sample indicated that they did not follow the exact method. The level of non-conformance did not vary significantly across the organisations. Just under half of the respondents in Company D reported not following the maintenance manual procedure (47%). Just over a third of respondents in Companies C (37%) and B (36%) reported not following the maintenance manual procedure compared with (30%) in Company A.

The most common reasons for not following the maintenance manual included because there was an easier, quicker and better way to do the task and because time pressures did not allow following the official procedure. Again these results were largely reflected within each of the individual organisations (see figure 7 for reasons for not following the official maintenance manual procedure). Other reasons included the task was too difficult; shown another way to do the task by a colleague/supervisor; and wished to try out other ways of doing the task.

Figure 7 - Reasons for not following the Maintenance Manual



Because one of the main objectives of the study was to examine the level of non-conformance of official procedures and its relationship with other aspects of the task, the data were categorised as follows:

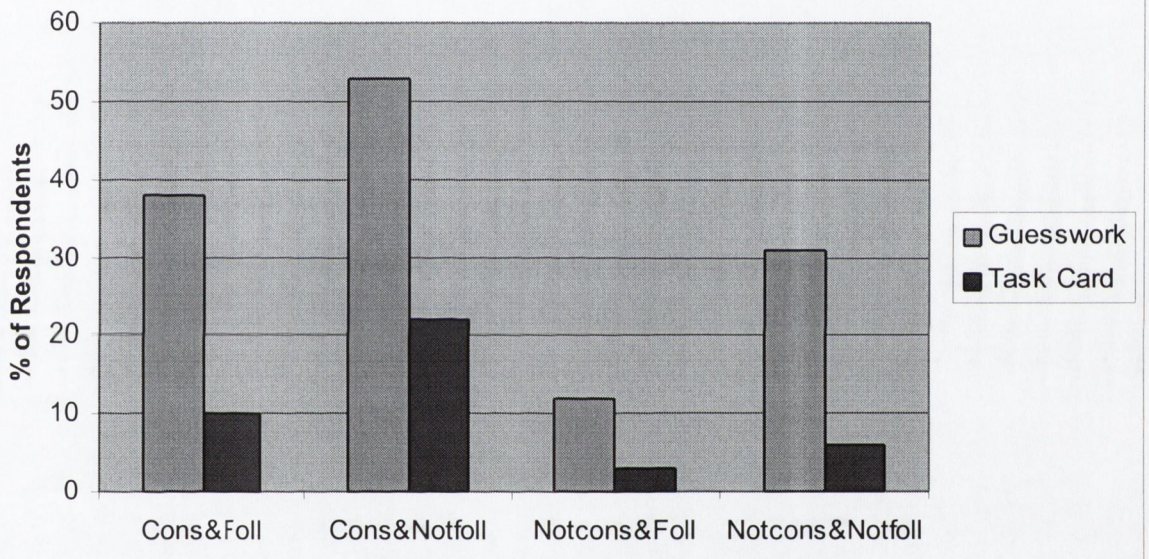
- Those who both consulted and followed the MM official procedure
- Those who consulted but did not follow the MM official procedure
- Those who did not consult the MM but followed the official procedure
- Those who neither consulted the MM nor followed the official procedure

Overall an average of 12% of the total sample reported consulting the maintenance manual and not following it with very few differences between the organisations. Companies A and B were more likely to report that they both consulted and followed the maintenance manual procedure, while significantly more respondents in Company C reported not consulting the maintenance manual but following it compared to Company B ($\chi 2=22.306$, $p<.05$).

22% of those that consulted the manual, but did not follow the MM procedure reported that it was not clear from the work card what steps to take to complete the task ($\chi 2 =21.706$, $p<.005$). This can be compared to an average of 6% across the other conditions of non-conformance. Also significantly more respondents reported

guesswork, trial and error or problem solving skills to complete a task when they had consulted but had not followed the procedure ($\chi 2=27.830$, $p<.0005$). Figure 8 outlines the results for task clarity and guesswork across the different levels of non-conformance. Therefore when the task card was unclear and guesswork was required respondents while consulting the manual did not follow it. Again this raises questions on the adequacy of maintenance manual procedures and how useful they actually are as a support for the maintenance aircraft engineer.

Figure 8 - Use of guesswork/problem solving and task clarity across levels of non-conformance



How did the two groups who reported *not* following the official method differ? Those who consulted the manual and those who did not were compared in terms of the reasons given for not following the official procedure. Only one reason significantly differentiated the two groups. This was the statement, "because there is a quicker way to do it than the MM method". Individuals who neither consulted nor followed the MM method were more likely to report that they had used a quicker method than that in the MM ($\chi 2=78.039$, $p<.0001$).

Task Support Documentation

The final section of the survey focused on the quality of documentation support. Problems were reported with the Maintenance Manual (MM), the Illustrated Parts Catalogue (IPC), the Wiring Diagram Manual (WDM), Structural Repair Manual (SRM) and the Minimum Equipment List (MEL). Poor print quality of the manuals from reader printers and information missing were the highest reported problems across all the sources of documentation. Other problems highlighted across all sources of documentation included inaccuracies in information, out of date information, and too much unnecessary detail. These problems were reported across all the organisations. In order to further explore the supporting technologies for documentation in aircraft maintenance an ergonomic assessment was carried out on the use of microfilm reader printers and CD-ROM as supports for task completion for the aircraft maintenance engineer.

Ergonomic Assessment (CD-ROM and Microfilm Reader Printer)

A number of research studies have identified a number of potential problems, which reduce the comfort, well being, and efficiency of display screen users (see for example, Schmidtke; 1980; Steward, 1995). Regulatory and other official bodies have also recognised the importance of good ergonomics in the design and use of display screen equipment. As a result regulatory bodies have developed standards, guidelines and regulations in order to protect the health, safety, comfort and efficiency of display screen users. Although the regulations are on the whole orientated towards the typical display screen user in the standard office, some attention has also being given to the non-standard environment.

The objective of this study was to determine if ergonomic requirements have been met in the use of microfilm reader printers and CD -ROM in the aircraft hangar and in the line maintenance environments. The aircraft hangar and line maintenance should contain one or two libraries, containing all the support documentation for maintenance engineers to carry out their tasks. Examples of support documentation accessible on CD-ROM or the more widely used microfilm reader printer include, for example,

Maintenance Manuals (MM), Illustrated Parts Catalogues (IPC) and the Standard Repair Manual (SRM).

An observational study in each of the organisations was conducted as aircraft engineers carried out a task. This was supplemented by brief interviews with the aircraft maintenance engineers when they had completed the task in hand.

An assessment of the microfilm reader printers and the CD-ROM was carried out separately and the findings were analysed under four broad areas:

1). Workstations (work desks/stations, work chairs)
2). Legibility of Displays
3). Hardware
4). Length and distribution of time operating the machine.

Microfilm Reader Printer

Workstations

All of the organisations had between 2 and 5 microfilm reader printers in the observed location. Company A had 5 in the hangar, company B had 2 on the line and 3 in the hangar, company C had 2 in the hangar and company D had 2 on the line and 2 in the hangar. In all the organisations there was a mix of both older and newer models of the reader printers and they were conveniently located to most tasks in the hangar. Obviously on the line, the aircraft engineers were required to access the reader printer located in line maintenance offices. In most cases the microfilm reader printers had large work surfaces with sufficient usable space. While one reader printer in Company B did have a large work surface, it was reported inadequate as it had to accommodate displays screens (parts ordering), keyboards, large old microfilm reader printer and microfilm cartridges (' [this] has added to congestion here on a few occasions...especially as it is necessary to spread documents on the work surface').

Only two of the companies (C and D) had adequate filing systems for the microfilm cartridges. Each of the cartridges were clearly labelled in relation to aircraft type and chapter number and filed systematically and conveniently to the microfilm reader

printers. This can be compared to the situation in Company B where the aircraft engineers when finished with a microfilm cartridge left it either by the machine (if there was sufficient space) or randomly placed it somewhere in the surrounding workspace. As a result many of the aircraft engineers reported that it usually took extra time (and 'much frustration') to locate the relevant cartridge.

In all of the companies the work chairs were assessed to be completely unsatisfactory. The work chairs were not stable and did not allow the user comfort or freedom of movement. Most of the chairs did not have seat backs and in those that did the seat backs were not adjustable in either height or tilt. By and large the chairs were in use for short periods of time, however it was reported that on a few occasions prolonged use was necessary because of the time it took to find particular procedures and diagrams.

Legibility of Displays

The requirement of this part of the checklist was to ensure that the image on the screen was legible under normal working conditions; and that there was sufficient adjustability in the display to allow the user to work comfortably and efficiently.
Since microfilm reader printers were usually used for archival storage, the image quality was dependent on the original source document. In practice, these were often poor and presented relatively low contrast images with extended use.

In many cases the actual screens were not kept clean or free from grime, which greatly reduced legibility. In most cases it was very difficult to read directly from the screen as both the screen and the microfilm were badly scratched or marked. This was not seen as too much of a problem by the aircraft engineers as they only read from the screen when they simply wanted to check something. Standard practice was to locate the relevant page, print it off and then read it.

Print outs from older models were of A3 size. This was reported useful as it placed related text and a diagram together rather than flicking between two pages. The quality, however from these print outs was generally very poor. Findings from the Procedure Survey also found that poor print quality was one of the problems experienced with the manuals. The print out quality from some of the newer machines was reported to be far superior but only A4 printouts were available therefore separating

experienced with the manuals. The print out quality from some of the newer machines was reported to be far superior but only A4 printouts were available therefore separating text and diagrams. Everyone agreed that the availability of the text and diagram was much more practical and useful on the one page rather than trying to compare two separate pages.

An aircraft engineer was usually given a maintenance manual chapter number on their work cards. Each microfilm cartridge contained a particular chapter number. Each chapter would have a few pages of contents with corresponding page numbers. The aircraft engineer would flick to the relevant page number and locate the information required. The quality of layout of this information appeared to depend on the manufacturer (Boeing or Airbus). There was overwhelming consensus that the Boeing format was much more practical than Airbus for a number of reasons. Aircraft engineers reported that the information in Airbus Manuals included too much unnecessary detail making it necessary to sift through a lot of extraneous information before locating what was required. For aircraft engineers who were accustomed to working with Boeing Manuals, Airbus's sequencing of information seemed illogical and was reported as 'a nuisance'. However this could be explained by the fact the Airbus Manuals were designed for CD-ROM use rather than microfilm reader printers.

Hardware

In the older microfilm reader printers most of the function buttons were not labelled. Aircraft engineers reported problems as some of the functions were too close together. For example the rewind (speed) and rewind (slow) functions were felt to be positioned too close together so if an engineer wanted to flick back page by page (rewind slow) he often found himself accidentally hitting the rewind (speed) button which took him right back to the start of a document. This was cited as the cause of much frustration, particularly in Company B.

In one of the older models in Company A the print button had to be positioned centrally before printing, sometimes it could be difficult to determine where exactly the central position was as the print function was very loose and had the tendency to swing back and forward. In addition when rewinding/fast forwarding there was no indication on the

screen how close you were to what you were actually looking for (that was the case in both the old and new machines). Overall the newer models were reported to be much more effective as all the functions were clearly labelled.

Length and Distribution of time spent operating the microfilm reader printer

In all of the organisations the aircraft engineers reported that in some instances they had to queue or wait to use the microfilm reader printer, especially if only one or two of the machines were working properly. The microfilm reader printers were used frequently and reported to be very unreliable. In one location (Company A) it was observed that only one out of a possible five was serviceable. Another problem cited, particularly in companies A and B, was the frequency of replacing the microfilm light bulbs. Breakdowns were not always reported even though under the Health & Safety regulations it is "an offence to leave any piece of equipment unserviceable or unreported". It was reported that due to the frequency of the breakdowns the aircraft engineers saw no point in reporting breakdowns every time.

Some of the aircraft engineers reported that they usually didn't spend too much time operating the reader printers once they knew what they were looking for and everything was in sufficient working order. However many did report that they still preferred to use the hard copy because it was much quicker and "easier on the eye".

CD-ROM

Workstations

Company B was the only organisation where their aircraft engineers did not have access to CD-ROM version of key manuals. However the company were in the process of investing in this resource. In the other three companies only certain manuals were loaded on the CD-ROM. The CD-ROM in these three organisations was used sufficiently during the observation in order to assess their utility. A large usable work surface was available for the users working on the CD-ROM. The same type of work chairs were used as for the reader printers and again were assessed to be completely unsatisfactory.

Legibility of Displays

The design of the user computer interface has a major impact on the job of many display screen users. The CD-ROM in all three of the companies had a large screen and it was kept clean and free from grime (all the machines were very new).

On observation it appeared that the software was easy to use and suitable for the task. Information presentation was reported to be very effective (e.g., helpful screen layouts, clever use of colour, the use of abbreviations which were meaningful to the users). The system also displayed the information in a format and at a pace, which was compatible with the user. The aircraft engineer could type in a task number (if available) and could directly locate the relevant information. The quality of the print outs and search facilities (e.g., keyword) were also reported to be very effective and helpful.

Hardware

The screen image was reported to be stable and free from reflection and glare. All the keyboards were tiltable and separate from the screen so allowing the user to find a comfortable working position avoiding fatigue in the arms or hands. In this environment as the users were not typing but making extensive use of a limited number of keys, it was helpful to rest the arms or the wrist, especially waiting for the system to respond, there was sufficient space to do this. The feel and travel of the keys are important for both accuracy and comfort. All the keyboards had suitable key actions and key top size. The keyboards did not suffer from sticking keys or inconsistencies. The CD-ROM was never known to break down in any of the companies although this may be explained by its lack of use and the fact that the equipment was relatively new.

Length and Distribution of time spent operating CD-ROM

Accessing CD-ROM was much quicker than microfilm reader printers. However on talking to the aircraft engineers in companies A and C it was found that they were not familiar with all the capabilities and functions that CD-ROM could offer (e.g., the key word search). Therefore in some instances they were spending more time than was necessary in accessing the information required. The aircraft engineers in Company D had just received training on the use of the CD-ROM and were therefore much more competent in its use. Training in the other two companies was quite limited although

there were plans to offer more comprehensive training courses. In addition those aircraft engineers working on Airbus aircraft reported that the presentation of the manuals on the CD-ROM was not very systematic, as they had to refer to different CDs for references etc.

Overall the findings from the ergonomic assessment indicated that the microfilm reader printers did not meet many of the requirements set by the regulations. In particular the poor standard and legibility of both the screen display and the print outs was highlighted as ongoing problems across the four organisations. The reader printers were also reported as unreliable, in Company A only one out of a possible five was actually serviceable, and constant breakdown seemed to be accepted as normal operational practice across the organisations. It also appeared that accessing the information from the reader printers was quite time consuming because of their unreliable nature and their limited functionality. In contrast accessing CD-ROM was found to be much quicker and the computer interface was reported to be much more compatible with users requirements. The quality of the print-outs, key functions such as key word search and quicker accessibility were all reported to be very effective support for the maintenance task.

The aircraft engineers did report, however, that they preferred to use the microfilm reader printers. This could be explained by the fact that the engineers were very familiar with and experienced in using the reader printers. Therefore many of the users opted to "stick with what they knew best".

On the other hand the CD-ROM was relatively new and training in its use was quite limited in companies A and C. Company D had just received training in using the CD version and they reported higher levels of use.

In most instances, the use of the microfilm reader printers was for short periods. Nonetheless, such work can be visually demanding and could potentially pose many visual and postural problems in the above environments. While the CD version appeared to be superior it appears vital that comprehensive training is provided to

ensure that the maintenance engineers obtain optimal efficiency in accessing the support documentation that is essential for their everyday tasks.

Overall Summary

This chapter reported on a selected number of findings from a study carried out as part of the ADAMS project – "Tasks Procedures in Aircraft Maintenance" (Daly, Corrigan & Mc Donald, 1997). The particular objective of this chapter was to focus on normal operational practice across the four maintenance organisations and assess if different practices had any impact on the level of non-conformance with official task procedures.

In this study aircraft maintenance personnel across the four maintenance organisations completed a Survey of Procedure Compliance and took part in an observational study assessing the ergonomics of the supporting task technologies (e.g., microfilm reader printers, CD-ROM).

A total of 286 aircraft maintenance tasks were represented in the survey. The objective of which was to identify the extent to which deviations from the official maintenance manual procedure occurred in completing maintenance tasks and to assess the most common factors underlying these deviations.

A number of significant differences were found across the four maintenance organisations, particularly in relation to planned vs unplanned tasks; the practice of attaching the maintenance manual to the work-card; use of problem solving, guesswork and trial and error in completing tasks; levels of maintenance manual consultation; and the use of CD-ROM in supporting maintenance tasks. While quite high levels of non-conformance with the official task procedures were found across all four organisations, no significant differences were found between the organisations in the levels of non-conformance.

Company D reported significantly higher levels of unplanned tasks compared to the other companies while Companies A and C reported higher levels of planned maintenance tasks. The survey did request a maintenance manual reference number and a work card number in order to identify each particular task, though very few of the respondents offered this information. Respondents explained they were reluctant to

submit this information as it would not only identify the task but would also identify the individual. Therefore if they admitted to not following the maintenance manual procedure they were in effect admitting to 'breaking the law'. Some respondents even refused to give their certification level and number of years service specifically reporting that they wished to be completely anonymous. As a result it was almost impossible to determine why there were differences in planned and unplanned tasks in each of the organisations. One could infer from the results of the management interviews that both companies A and C were much more dedicated and committed to improving the planning systems for maintenance operations compared to Company D and this may have an impacted the higher levels of planned tasks.

It was found that it was significantly more likely that Companies C and D would have the maintenance manual procedure attached to the work card, although when one compares the overall level of non-conformance both these companies reported higher levels of not consulting and not following the maintenance manual procedure compared to the other organisations. So therefore it would appear that having the relevant part of the maintenance manual copied and attached to the work-card does not necessarily ensure conformance with the task procedure.

Just under one third of the respondents reported that it was necessary to use guesswork, trial and error and problem solving in order to complete a task. Again a significant difference was found between the organisations, with respondents in Company B significantly more likely to undertake such activities in order to complete the task. Also significantly more respondents reported using guesswork etc even when they did consult the maintenance manual but did not follow it. All of this raises questions with regard to the adequacy of the maintenance manual procedure itself and the confidence aircraft engineers have in their usefulness when they still have to resort to guesswork and trial and error even when they have consulted the official procedure.

The results of this survey showed that overall 34% of respondents reported not following the official procedure for the task because there was either an easier way, a quicker way or better way to complete the task than what was laid down in the manuals. In addition problems were reported with a range of key manuals including the Maintenance Manual (MM), the Illustrated Parts Catalogue (IPC), the Wiring Diagram

Manual (WDM) and the Structure Repair Manual (SRM). Poor print quality of the manuals from the reader printers and information missing being the highest reported problems across all sources of documentation.

The ergonomic assessment of the microfilm reader printer supported the problems uncovered by the survey. It was found that poor serviceability, frequent breakdowns, limited functionality and inadequate workspace and storage as well as poor quality printouts characterised the reader printers in the organisations. While the introduction of the CD-ROM version of manuals did appear to overcome many of these problems, their introduction was relatively new and only Company D had offered extensive training in their use. Therefore aircraft engineers in companies A and C tended to choose the more familiar but highly unreliable reader printers over the CD-ROM.

In conclusion the quality of task documentation and usability of documentation technology across the four maintenance organisations was reported to be inadequate and in over one third of tasks aircraft engineers reported that they did not follow the procedure according to the maintenance manual. Even though differences were found in each of the organisation's operational practices, no significant differences were found in their levels of non-conformance with official task procedures. All of the organisations reported that there was an easier, quicker and better way to do the task that what was prescribed by the official documentation. So what are the implications of these results?

Maintenance personnel were not surprised at these findings. In fact, it was suggested that the level of non-compliance reported was an underestimate of its true level. This may be so - these aircraft engineers were, after all, reporting an illegal act, which could in principle have had severe consequences if traced back to them. The survey was conducted with a guarantee of confidentiality, otherwise it would have been impossible. One of the consequences of this was that it was impossible to identify the tasks, which had just been carried out, as this information could, in principle, be used to identify the aircraft engineer involved. Thus the opportunity to study in detail the characteristics of tasks and related documentation where procedures were not followed was lost. This exemplifies a dilemma, not just for the survey, but also for the industry. Virtually everyone close to the industry knows that procedures are not strictly complied with, but

there is a reluctance to formally admit it. Thus there is an ever-widening gap between practice and official rules and procedures.

While the frequency of non-conformance with official methods was established at 34%, it was not assumed that this implied unsafe practice in 34% of tasks. It seems to be the case that aircraft engineers do not actually need the detailed information in the manuals, and rely instead on illegal 'black books'. Black books are unofficial versions of task documentation. These 'black books' can be anything between photocopies of frequently used parts of the official manual to notebooks with a variety of details from the manuals, recorded for use as a memory aid (torque values for particular bolts, for example). Virtually every aircraft maintenance engineer will admit (informally) to having his own 'black book'. However these are illegal documents, as only the official maintenance manual may be used as a guide to task performance. As manuals are frequently updated and amended, the great danger of unofficial 'black book' documentation is that it contains information which is out-of-date or otherwise inaccurate, and which therefore leads to incorrect task execution. The fact that virtually every aircraft engineer, despite their illegal status, uses these unofficial black books suggests that there is something very important lacking in the official documentation, which is available to aircraft engineers as they perform their work.

Aircraft maintenance engineers and their managers also have a contradictory understanding of what the job of the aircraft maintenance engineer involves (Biemans et al., 1997):

- The aircraft engineer sees himself as being responsible for the safety of the aircraft, and to use his judgement to do what is necessary to ensure this (not always exactly as in the manual – sometimes more).
- The manager sees the primary role of the aircraft engineer to follow procedures as laid down – if this is done, safety will be ensured. On the other hand it is often stated that if work was done strictly according to the written procedure, nothing would get done on time.

Therefore maintenance engineers are constantly expected to consult these detailed manuals and carry out lengthy procedures in order to complete a task correctly. However, they are also under pressure to complete each task by a certain deadline, and

thus a problem arises: to get the task done safely requires time that the aircraft engineer often cannot afford.

Informal comments and comments on the questionnaires indicated that respondents were well aware of the "double standard" of being required to work under time pressures *and* follow official procedures. There is an official way of doing things, which is laid out in the documentation, which has legal status, but which objectively does not meet user needs. Then, there is the way in which work is actually done, which is supported by unofficial documentation and which frequently diverges from the official way. Therefore the maintenance organisations' quality control departments, engineering departments and company management are unaware of the information that is actually being used for task completion. Only one of the maintenance organisations in this study (Company D) officially recognised that some alternative to the lengthy manuals was required, where they were planning to review the use of 'black books' and assess the possibility of developing some sort of formal black book that the aircraft engineers could utilise.

Overall there is little evidence that aircraft engineers see the official task documentation as a useful real-time resource in carrying out their work. At the point of maintenance operations, documentation does not have a close relationship with task performance. Therefore, making better documentation may not have more than a marginal effect on task performance or lead to greater compliance with procedures as documented, unless more fundamental issues are tackled to do with the way in which the task is understood or performed.

The official way of doing things is laid out in the documentation, which has legal status, but objectively does not meet user needs. Then, there is the way in which work is actually done, which is supported by unofficial documentation and which frequently diverges from the official way. The unofficial and illegal status of these informal work practices means that they tend to be hidden and unavailable to scrutiny. It is thus impossible to know how much of this informal work practice represents better ways of doing things than following the manual to the letter, or how much this might increase risk because important safe-guards contained in the documentation are being ignored.

This study as well as identifying the extent of deviations from official maintenance manual procedures in aircraft maintenance, has also raised important questions about the actual role of official documented task procedures in aircraft maintenance. For example issues to do with the design and function of procedures need to be addressed in a systematic manner. In addition key issues on the role of unofficial documentation needs to be addressed at both an organisational and regulatory level in supporting safe and reliable ways of working in aircraft maintenance in a transparent and open manner.

Chapter 5 – Managing Safety: Analysis of Safety Attitudes, Safety Climate and Incident Management

Introduction

Describing and comparing the key functions of safety systems cannot provide all the necessary information to evaluate safety systems or the underlying culture. Definitions of safety culture imply the beliefs and attitudes of individual employees underpin the key elements of a safety culture, and that these underlying beliefs are shared among employees. Research in this area has focused largely on understanding employee's safety attitudes and perceptions on the effectiveness of their safety management. Understanding the underlying culture requires an assessment of both the key safety rules, practices and processes as well as the less visible norms, attitudes, values, beliefs and perceptions towards the overall safety system itself.

Three separate surveys measuring safety attitudes, safety climate and incident reporting were developed. The objective of these was to provide a quantitative assessment of individual's attitudes towards safety and their overall perceptions of their safety and incident management systems. These data provide an indication of the underlying culture of each of the organisations, as safety climate can be regarded as a surface feature of the safety culture discerned from the work-force's attitudes and perceptions at a given point in time (Schneider & Gunnarson, 1991; Cox & Flin, 1998). In addition the determination of safety climate has been put forward by some authors as an alternative indicator of safety performance compared to the more retrospective analysis of accidents and incidents. A survey assessing the perceived consequences of incident involvement and reporting was also developed. The inclusion of the incident survey provided a quantitative assessment of the overall incident management system focusing on probabilistic assessment outcomes given certain scenarios (e.g., comparing perceptions of outcomes depending on whether or not they led to a reported flight incident). The safety attitude, climate and incident survey were administered together as one survey across the four organisations.

The objective of the research was to carry out a comparative analysis of safety management systems and safety culture across four organisations. Therefore a FA was conducted in order to determine the key dimensions of Safety Climate and each of the

organisations were assessed on these dimensions. A number of MANOVA's were conducted in order to assess interactions between the safety climate factors and job types within each of the organisations.

As the safety attitude and safety climate surveys were adapted from scales developed for aircraft ramp maintenance (Cabrera et al., 1997), the first objective of the analysis was to determine the reliability of each scale. As a step towards identifying the key dimensions of safety climate in aircraft maintenance, a Factor Analysis using SPSS (via principal component analysis with varimax rotation of factors) was carried out on the safety climate scale. Two factors were identified from the scale. As the objective of the study was to describe and compare safety management systems and culture both across and within the organisations, One Way Analysis of Variance (ANOVA), Multivariate Analysis of Variance (MANOVA) and Tukey post hoc comparisons were conducted in order to compare each of the factors across the organisations and across different job types. A number of significant differences were found when the factors were compared across organisations and different job types and these differences largely reflected the interview analysis. The results also supported the existence of different climates within companies (e.g., Reichers & Schneider 1990).

The primary objective of the analysis of the attitude scale was to determine the overall level of safety attitudes both across and within each of the organisations. One Way Analysis of Variance (ANOVA) and Tukey post hoc comparisons were conducted in order to compare levels of safety attitudes across the organisations and across different job types.

As the incident survey data was categorical in nature Chi-Square analyses were conducted to assess differences both within and between organisations in relation to consequences of incident involvement and sources of information for incident notification. Again a number of significant differences were found both across and within organisations in their perceptions of their company's response to incident involvement.

This chapter consist of seven main sections:

- Analysis of the Survey Sample

- Reliability Analysis on Safety Climate Scale
- Factor Analysis on Safety Climate Scale
- Reliability Analysis on Safety Attitude Scale
- Analysis on Safety Attitude Scale
- Analysis on Survey Measuring Incident Management
- Overall Conclusions.

Analysis of overall Survey Sample

A total of 800 questionnaires were distributed across the 4 maintenance organisations and 669 were completed and returned (a response rate of 83.6%). From the sample 581 were male, 11 were females and 77 didn't indicate either way.

A wide range of job categories across all of the organisations took part in the survey. Respondents included unqualified operators; apprentices; aircraft engineers; licensed aircraft engineers; supervisors; shift managers; material personnel; quality personnel; graduate engineers; planning personnel and a range of operational management. Comparability of job categories across organisations was not always self-evident, therefore it was not always possible to pre-plan filling job categories with equal numbers. In particular a number of low responses were found in some of the job categories across the 4 organisations. As result, for the sake of analysis the range of job types were separated into three broad categories: operational staff, operational management and support personnel. 230 questionnaires were completed in Company A, 141 in Company B, 76 in Company C and 222 in Company D. Table 9 provides a breakdown of job types by organisation.

Table 9. Breakdown of Job Types by Organisation

	Operational Staff	Operational Management	Support Functions	Total
Company A	182	26	16	224
Company B	109	17	15	141
Company C	51	9	14	74
Company D	156	30	31	217
Total	498	82	76	656

While 669 questionnaires were collected only 656 indicated their job type leaving 13 missing cases. The 13 cases were included in the analysis except those by job type.

The category of operational staff included aircraft maintenance engineer, licensed aircraft maintenance engineer, apprentices and unqualified operators. Operational management included crew manager, shift manager, aircraft overhaul manager, production unit manager and general manager. The support category included quality, planning and engineering personnel as well as some administrative grades. Operational staff accounted for the biggest percentage (72%) of the overall sample, and the largest percentage of the sample within each of the organisations. This is not surprising as operational staff accounted for the largest group of personnel in all of the organisations.

The average length of time in the job across the companies was 3 years and ranged from 'just started' to 42 years. For the sake of comparative analysis length of time in company was categorised under the following: less than 1 year; 1-5 years; 6-10 years; 11-15 years; 16-20 years; 21-30 years; 31-42 years. Table 10 provides a breakdown of respondents by length of time in the company. The overall average length of time working in the companies was 14 years and it ranged from just 5 months in the company to 42 years. 16 years was the average length of time in companies A, B and C, while 10 years was the average length of time in Company D.

Table 10. Breakdown of respondents by length of time in company

	Company A	Company B	Company C	Company D	Total
> 1 year	6	4	1	15	26
1-5 years	7	3	4	37	51
6-10 years	86	51	23	79	239
11-15 years	17	9	20	63	109
16-20 years	25	27	8	14	74
21-30 years	68	29	15	3	115
31-42 years	15	15	4	8	42

While 669 questionnaires were collected only 656 indicated their length of time in company leaving 13 missing cases across the organisations.

Analysis of Safety Climate Scale

Reliability Analysis of Safety Climate Scale

A reliability analysis and item correlation study showed an internal consistency (Cronbach Alpha) value of .8861 on the Safety Climate Scale. However one item 'Employees who are trained in safety perform their work better' obtained a low correlation (.0934) with the scale total compared to the other items. As a result this

item was eliminated and resulted in a slight increase in the overall scale reliability (Cronbach Alpha) value of .8901. The reliability of the scale was just slightly below the original safety climate scale where the reliability analysis and item frequency distribution study showed an internal consistency (Cronbach Alpha) value of .93 (Cabrera et al., 1997).

Factor Analysis on Safety Climate Scale

Although the Cronbach alpha was high the study was interested in evaluating what type of dimensions constituted the concept of safety climate. The total sample across the 4 organisations was included in the Factor Analysis. This was on the assumption that the close similarity in type of work and in safety management systems between the organisations would have resulted in a common underlying factor structure by which each of the organisations could be assessed and compared. It was also felt that pooling the sample across all four organisations increased the overall sample size of the data and therefore provided more reliable results. In the 20-item Safety Climate Scale, 17 of the items were expressed positively and 3 were expressed more negatively. All 17 positive items were reversed for the purposes of the analysis.

A factor analysis using SPSS (via principal components analysis with varimax rotation) was conducted in order to establish the factor structure of the scale. The factor analysis identified three factors with eigenvalues greater than one. Twelve of the items loaded onto Factor 1, 6 items loaded on factor 2, and only 1 item loaded onto a third factor. As one item does not really constitute a factor, this item was also eliminated and a second factor analysis was conducted on the remaining items.

The second Factor Analysis identified two factors with eigenvaulues greater than 1 that accounted for 51% of the overall variance. The first, and by far the most important dimension (or factor) was concerned with management's or the company's commitment to safety. The factor included dimensions such as management commitment to compliance with safety standards and procedures, management response to safety problems and safety violations and management's priority to safety matters. Factor 1 (Management Commitment to Safety) accounted for 44% of the variance and contained 12 of the 18 items. The second factor was concerned with management's communication and resources on safety matters and included dimensions such as

management's willingness to adapt new ideas to improve safety and procedures for making suggestions to improve safety. Factor 2 (Communication and Improvement) accounted for 7% of the variance and contained 6 of the 12 items. See table 11 for the two factors of safety climate.

All of the items were clearly distributed in each factor except for item 11 that loaded on both factors. For the purposes of the analysis it was decided to retain this item in Factor 1 as it loaded highest on this factor and it just made the cut off in Factor 2. A reliability analysis showed and internal consistency (Cronbach Alpha) values of .8781 for factor 1 and .6968 for factor 2.

The original scale developed by Cabrera et al., (1997) consisted of 5 dimensions while the analysis of the scale in this study uncovered 2 dimensions. However the original scale consisted of a larger number of items and was administered to a ground handling population. Therefore a direct comparison between the two scales is not applicable.

Table 11. Factors for the items related to safety climate in the total sample

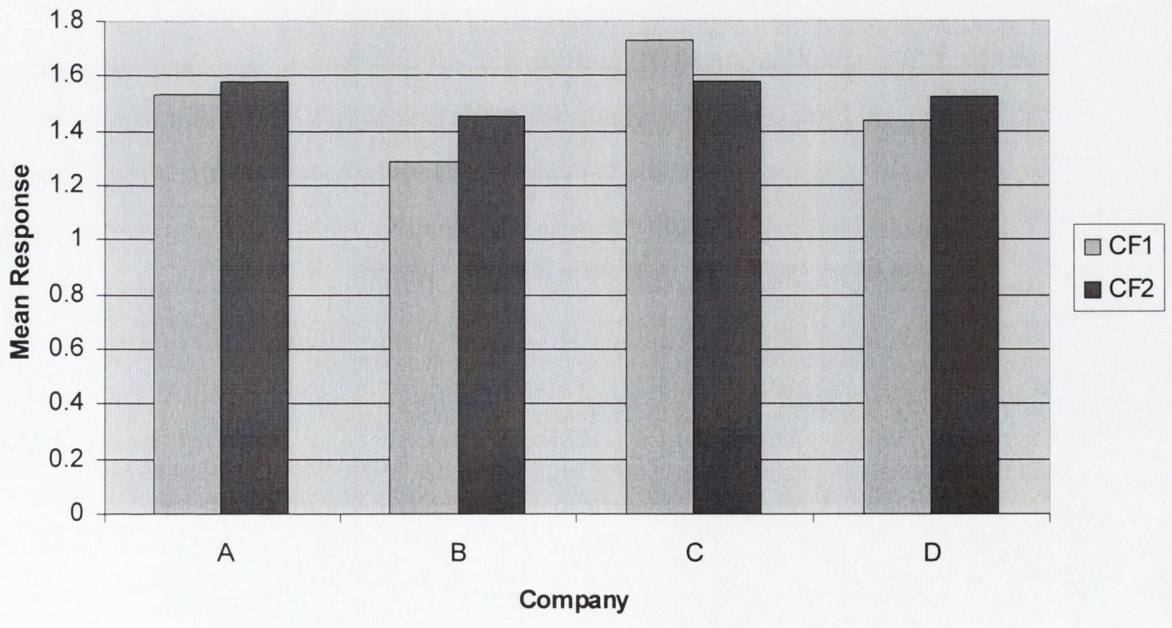
ITEMS	F1>.3)	F2 >.3)
Company commitment to safety		
1.My Company invests sufficient funds and resources in the prevention of accidents	.762	.127
5.In my Company, productivity is more important than safety	.718	.170
2.My Company managers are strongly committed to full compliance with safety standards and procedures	.717	.265
6.My company managers are really concerned about safety problems	.712	.293
4.When my Company management becomes aware of a safety problem arising at work, it quickly takes corrective action	.627	.196
11. My Company places great importance on full compliance	.579	.312
8.It is just a matter of time before I find myself involved in an accident	.576	-.284
14. Those in authority respect safety standards and procedures	.569	.223
13. Working safely is the top priority in my Company	.514	.215
7.Our managers take safety standard violations very seriously even when they do not result in an accident	.506	.138
15. In comparison with other maintenance facilities, this is one of the safest	.467	.145
3. My co-workers respect safety standards and procedures	.375	.244
Communication and Improvement		
16. My company regularly reminds the workforce about safety standards	.129	.659
18. My company managers would like to invest more resources to improve safety levels	.103	.614
9. We have a simple procedure for making suggestions to management in order to prevent accidents	.115	.566
17. Management in my company is continually informed whether work safety standard are complied with	.293	.561
10. Resources directed at safety training make a positive contribution to the functioning of our Company	.119	.523
12. The managers in my company are willing to adopt new ideas in order to improve safety	.164	.477
Percentage of variance explained	43.768	6.990
Cronbach Alpha	.8781	.6968

Comparison of Safety Climate Factors across organisations

The next step involved comparing each of the two climate factors across the organisations to determine if there were any significant differences or trends. Figure 9 demonstrates the differences on each factor across the four organisations with 1 being the lowest possible score and 2 the highest (1.5 is the midpoint).

One way analysis of variance (ANOVA) indicated a significant difference between the organisations on Factor 1 ($F(3,661)= 41.89$), $P<0.001$. Tukey's post hoc comparisons showed each of the organisations differed significantly from each other on this factor ($P<0.001$). Company C (1.73) scored most positively on this factor, Company A (1.53) scored just above the average, while Company D (1.44) and Company B (1.29) scored below the average. Therefore Company C was more likely to perceive that their company management were committed to safety compared to the other three organisations and Company B were found to have relatively negative perceptions on their company management's commitment to safety. This finding mirrors the results from the interview study where expressed commitment to safety ranged from safety being seen as core to commercial success in Company C to being in tension with commercial survival as portrayed in Companies B and D.

Figure 9 - Safety Climate Factors by Organisation



The results on the factor analysis on factor 2 also largely reflected the interview analysis. A significant difference between the organisations on Factor 2 ($F(3,655)=3.782$) $P<0.05$ was also found. Tukey's post hoc comparison showed that Company A (1.56) demonstrated a significantly more positive response compared to Company B (1.45).

These results indicate that Company A perceived their safety communication and improvement strategies to be more effective than they were in Company B. Company A had invested in dedicated resources in a number of different communication channels. For example the adoption of a number of human factor approaches to investigating and disseminating incident information (e.g., human factor magazine) that continually reminded the work force on safety standards. Also their organisational change initiative was widely disseminated throughout the organisation as an integrated tool for improvement in 'safety, reliability and efficiency'. On the other hand Company B's communication strategy was less formal where company management relied on verbal briefings which were meant to 'cascade down' to their subordinates in a sequence of briefings at junior levels. Company C (1.55) and Company D (1.52) were found to rate their company's safety communication and improvement strategies in a moderately positive light.

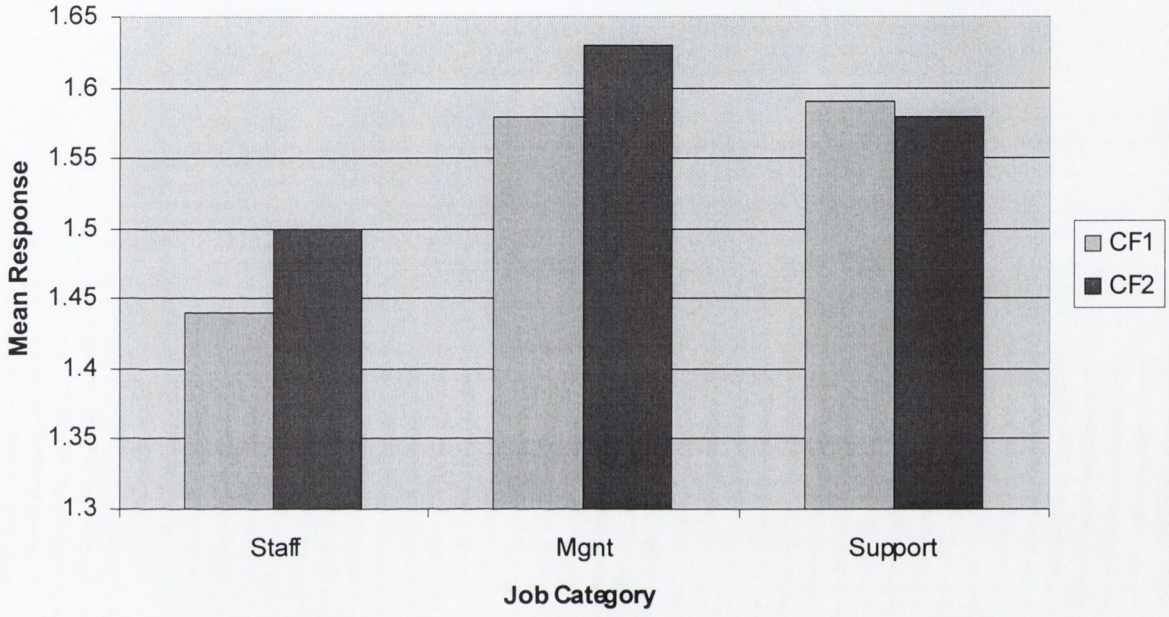
Comparison of factors across job types

Significant differences were also found on both factors across job types. Figure 10 demonstrates the comparison of factors across job types with 1 being the lowest possible score and 2 the highest (1.5 is the midpoint).

One-way analysis of variance (ANOVA) results indicated a significant difference between job type and factor 1 ($F(2, 650)= 12.62$) $P<0.0001$ and between job type and factor 2 ($F(2,645)=7.402$) $P<.001$). Tukey's post hoc comparisons showed that support personnel (1.59) and operational management (1.58) were more likely to perceive that company management were committed to safety compared to operational staff (1.44). ($P<0.05$). Likewise on factor 2, Tukey's post hoc comparisons showed a significant difference between operational management and operational staff ($P<0.05$). It was

found that operational management (1.63) were more likely to believe that company management were committed to communication and improvement strategies in managing safety compared to operational staff (1.50).

Figure 10 - Safety Climate Factors by Job Type



It would be expected that operational management would rate their company's commitment to safety and their communication and improvement strategies positively as in their management role they have the responsibility of communicating the safety message. Likewise it was expected that support personnel would have more positive perceptions of the company's commitment to safety. For example Quality personnel have the responsibility of monitoring and ensuring high levels of safety practice. Other support functions (e.g., planning and engineering) are usually somewhat removed from the actual operation and therefore operational safety standards may not always strictly apply to their everyday work. On the other-hand operational staff are in the position where they have to complete their tasks to specific deadlines and adhere to safety procedures and standards. The analysis of the management interviews indicated differences in expressed commitment to safety at the different levels within the organisations. It was found particularly in companies B and D that their operational staff felt that management were more concerned with commercial aspects of the operation than the safety aspects. Also the results of the survey of procedure

compliance highlighted the existence of a "double standard" between the official and unofficial way aircraft maintenance work is carried out.

In order to further explore the dimensions of safety climate, a MANOVA was conducted in order to assess interactions between each of the safety climate factors and organisation and job type. While significant main effects were confirmed between organisations and on the safety climate factor 1 ($F(3, 636) = 26.92$) $P<0.0001$, and job type and on the safety climate factors 2 ($F(2, 636) = 14.73$), $P<.0001$, no significant interaction effects were found for the climate factors and organisation and job type.

While there were no significant main effects between job type and organisation a number of interesting trends did emerge from the data. While operational staff in Company C had less positive perceptions of their company's commitment to safety (safety climate factor 1) compared to management and support, they had more positive perceptions compared to operational staff across the other three organisations. Operational management and support personnel in Companies B and D had somewhat negative perceptions towards their company's commitment to safety compared to the other two organisations. Figure 11 presents the comparison of climate factor 1 by organisation and job type.

Likewise while there were no significant main effects between job type and organisation on safety climate factor 2 (see figure 12) a number of interesting trends did emerge from the data. Operational staff across the four organisations were found to have only moderately positive perceptions towards their management communication and improvement strategies, with Company B staff having slightly more negative perceptions. Operational management across companies A, B and C were found to have very positive perceptions. Company D's management displayed slightly less positive responses while their support personnel were found to have more positive perceptions compared to support personnel across the other organisations.

Figure 11 - Safety Climate Factor 1 (job type by organisation)

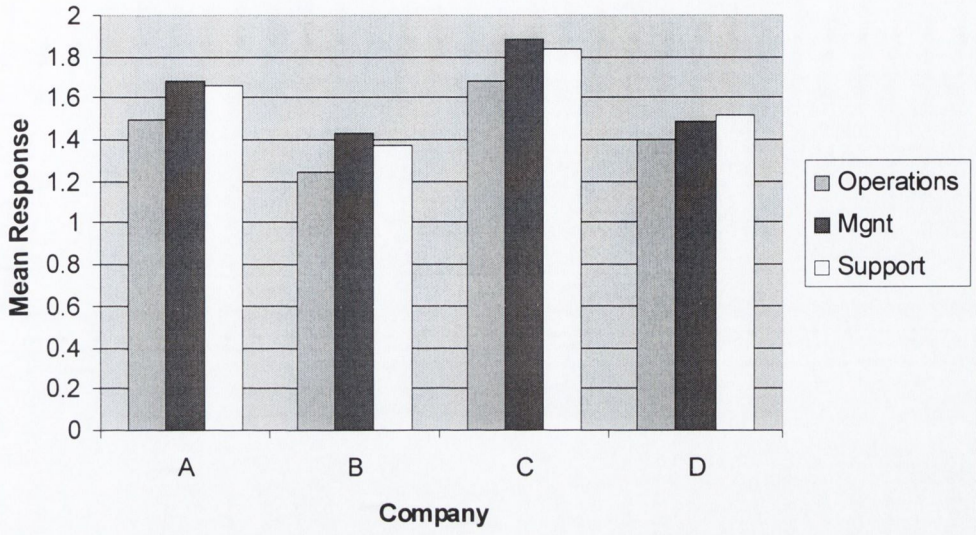
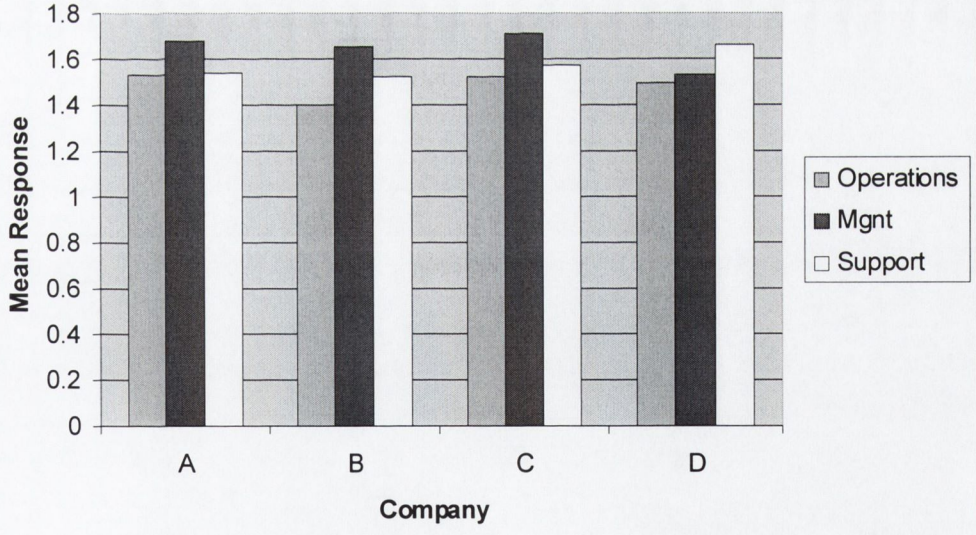


Figure 12 - Safety Climate Factor 2 (job type by organisation)



Overall a number of significant differences and interesting trends were found across both of the safety climate dimensions and both within and across the organisations. To a large extent these differences mirrored the analysis of the management interviews and findings from the survey of procedure compliance.

Analysis of Safety Attitude Survey

Reliability Analysis of Safety Attitude Scale

A reliability analysis and item correlation study showed an internal consistency (Cronbach Alpha) value of .56 on the Safety Attitude Scale. This was quite a low reliability value for the scale and was substantially lower than the (Cronbach Alpha) value for the original scale 0.78 (Cabrera et al., 1997). Rather than reject all further analysis on the safety attitude scale it was decided to further explore the scale particularly in light of some of the findings from the study. The scale adopted in this study, as in most studies on safety attitude, focuses on the degree of compliance with safety standards, rules and procedures. However this study found that the formal system of safety standards, procedures and rules does not always support safe and reliable ways of working. Therefore it seems quite paradoxical that a safety attitude survey should focus on the degree of compliance with safety standards, rules and procedures, when the evidence indicates that these standards and procedures do not always support the actual operation.

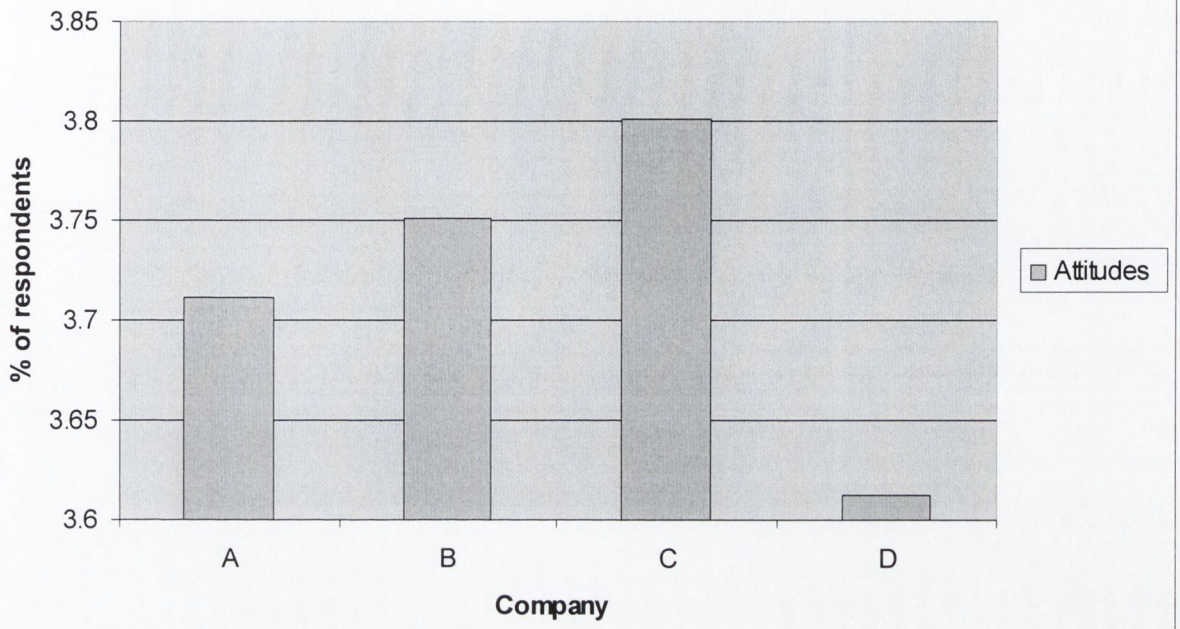
In order to further explore the scale of safety attitudes a Factor Analysis using SPSS (via principal component analysis with varimax rotation of factors) was carried out. Five factors were identified from the Factor Analysis, however items 7,8 and 9 loaded onto three of the five factors. As a result these items were removed and a second Factor Analysis was conducted which resulted in four factors, one of which contained only 1 item (item 2). This item was also eliminated and a third Factor Analysis was carried out which resulted in three factors that could be categorised as Safety Rules (5 items), Compliance (3 items) and PPE (3 items). See Appendix 5 for results of this final factor analysis. However the Cronbach alpha value for each of the dimension was low for Factor 1 – Safety Rules (.51) and very low for factors 2 (.27) and 3 (.09). As the Factor

Analysis did not result in any clear dimensions or improved reliability it was decided to conduct analysis on the overall scale.

Levels of safety attitudes in the four organisations

The overall mean safety attitude score for all the companies was 3.70. The safety attitude scale ranged from 1 (an entirely negative safety attitude) to 5 (an entirely positive attitude). Therefore an overall safety attitude score of 3.70 represented a moderately positive safety attitude score (3 being the midpoint). While all of the companies demonstrated positive safety attitudes (see figure 13), there were significant differences in the overall pattern of safety attitudes across the organisations ($F(3,664)=7.38$, $P<0.001$). Tukey's post hoc comparisons showed that Company D (3.61) differed slightly but significantly from the other three organisations in having a more negative level of safety attitudes ($P<0.05$). Company C were the most positive with a mean score of (3.80), company B had a mean score of (3.75) and company A scored (3.71). Again Company C were found to have the most positive attitudes towards safety and while Company B were found to have less positive perceptions of their company's commitment to safety than the other organisations they were found to have more positive safety attitudes compared to Companies A and D.

Figure 13 Comparison of safety attitudes across organisations

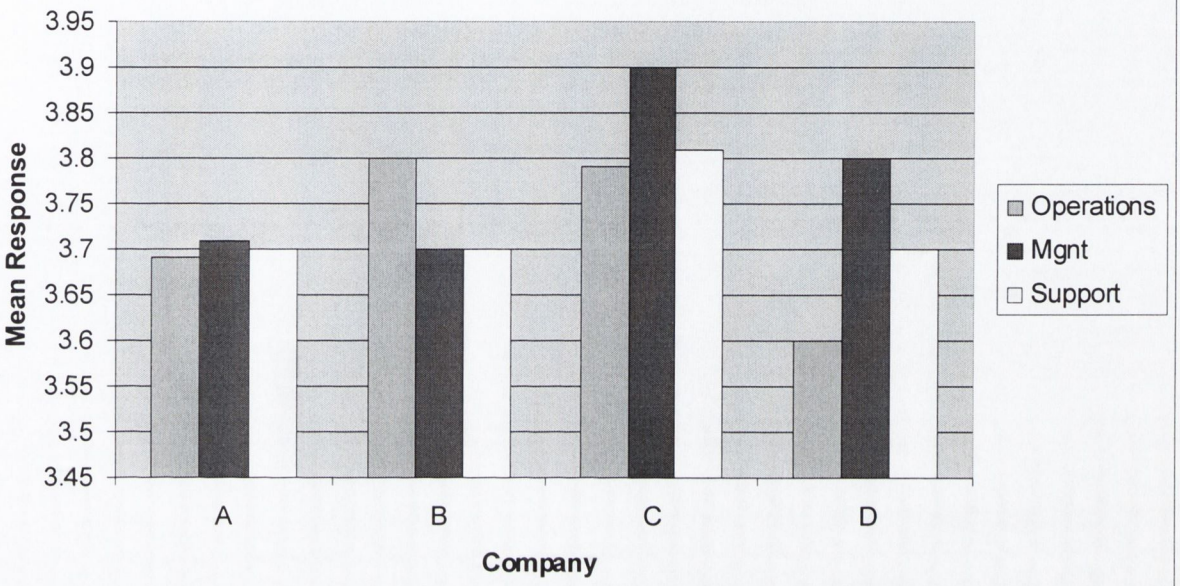


No significant differences were found when safety attitudes were compared across the different job types. Operational management (3.8) were found to have only marginally more positive levels of safety attitudes compared to operational staff or support personnel (3.7).

A MANOVA was also conducted to assess key interactions between safety attitude, job type and organisation. No significant differences or interactions were found when safety attitudes were compared across job types within each of the organisations. Although some interesting trends did emerge from the data (see figure 14). Operational staff, management and support personnel in each of Companies A, B and C were found to have similar levels of safety attitudes, however the three categories of staff in Company D were found to have different levels of safety attitudes. Operational staff in Company D were found to be somewhat less safety conscious than their managerial and support staff. Operational staff in Company D were also found to be less safety conscious than operational staff in the other organisations. This result also confirms findings from the management interviews

where inconsistent commitment to safety was also reported at the different levels within company D.

Figure 14 - Comparison of Safety Attitudes Across Job Types Within Each Organisation



Analysis of Survey measuring Incident Analysis

A total of 669 surveys were completed and returned. 327 were returned containing version A (led to a reported flight incident) and 342 were returned containing version B (did not lead to a flight incident). Table 12 presents the break down of each version across the 4 organisations.

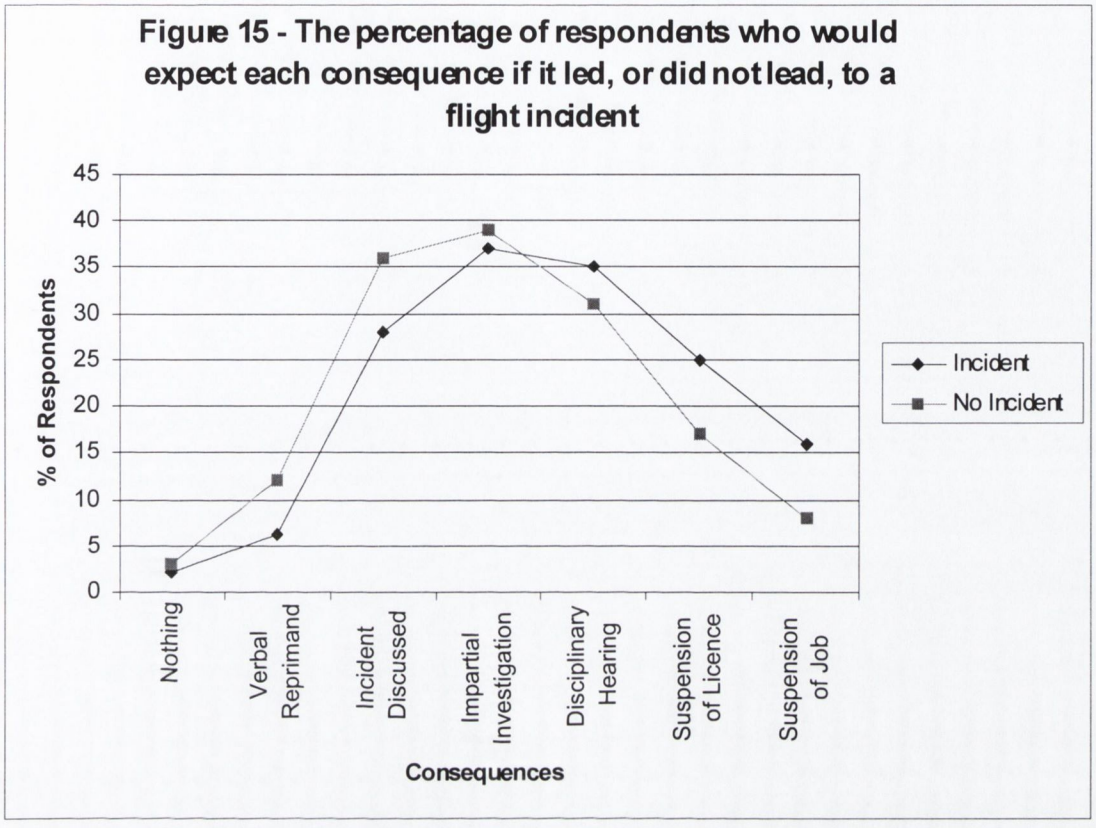
Table 12. Breakdown of each version of incident survey across organisations

Company	A	B	C	D	Total
Version A	115	71	30	111	327
Version B	115	70	46	111	342

Expected consequences of Incident Involvement[2]

Overall when asked what they would expect to happen if any of the incident scenarios occurred in their company, the most common response was impartial investigation to find out what factors gave rise to the incident (38%). 33% felt a disciplinary hearing would ensue and 32% reported that they would expect the aircraft engineer(s) involved to have the incident discussed with them so that they could learn from their mistakes. Very few people reported that nothing would happen (3%) or that a verbal reprimand would ensue (9%). A number of significant differences were found when responses were compared for the reported consequences for scenarios which led to an incident with those which did not lead to an incident. See figure 15 for the full range of responses.

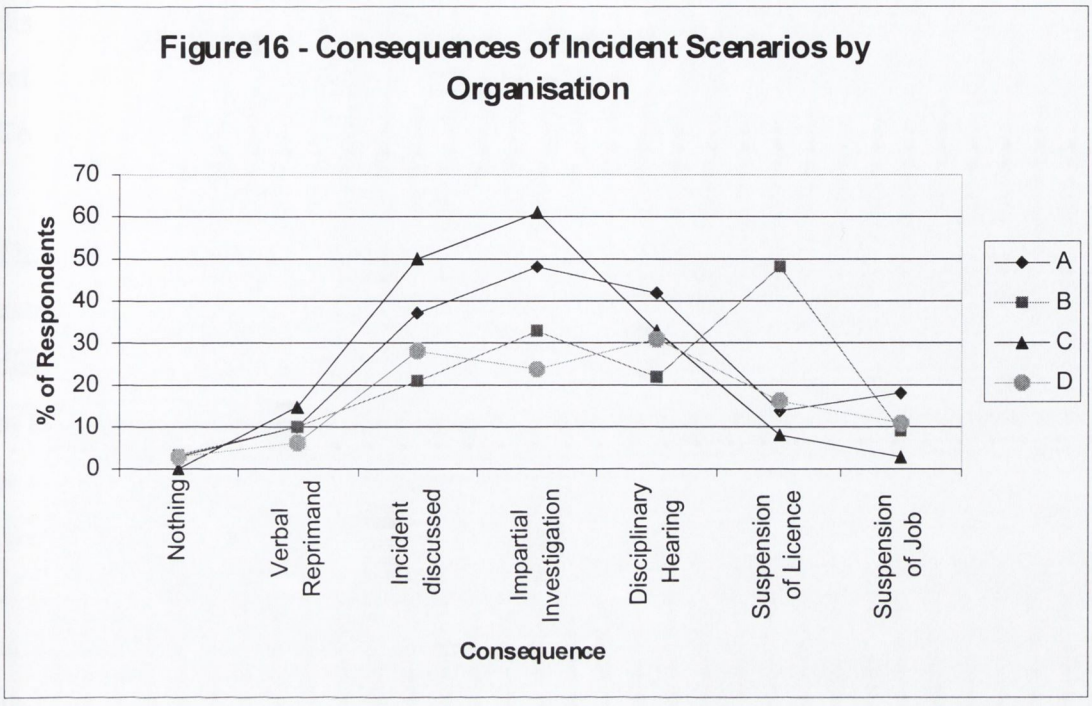
[2] Only significant results are reported here. See Appendix 6 for all other results



Significantly more people felt that a verbal reprimand ($\chi 2=7.118$, $P<0.05$) and incident discussed ($\chi 2=5.055$, $P<0.05$) would be the resulting action when no incident occurred. It was significantly more likely that respondents would indicate a 'loss of licence' as a consequence of a scenario which led to a flight incident than one that did not ($\chi 2=5.112$, $P<0.05$). Similarly the 'suspension of job' was perceived as a more likely consequence if the scenarios led to a flight incident condition ($\chi 2=9.563$, $P<0.05$). Overall the pattern of results reflected more serious outcomes for the "led to a serious flight incident" condition however the whole range of possible outcomes received responses indicating considerable variance in the opinions of respondents.

Comparison of reported consequences by company

There were significant differences between the organisations in the consequences of the scenarios regardless of whether they led to a flight incident or not (see Figure 16).



The types of consequences which would occur differed significantly between companies on six of the seven items. Only the frequency of 'nothing would happen as a result of the scenarios' did not differ significantly across companies.

It was significantly more likely in Company C, compared to the other companies, that the incident would be discussed with a view to learning from the mistake ($\chi 2=28.571$, $P < .001$), that an impartial investigation would be carried out to identify causal factors ($\chi 2=49.747$, $P < .001$), and that a verbal reprimand would ensue ($\chi 2=14.06$, $P<0.05$). Company C respondents were much less likely to report licence suspension and job suspension compared to the other organisations. These findings confirm the more open policy and less severe consequences for the individual in relation to incident management within the company.

In contrast Company B appeared to have a relatively consistent policy of suspension of licence pending disciplinary hearing, which was significantly higher than the other three

organisations ($\chi 2=85.328$, $P < .001$). Company B also had the lowest reported level of discussion of the incident with the individual and disciplinary hearing. Again this result reflects a much more closed and disciplinary response to reported incidents within Company B.

The pattern of responses in Company A reflected the responses in Company C to some extent though it was less marked. Respondents were significantly more likely to report a disciplinary hearing ($\chi 2=20.981$, $P < .001$) and while Companies B and D were more likely to report suspension of licence, significantly more respondents in Company A were likely to report suspension of job ($\chi 2=28.150$, $P < .001$) compared to the other organisations. The likelihood that Company A were more likely to report suspension of job as a consequence of incident involvement is further evidence that the relationship between disciplinary actions and the new human centred approach to incident reporting were not fully articulated and/or understood by the organisation.

In Company D, impartial investigation and verbal reprimand was the least likely response compared to the other organisations. Discussion of the incident with a view to the individual learning from their mistake was the third lowest of the companies with Company B reporting less likelihood of discussion of incident. The "disciplinary hearing" consequence was the most ticked consequence for Company D respondents although this was comparable to the level in Company C while lower than that in Company A and higher than that in Company B. Similar to the responses in Company B the incident management process in Company D is characterised by a very cautious and controlled disciplinary approach.

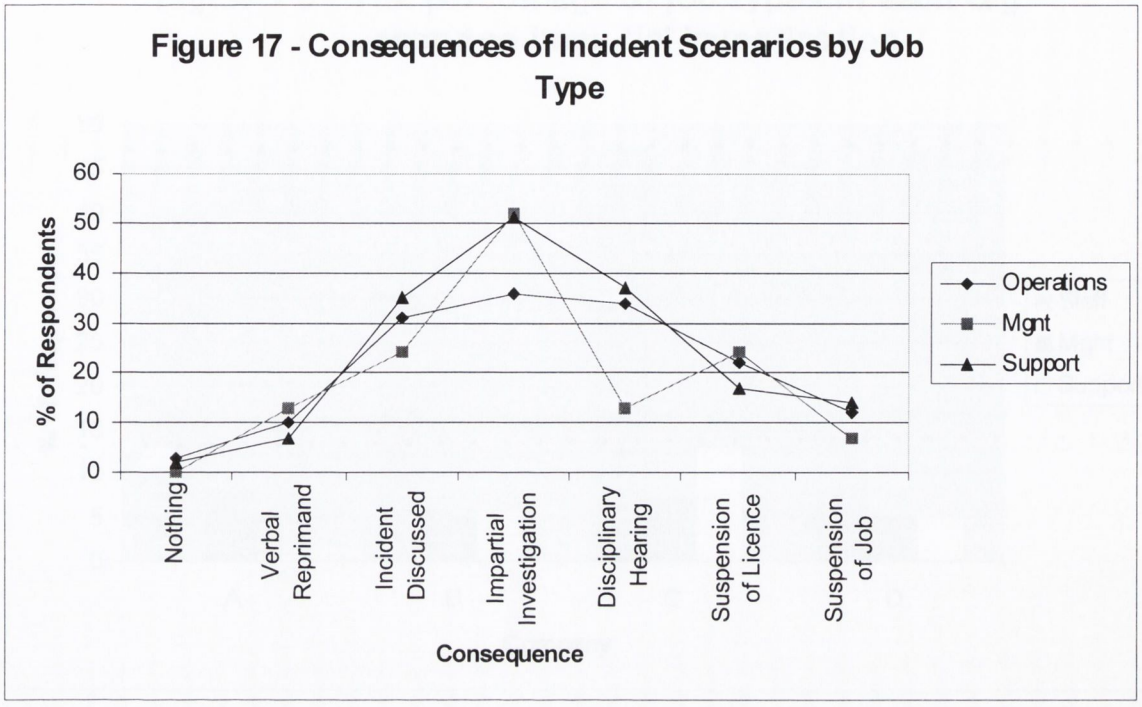
Comparison of reported consequences by job types

The next level of analysis involved comparing each reported consequence across the different job types (see figure 17). Overall there were very few significant differences

between the different job categories in what they thought the consequences of the incidents would be. The most popular response was "impartial investigation" however operational staff were significantly less likely to believe that an impartial investigation would ensue compared to operational management and support personnel ($\chi 2=10.608$, $P<0.05$). Disciplinary hearing was the second most common response. It was found that operational management were significantly less likely to believe that a disciplinary hearing would ensue compared to support personnel and operational staff ($\chi 2=8.109$, $P<0.05$). Operational management were also less likely to believe that an incident would be discussed ($\chi 2=5.548$, $P<0.01$). Comparable responses were found between operational management and staff in relation to the likelihood of suspension of licence.

Overall the least likely responses across job types included nothing, verbal reprimand and suspension of job, however operational management were also significantly less likely to believe that suspension of job would occur compared to support personnel and operational staff ($\chi 2=8.036$, $P<0.05$).

Operational management and support personnel were found to have similar responses across many of the consequences. However operational management were less likely to believe that a disciplinary hearing, discussion of incident or suspension of job would occur. Rather management were more likely to believe that a more intermediary outcome would result (e.g., impartial investigation).



Comparison of reported consequences by job type and by organisation

When each consequence was compared by job type and organisation a number of significant differences emerged. Operational staff in all of the organisations were found to report higher levels across most of the reported consequences.

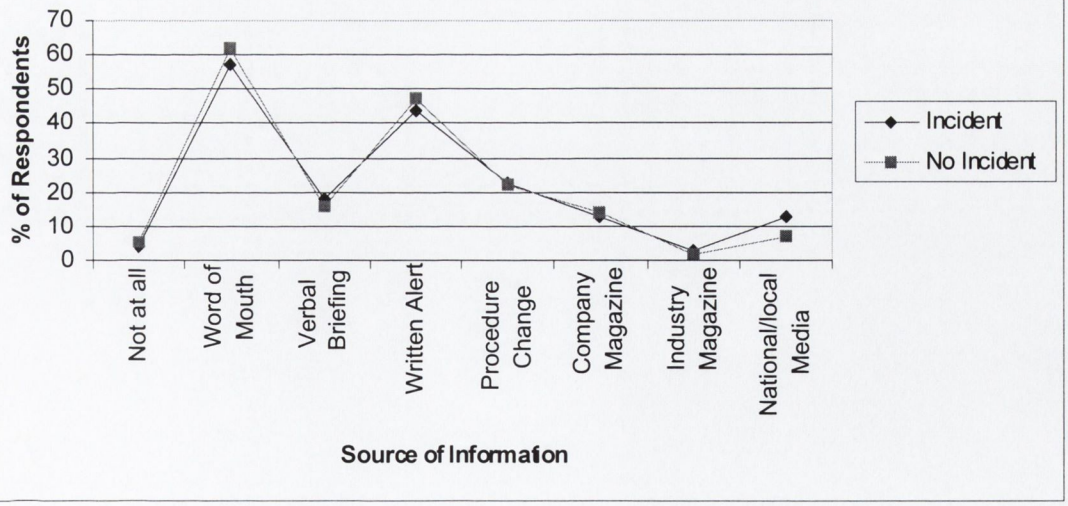
Significant differences across job types within the organisations were found across three of the reported consequences, impartial investigation, disciplinary hearing and suspension of licence. Operational staff in Company C were found to report significantly higher levels of impartial investigation ($\chi 2=18.417$, df=6, $p<.005$) compared to management and support (see figure 18).

views across job types in Companies B and D. Likewise in relation to suspension of licence, similar viewpoints were expressed across all job types in Companies A, C and D, while more divergent views were expressed in Company B. Therefore certain aspects of the incident management process are understood quite differently among different groups of personnel.

Dissemination of Incident information[3]

The second part of the survey focused on how information on both reported and unreported incidents was communicated within organisations. When the reported sources of information were compared between the condition that led to a flight incident and the condition that did not only one item revealed a significant difference, namely "through national or local media"($\chi 2=6.42$, $P<0.001$). This would seem logical as a flight incident would not only be more likely to be observable by national and local media but would also be more likely to be "newsworthy". All other items did not differ significantly. Figure 21 shows the pattern of responses.

Figure 21 - The percentage of respondents who would expect each source of information if it led, or did not lead, to a flight incident



[3] Only significant results are reported here. See Appendix 7 for all other results.

Figure 19 - The percentage of job types in each organisation who reported disciplinary hearing

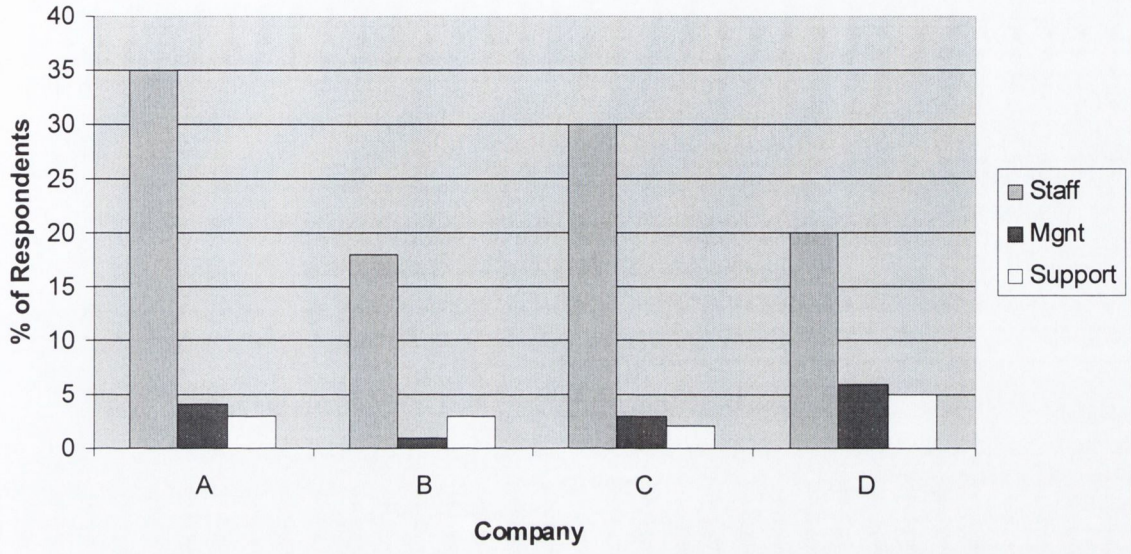
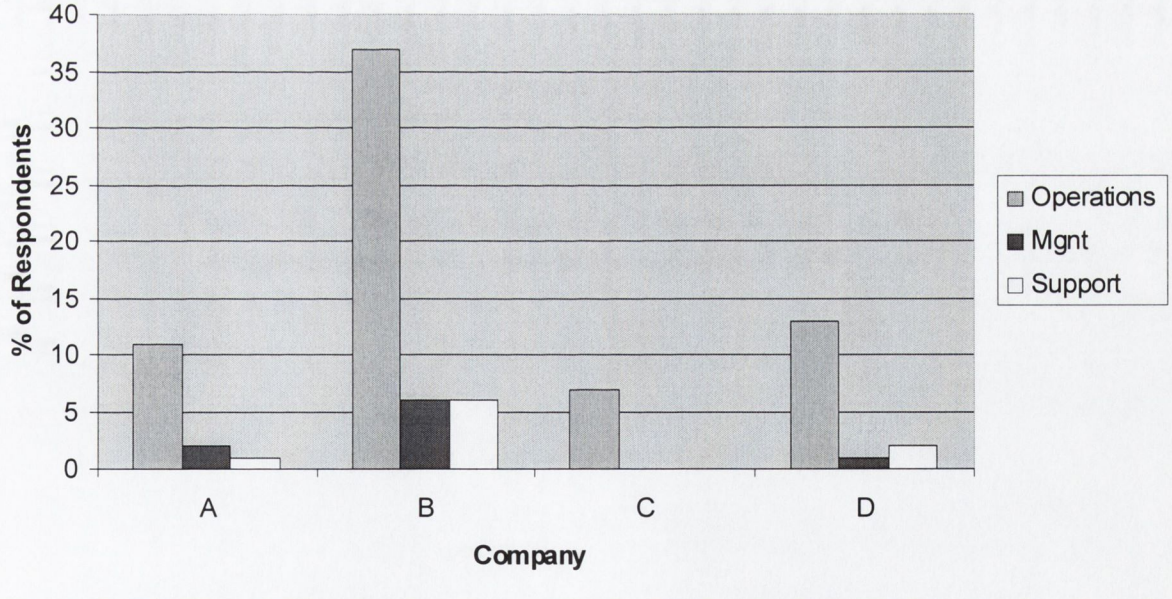


Figure 20 - The percentage of job types in each of the organisations who reported suspension of licence



What is interesting about these results is that quite divergent views were expressed in relation to impartial investigation in Companies A and C, compared to the more similar

views across job types in Companies B and D. Likewise in relation to suspension of licence, similar viewpoints were expressed across all job types in Companies A, C and D, while more divergent views were expressed in Company B. Therefore certain aspects of the incident management process are understood quite differently among different groups of personnel.

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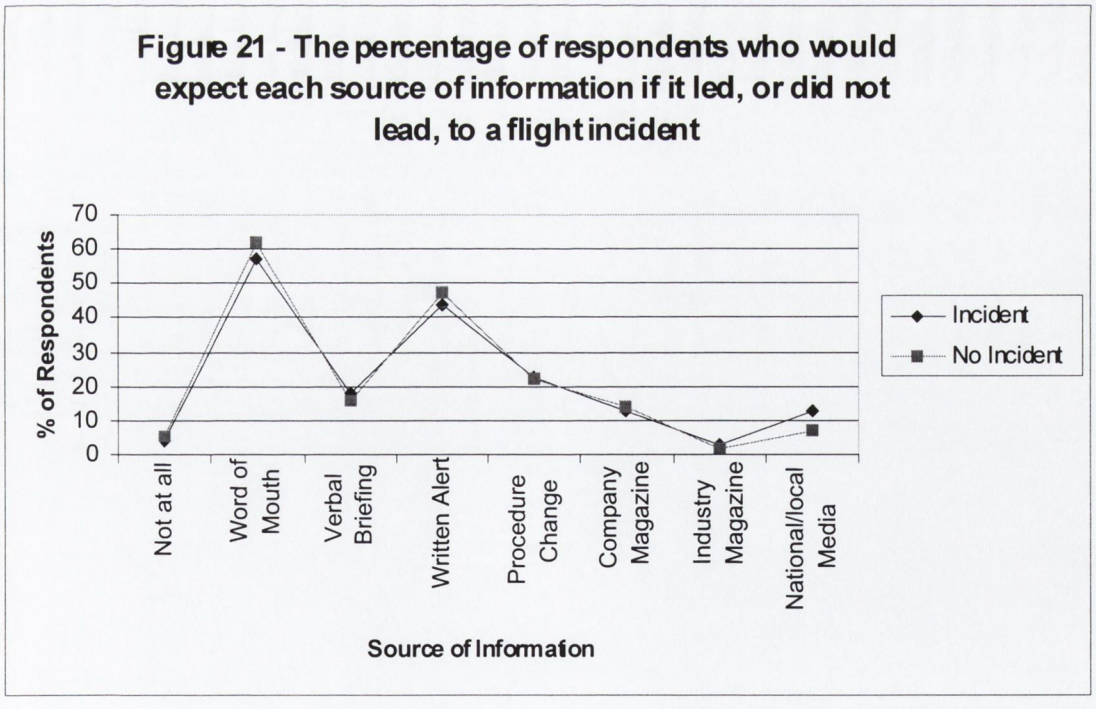


[3] Only significant results are reported here. See Appendix 7 for all other results.

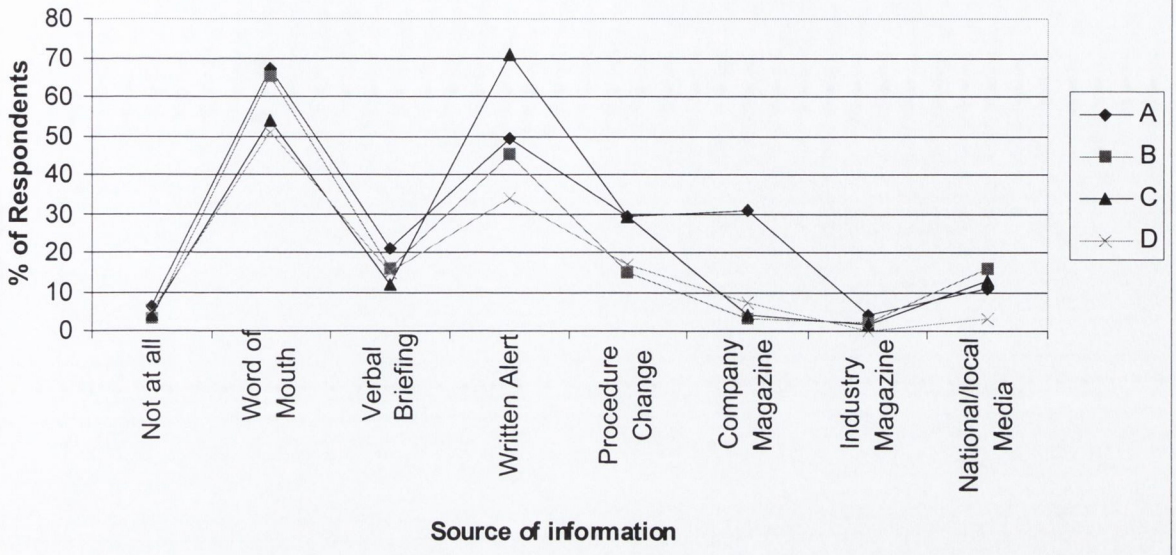
Comparison of source of information by company

A number of significant differences were found when the source of information reported was compared across organisations. The most common response to hearing about the events across all four of the organisations was 'word of mouth' followed by a 'written alert'. The least common responses included industrial magazine and to hear nothing at all. See figure 22 for breakdown of each information source by organisation.

Word of mouth was a significantly more likely source of information in Company A and B than in Company C and D ($\chi 2=17.219$, $P<0.001$). The interview analysis also highlighted the reliance, particularly in Company B of a more verbal and informal approach to disseminating information regarding incidents. Company A and Company C respondents were also significantly more likely to hear about the incidents through notification of a procedure change ($\chi 2=20.761$, $P<0.001$) and Company C respondents were significantly more likely to receive information in a written alert than the other three organisations ($\chi 2=32.636$, $P<0.001$). This may be a result of the formal and systematic approach to incident reporting where everything is clearly documented and communicated.

Company A were significantly more likely to hear about incidents through company magazines ($\chi 2=96.824$, $P<0.001$). Company A had a number of internal company magazines including a human factor magazine where incident accounts were routinely disseminated. Company D were significantly less likely to report hearing about incidents through national or local media, suggesting perhaps more effective control of information in that organisation (($\chi 2= 29.250$, $P<0.0005$).

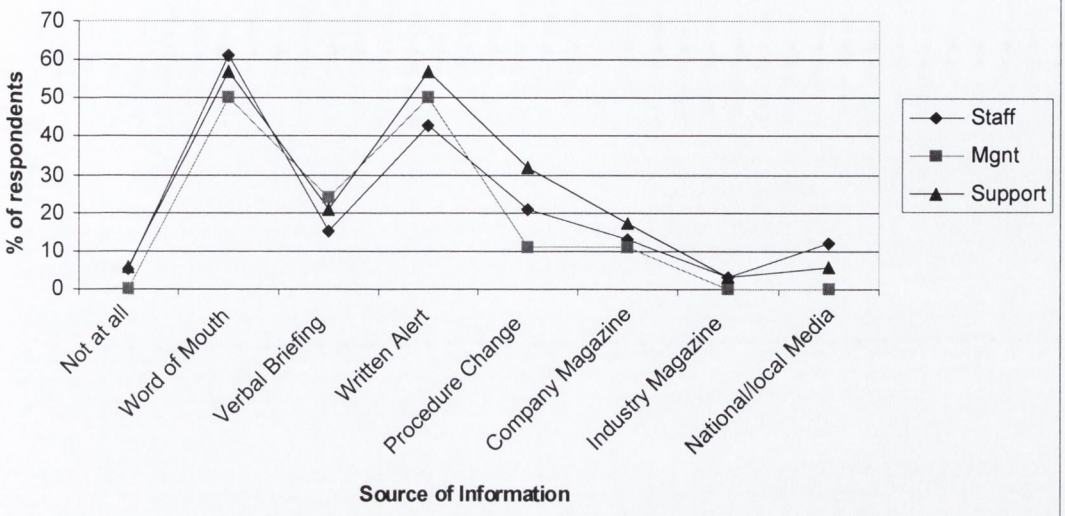
Figure 22 - The percentage of respondents in each organisation who selected each information source



Comparison of source of information by job type

The most common response across all job categories was 'word of mouth' followed by 'a written alert'. The least likely responses included to hear about an incident through an industry magazine or to not hear about the incident at all. Operational management and support personnel were significantly more likely to believe that they would hear about an incident through a verbal briefing ($\chi 2=8.661$, $P<0.05$) and a written alert ($\chi 2=9.227$, $P<0.05$) compared to operational staff. On the other hand operational staff and support personnel were significantly more likely to hear about an incident through a procedure change ($\chi 2=13.508$, $P<0.005$) or through national or local media ($\chi 2=8.107$, $P<0.05$). This result may be explained by the fact that operational management would not be referring to task procedures on a daily basis and if an incident did occur management would be more likely to hear about it before other personnel in the company and before it went public.

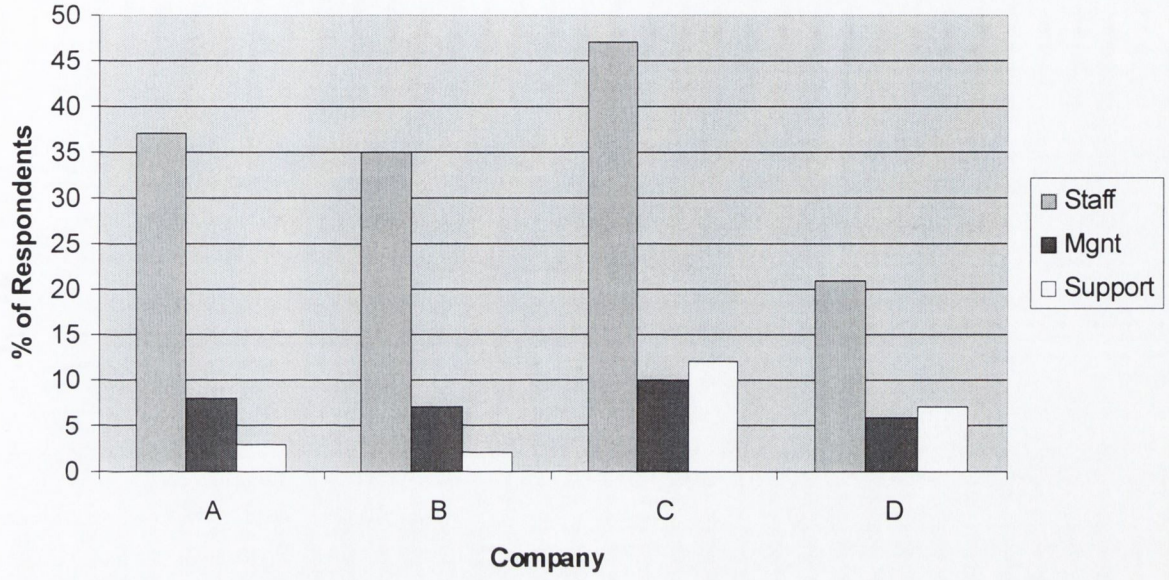
Figure 23 - The percentage of respondents in each job type who selected each source of information



Comparison of source of information by job type by organisation

When each source of information was compared across job types within organisations a number of different significant differences emerged. It was found that operational staff in Company C were significantly more likely to report alert bulletin ($\chi 2=12.177$, df=6, $p<.05$) compared to the management and support functions within the company (see figure 24).

Figure 24 - The percentage of job types in each organisation who reported alert bulletin



On the other hand, operational staff in Company A were significantly more likely to report a procedure change ($\chi 2=12.874$, df=6, $p<.05$) and were also more likely to report company magazine ($\chi 2=11.345$, df=6, $p<.05$) compared to management and support functions in their company. See figures 25 and 26.

Figure 25 - The percentage of job types in each organisation who reported procedure change

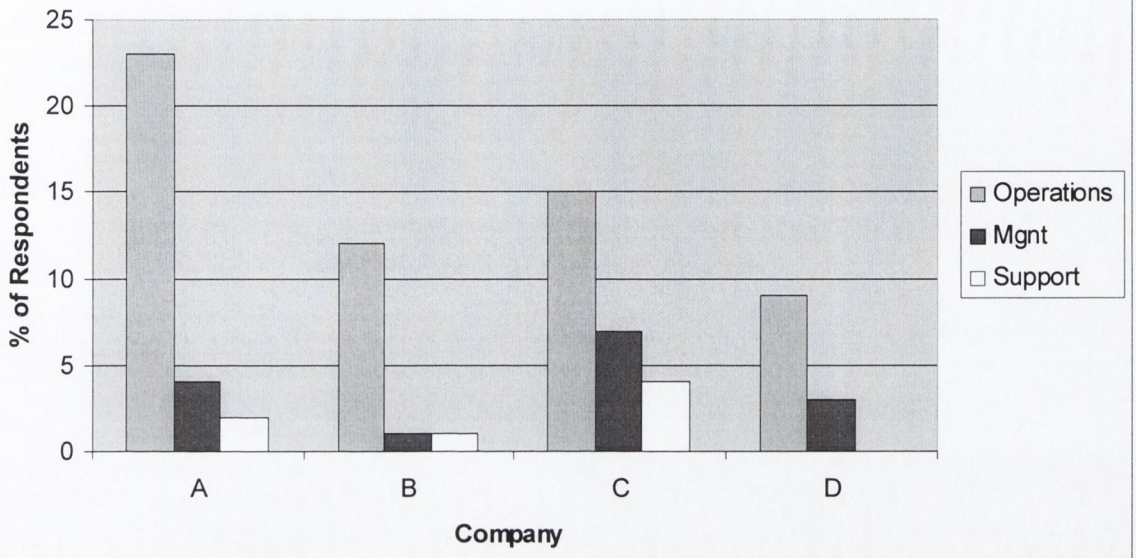
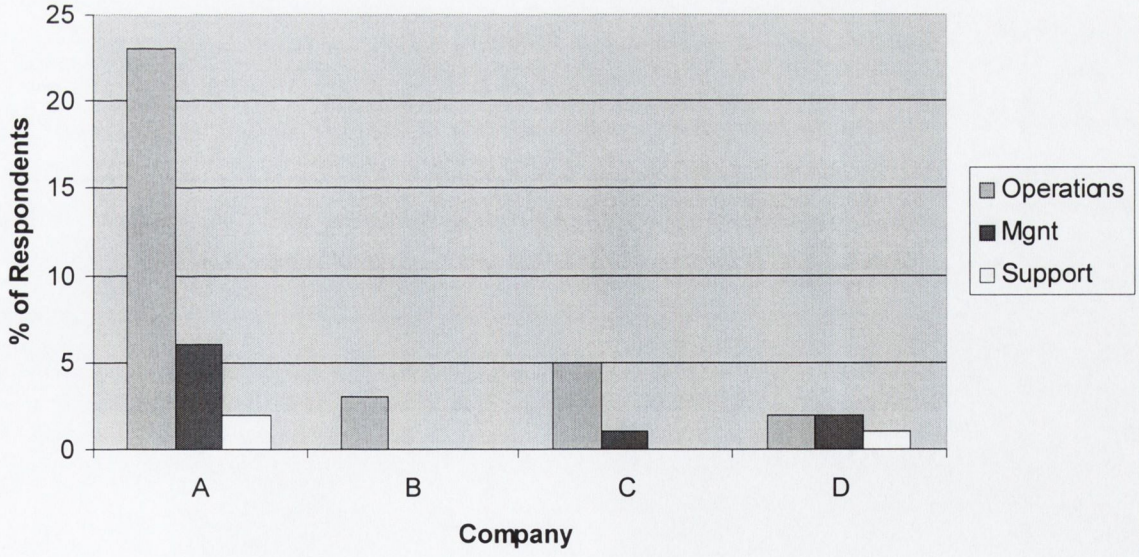


Figure 26 - The percentage of respondents across job types in each organisation who reported company magazine



Overall a number of significant differences were found when both the reported consequences of incident involvement and the source of incident information were compared within and between organisations.

Overall Summary

A key objective of the study was to describe and compare the organisational aspects of safety management systems and the underlying safety culture in aircraft maintenance. The model highlighted a number of key elements of safety management and aspects of safety culture which were assessed by the measurements of safety climate and safety attitudes. Safety Climate and Safety Attitudes were not distinguished as explicit components in the model, rather they were seen as elements of safety culture underpinned by the beliefs, attitudes and perceptions of individual employees. Understanding of the underlying culture requires an assessment of both the key safety rules, practices and processes as well as the less visible norms, attitudes, values, beliefs and assumptions towards the overall safety management system itself.

A total of 669 questionnaires were collected across the four organisations measuring safety climate, safety attitudes and perceived consequences of incident involvement. A number of significant and interesting results were found both within and across the organisations, which largely reflected the findings from the interview analysis, procedure compliance survey and observational studies.

Safety Climate

This study found two key dimensions that constituted the safety climate concept (i) management commitment to safety and (ii) communication and improvement strategies. Features of the first dimension included management's commitment to compliance with safety standards and procedures, management's response to safety problems and safety violations and the priority of safety matters. The second dimension included management's willingness to accept suggestions and adapt new ideas to improve safety. Significant differences were found across the organisations on both of the dimensions of safety climate. Company C were significantly more likely to perceive that their management were

committed to safety and were more likely to believe in their company's communication and improvement strategies. It was also found that Company A were significantly more likely to perceive that their safety communication and improvement strategies to be more effective than they were perceived in Company B.

When each of the two safety climate factors were compared across the different job types it was found that management differed significantly from operational staff on both factors. Management were more likely to believe in their commitment to safety and the effectiveness of their communication and improvement strategies compared to operational staff.

Safety Attitudes

While the safety attitude scale was found to be only moderately reliable, (Cronbach Alpha) value of .56, analyses were carried out in order to compare safety attitudes both across organisations and across job types. While all the organisations and job categories were found to have high levels of safety attitudes it was found that Company D had significantly more negative levels of safety attitude compared to the other organisations. No significant differences were found across the job types.

Incident Survey

Two versions of the incident survey were distributed across the four organisations. One version resulted in a reported flight incident and the second version did not lead to an incident. The survey consisted of two main sections, the first of which focused on the perceived consequences for the aircraft engineer under both conditions. The second section focused on how maintenance personnel might hear about the scenarios whether they resulted in a reported incident or not.

The most common consequences regardless of the outcome were impartial investigation, disciplinary hearing and discussion of incident. Significantly more respondents felt that a verbal reprimand and discussion of incident would be the resulting action if no incident occurred, while suspension of job and licence were perceived as more likely consequences

if an incident had occurred. Therefore more serious consequences were found for the condition that led to an incident.

Significant differences were also found between the organisations regardless of whether they led to an incident or not. Overall Company C displayed a much more open policy to incident management where they were significantly more likely to report impartial investigation, discussion of incident and verbal reprimand compared to the other organisations. On the other hand Companies B and D showed a much more closed and controlled approach to managing incidents within the organisations. Company B were, for example, significantly more likely to report suspension of licence and they had the lowest level of incident discussion.

When consequences were compared across job types it was found that operational staff were significantly less likely to believe that an impartial investigation would ensue, while operational management were significantly less likely to believe that a disciplinary hearing or suspension of job would result. Significant differences across job types within the organisations were also found. Operational staff in Company C were found to report significantly higher levels of impartial investigation, while operational staff in Company A were significantly more likely to report disciplinary hearing. And finally operational staff in Company B were significantly likely to report suspension of licence.

The most common response to hearing about the events was by word of mouth and written alert where word of mouth was significantly more likely in Companies A and B and a written alert was significantly more likely in Company C. Notification of an event through a procedure change or through a company magazine was significantly more likely in Company A, while Company D was significantly more likely to hear about incidents through national or local media. When the source of information was compared across job types it was found that operational staff were significantly less likely to find out through a verbal briefing or through a written alert, while operational management were less likely to find out through a procedure change or through national or local media.

When the consequences and the source of information were compared within organisations it was interesting to note quite different views among different groups of personnel. For example operational staff in Company C had very different views on impartial investigation and alerts bulletins compared to management and support functions. Likewise operational staff in Company B were more likely to report suspension of licence as an outcome compared to management and support functions, and operational staff in Company A were more likely to report procedure change and company magazine than other groups of personnel within the company. On the other hand different groups of personnel in Company D had quite similar views across all of the different consequences and sources of information. Therefore certain aspects of the incident management process appeared to be understood quite differently among different groups of personnel in Companies A, B and C.

Overall the measure of safety climate and incident management systematically discriminated within and between each of the organisations studied and did so in a manner, which was quite congruent with the interviews and incidents survey. The differences within and between the organisations in relation to their expressed commitment to safety, standards, planning and organisation, monitoring and feedback were reflected in the differences in safety climate. On the other hand, the pattern of results in the procedures survey (representative of 'normal operational practice') and the safety attitude survey (another component of safety culture) did not show the same pattern of results. The incidence of non-compliance with task procedures showed no significant differences between the four companies. The safety attitude survey showed a similar pattern with the exception of a small but significant difference between company D and the other companies. When broken down by job type, it was the operational staff in Company D who differed (though not significantly) from the operational staff in the other three companies.

Thus, while some aspects of the organisational safety culture (safety management system, safety climate, expectations of response to incidents) are strongly differentiated both within and between organisations, other aspects (the behaviour and attitudes of aircraft engineers) are not. The findings from the procedure compliance survey and the measures of safety climate, safety attitude and incident management would seem to suggest the existence of a

'professional sub-culture' amongst aircraft maintenance engineers that spans all four organisations (with the exception of safety attitudes in company D which diverge slightly). As already mentioned some understanding of the nature of this sub-culture comes from some findings of a Human Factors "Bottlenecks Survey" (Biemans et al., 1997) which indicated that there was a gap in "job perception" between aircraft maintenance engineers and management. Putting it fairly crudely, technicians believe that they are responsible for the overall safety of the aircraft, and that it is their role to exercise their knowledge, skill and professional values to enable them to fulfil that responsibility. Procedures are there to support that goal. Management on the other hand believe that the role of aircraft engineers is to follow the task and organisational procedures explicitly, though it is often acknowledged that if every one followed procedures to the letter, production would be hugely delayed. This difference in perception means that aircraft maintenance engineers perform their tasks differently from the way that the company expects. This difference in perceptions was also reflected in the differences between operational staff and management (across all the organisations) in relation to management's commitment to safety and communication and improvement strategies, where operational staff were less likely to believe in their manager's commitment to safety. Therefore it is tempting to suggest that this analysis indicates that there is a strong professional sub-culture, which is relatively independent of the organisation.

Overall the data from the management interviews, the survey of procedure compliance, the incident survey and the safety climate survey exhibited a large measure of agreement in differentiating between the different safety management systems and safety cultures of the four organisations. The next chapter further explores and discusses the main differences and similarities between the four organisations and highlights the implications for the safety management model.

Chapter 6 - Discussion and Implications for the Model

Introduction

The previous three chapters focused on describing the safety management systems and cultures across four aircraft maintenance organisations. Each element of the model was explored through a range of methodologies in order to compare and evaluate the safety management systems and their cultures. The comparative analysis across the four organisations provided a vehicle for understanding how aircraft maintenance organisations manage safety in their operations, with particular emphasis on the human centred and organisational aspects of safety. This study has demonstrated that it is possible to differentiate between different organisations' safety management systems in systematic ways. It also enabled an evaluation of the strengths and weaknesses of different real operational systems. The measure of safety climate, for example, can be interpreted to reflect the internal credibility of the company's safety policy and its implementation.

The overall objective of this chapter is to provide a more in-depth comparative analysis of the main distinguishing features of each of the organisations based on each element of the model. Each element is discussed, where relevant, in light of the findings from the Management Interview, Documentation Analysis, the Safety Attitude, Safety Climate and Incident Management surveys, and key findings from the Procedure Compliance Survey and from the ergonomic assessment. The implications of the findings are also discussed in relation to effectiveness of the proposed model as a descriptive account of key features of the safety management process.

Table 13 summarises the main distinguishing features of the four organisations' safety management systems along the five elements of the model. Each of these distinguishing features are further explored and compared across the organisations in the next sections of this chapter. The final section of the chapter concentrates on the further development of the model in light of the findings.

Table 13- Summary of the elements of safety management systems across the 4 organisations

Model Elements		Company A	Company B	Company C	Company D
Safety Strategy & Policy	*Expressed commitment to safety*	Safety embedded in professional culture	Safety has to be made compatible with commercial survival	Safety consistently expressed as being the key to success	Inconsistent commitment to safety at different levels within the company
Implementation of policy and setting standards	*Organisation of work*	Major initiative on process re-engineering. Not all goals have been realized	IR seen as a major constraint on planning. Recent investment in IT with customer focus	Strong commitment to the planning and organisation of work. Has invested heavily in IT to support this function	Demarcations and IR seen to inhibit effective planning, organisation and communication
	Management Training	Extensive management training not always rated effectively. HF training provided	Inconsistent management training. HF training provided	Comprehensive and effective management training. No explicit HF training available	Training in management skills not seen to be effective. No HF training provided
	Internal Standards	Reference to compliance with JAR145 as safety standard	Reference to compliance with JAR145 as safety standard	Internal safety standard built into management system	Reference to compliance with JAR145 as safety standard
Operational Norms	*Procedure Compliance**	30% reported not following MM procedures	36% reported not following MM procedures	37% reported not following MM procedures	47% reported not following MM procedures
	Ergonomic Assessment	Poor outputs from reader printers. Only limited availability and training on CD-ROM	Poor outputs from reader printers. CD-ROM not yet introduced in the company	Good quality output from reader printers. CD-ROM just recently introduced. Training planned in its use	CD-ROM widely available and used. Sufficient training provided
Monitoring	*Audits*	Main focus on documentation rather than actual work	Main focus on documentation rather than actual work though informal awareness of actual work standards	Audit both documentation and actual work	Main focus on documentation rather than actual work

	Quality Discrepancy Reports (QDR's)	QDR system frequently used but huge backlog and no systematic follow up	QDR system recently introduced no real follow up or analysis	Computerised QDR system recently introduced, only limited analysis	A reporting system is used but with no follow up or analysis
	Incident/Accident Investigation	Well developed and used HF based investigation	HF investigation tool developed not used by all investigators	Serious incidents or recurring incidents investigated by a multi-disciplinary team	No explicit HF method for incident/accident investigation
Feedback	*Incident/Accident Investigation*	Publication of both safety and HF issues in regular company magazines. Very open reporting with Aviation Authorities	Verbal briefings only. Not all incidents are openly reported to the Aviation Authorities	Very open in relation to disseminating information and reporting to the Aviation Authorities	Relatively poor communication of information. Very open reporting to the Aviation Authorities
	Change and learning	Difficulty translating HF based information into change	Routine 'retraining session' after incident involvement	Systematic change following recent incidents	No systematic mechanism for managing non-technical change

* *No significant differences were found between the organisations*

Discussion on key elements of the Safety Management Model

Strategy and policy

Three particular aspects of strategy and policy were addressed and compared across the organisation with regards to the importance of safety in relation to other company goals and in assessing the driving force of safety policy: (i) the impact of compliance with JAR145 regulations; (ii) company managers' expressed commitment to safety goals; (iii) and the role of human factor initiatives.

Compliance

Regulatory body requirements have a substantial input into strategy and policy. Therefore the interviews addressed the organisations relationship with regulatory bodies and how they responded to regulatory requirements. Compliance with the requirements of JAR 145 appeared to be a major factor driving safety policy and strategy in all of the organisations. In addition maintenance companies were also subject to audit by their customer airlines. Company C differed from the other companies in that their policy was to anticipate and go beyond the requirements of the regulations. The self-regulatory model of their safety system was designed to express the internal goals and standards of the organisation, which should equal or exceed those set by external regulators. In contrast to this, compliance with the requirements of JAR 145 in Company B appeared to have required a major administrative effort in order to accomplish the exposition document and initiate the new procedures manual.

Expressed commitment to safety

Company documentation in relation to safety statements and safety goals were analysed along with an analysis of how well the safety policy was articulated and communicated throughout each of the organisations. The verbally expressed commitment to safety goals differed both within and between the organisations and it was interesting to compare this to the results of the safety climate dimensions which recorded, across a wide spectrum of the organisation, the appraisal of a number of aspects of the organisational safety system.

During the interviews safety was consistently expressed at all levels in Company C as being the key to success of the company as a commercial enterprise. In Company A the strongly expressed view was that safety was embedded in the professional culture of the organisation. In the implementation of a major organisational change initiative, for example, the policy was clearly expressed that safety is at the front of all technical decisions.

In Company D, senior management highlighted that commercial pressures created a potential conflict between safety on the one hand and cost and punctuality on the other. They did stress that safety was a prior requirement before addressing cost and punctuality goals. Nevertheless there were different emphases on safety, rather than a consistent message, expressed in different parts of the company. For Company B the commitment to safety was clearly placed in the context of the priority to ensure the survival of the company and the necessity to get the economics of the company on the right footing.

These differences in expressed philosophy concerning the role and importance of safety were reflected in a consistent pattern of differences across the safety climate dimensions. There were significant differences in the companies both in their perceptions of their manager's commitment to safety and on the effectiveness of the communication and improvement strategies in their organisations. Company C were found to strongly believe both in their managers' commitment to safety and in the utility of their safety communication and improvement strategies. Responses in Company A were also positive. This can be compared with the reported lack of confidence in managers' commitment to safety and in their safety communication channels in Companies B and D.

Looking at the expressed commitment to safety within each of the organisations it was found that operational management and support personnel in Company B did not rate the managements commitment to safety in a very positive light compared to similar job categories across the other organisations. Also operational staff in Company B rated their managers' commitment to safety as the lowest across all the organisations. Again this can be compared with much more positive responses in Companies A and C and moderately positive responses in Company D. Similar responses were also found on the second dimension of safety climate.

Human factors

One of the major interests of this study was the extent to which the participant companies had or were planning to introduce specific policies and programmes concerning human factors.

While Company C had no policy or programme explicitly labelled human factors, there were two areas in which human factors concerns featured to a large degree. Since the mid-1980s the company had a comprehensive programme of management training, which had a strong focus on leadership, and other aspects of managing people. Secondly, the infrastructure and procedures for planning work were specifically designed to incorporate flexibility to ensure that there was adequate provision of human resources despite variations in the scheduling and sequencing of work. This flexibility also appeared to extend, in the shift rostering system at least, to being sensitive to individual needs and requirements.

Company A had an explicit policy and programme on human factors. They did have dedicated human factors personnel, which included a human factors manager and human factors coordinator. However at the time of research it was planned that the human factors personnel would no longer operate as a separate unit or department but their roles would be combined with other duties in the company (e.g., Quality and Flight Safety). The company also had a programme of initiatives that were particularly concerned with controlling error in aviation maintenance. The main components of one of the programmes were an IT-based tool for auditing the production process by aircraft engineers themselves. The other programme consisted of a methodology which supported a human factors based investigation of maintenance incidents. The company also published a magazine "Human Factors" which provided an extensive discussion of human factors aspects of maintenance and detailed discussion of incidents which had occurred in Company A and elsewhere. In addition the human factors manager conducted a series of briefings of the organisational change programme in order to try to ensure that the change process incorporated human factors principles and standards.

At the time of research, however, it appeared that the IT-based auditing tool was largely dormant. The investigation initiative was active with a programme of training the

investigators and a policy of using the tool to investigate selected serious incidents. Some managers felt that the very success of the tool in highlighting human and organisational problems was causing Company A problems by increasing its exposure to criticism both from inside the organisation and outside, including pressure from the CAA who were seen to be responding to criticism of their role contained in some of the reports of the AAIB. Two issues in particular arose in relation to the human factors programme in Company A:

- The major part of the human factor initiatives within Company A had been reactive (reviewing the system as it is, analysing incidents, and reporting on them, and the human factors magazine). Notwithstanding the fact that the IT-based program for auditing production processes had been labelled a "proactive" tool, it is only proactive in relation to a potential incident, not in relation to the organisational system, which underlies potential incidents. If the system was seen to have been relatively unsuccessful because of a lack of take-up of its analyses and conclusions, and if the "human centred" investigation tool was apparently causing pressure because of difficulty in responding adequately to the findings of its reports, this suggested that there may be a "bottleneck" in the area of the organisation's response to the outputs of these human factors initiatives. This in turn suggested two things:

  Firstly the organisation as a whole did not have a clear idea of what it expected to achieve from its human factors programme. Secondly those for whom the human factor-based recommendations are most salient (planning, quality and operations management) did not feel themselves in a position to respond adequately to the problems as presented, either because of their personal capabilities, the opportunities to respond which the organisation allows them, or because responding to these demands were not sufficiently aligned with the organisations goals and objectives.

- Another issue concerns whether it is advisable to set up a human factors programme in a separate administrative unit, with all the dangers of marginalisation and lack of impact. Where there is no breadth of human factors expertise throughout the organisation this might seem to be the most advisable path in order to ensure coherence and drive in a human factors programme. However if there is not already

a constituency in key areas of the organisation who want and need the outputs from a human factors programme, it may be very difficult to ensure the impact that the programme deserves. One might suggest that the impact of the human factors programme on the organisational change process was at best marginal in Company A.

While Company D had no policy or programme on human factors, as it was felt there would need to be clarification of the alignment of human factor based interventions and the disciplinary procedures, Company B appeared more open to experimenting with human factor initiatives. They had introduced a MEDA-style methodology for investigating incidents and a company wide human factor training programme.

So all of this begs the question what role should safety play in an aircraft maintenance company's overall strategy? This might seem a strange question to pose but, as we have seen, a variety of approaches to the role of safety amongst the organisations existed and this was associated with marked differences in the way in which company safety priorities were appraised in the safety climate survey.

For all of the organisations studied, compliance with the regulatory requirements was a major requirement of safety policy; for some it seemed to be the only major requirement. The question: "How do you know you are running a safe operation?" elicited the answer: "Because we are complying with the safety regulations". This poses the first dilemma for safety management: how to go beyond compliance to develop an independent, internal standard of safe performance?

The internal control concept of Company C was a deliberate attempt to create just such an internal self-regulating system. Maybe this is the type of approach which should be required by the regulatory approach of JAR145. This type of regulation, similar in approach to European Health and Safety legislation, is based on a self-regulatory model in which it is the organisation and its management system which are regulated, not the process of production itself. This is delegated to the enterprise itself (through the accountable manager), which, together with the quality department is then responsible to the regulatory authority. For all the organisations concerned, ensuring compliance required considerable administrative effort and resources, and for one company in

particular (Company B) it sometimes appeared that a disproportional effort was going into ensuring compliance, compared to engaging in more direct methods of ensuring safety. Therefore there is the possibility that the particular demands of the regulation itself could be distorting or impeding the internal organisational safety system.

One of the remarkable aspects of an industry which increasingly recognises the critical role of human factors in ensuring the highest level of safety was that while two of the organisations (A and C) had adopted a number of human factor based programmes, none of the organisations outlined a clear strategic perspective on human factors. Underlying this absence of a clearly stated policy could be a lack of agreement or understanding about what a human factors programme can achieve or could be expected to achieve. Without a strategic perspective on human factors it would be difficult to have a clear objective and mission for a human factors programme. If one of the problems confronting strategic management was not having a clear idea what can be achieved by a human factors oriented policy, then this focuses attention on the management systems of operations and quality departments, posing the questions: where do the problems seem to be and what could a human factors programme contribute to their solution?

Implementation of policy and setting standards

The model was also concerned to establish how strategy and policy priorities are planned and implemented in practice and in particular, where it would be possible to identify standards against which the successful implementation of policy could be judged. The practical realities of implementing safety policy highlighted the iterative links between organising, planning, resourcing, training, implementing, monitoring and reviewing. In looking at the implementation of policy across the organisations, four issues emerged as impacting its effectiveness; organisational change, co-ordination between departments, the role of technology and industrial relations.

Company C had a strong commitment to the planning of work and implementation of standards and had invested heavily in information technology systems to support this function. Together with the collaborative nature of the industrial relations system, this has led to the development of a system which was both highly flexible to short term variations in operational demand, and appeared to optimise the use of human resources

without significant recourse to overtime. Effective planning and setting standards were integral concepts to the "Internal Control Concept" which guided the organisational system in Company C. Company C had an extensive programme of middle management training since the mid 1980s, involving all managers. The courses extended over several weeks with several managers having undergone more than one of these training programmes. All managers interviewed rated the impact of these courses very positively. Their programme of management training was more extensive than the management training initiatives of the other companies, and all the managers interviewed reported positively on its effectiveness.

Company A had undergone a major process of reorganisation. On the one hand this process had a fairly radical impact on personnel, requiring many to reapply for their jobs which had been "reengineered" in the "new world" of Company A. Some of the fallout of this was expressed in concerns about "trust" in management, though the study was not in a position to examine this issue systematically. The organisational structure of Company A was redesigned around fleets with core and satellite teams. However, while quality was fully "reengineered" production was not. Thus the planned "fully engineered task", whereby each task was presented as a package with all tools, materials and resources to hand, was not achieved. Thus the major benefit of the organisational change for the planning and resourcing of work at the point of production did not appear to have been fully realised. Company A had a strong corporate commitment to managerial training which involved a varied programme of courses, including leadership. However the duration of the courses was not so extensive as those put on by Company C, and the assessment of their impact on managerial capability was more mixed with many negative comments.

In Company D, in certain departments, established practice, job demarcations and industrial relations were reported to inhibit the development of a fully effective organisation of work and communications between sections and between production staff and management did not always seem to facilitate effective identification and resolution of problems. However the company were planning to review the use of 'black books' and reach a compromise with the aircraft engineers in producing a useful documentation aid. Company D were the only organisation that had begun to address the problems with their microfilm reader printers in that they had invested in CD-ROM

versions on key maintenance manuals and had also invested in intensive training on their use. In the line maintenance department the development of the MOCC (Maintenance Operations Control Centre) was an initiative designed to improve communication and coordination between the different sections and departments concerned with maintenance and dispatch, however this development was designed primarily to improve punctuality. Company D had a policy of recruiting graduate engineers only to its managerial grades and of not promoting licensed aircraft engineers to a managerial level. Senior management were dubious of the value of training management in skills relevant to managing people and few managers reported receiving additional management training.

In Company B many aspects of the planning and organisation of work appeared to be an unresolved issue from the management point of view: while many managers remarked that there was a less than optimal allocation of personnel resources with plenty of slack in the system and a heavy and routine reliance on overtime, on the shop floor the comment was frequently that problems were frequently caused by a lack of adequate personnel resources at the right time and place. There was the strong impression that the industrial relations climate is inhibiting effective mechanisms for the planning and allocation of resources. Company B had no consistent policy of management training. Some managers had received training as part of the preparation of the setting up of Company B as an independent company, which had included a focus on planning and production control. These courses were rated as very effective, however the variety of other shorter courses many managers had received were not rated highly. Many managers had not received any specific management training.

Setting standards

The model highlighted that safety performance may be measured against pre-determined standards. This reveals when and where action is needed to improve performance. Regulatory bodies may set these standards externally, or there may be internal standards based on a variety of indicators of safety performance, which leads to the identification of standards, which are subject to monitoring.

In this study only one company had an explicit formulation of an overall standard of safety. The "internal control" concept of Company C was built around setting an internal standard for safety performance which was monitored and against which performance was measured, however it was not clear precisely how achieving this standard was measured. The expressed philosophy at Company A was to exceed the technical requirements of the regulator or the manufacturer where possible. A significant part of the work of the quality department concerned the computing and monitoring of trends of various indicators, but it was not clear if these trends related to any particular standard. For both companies B and D assessed compliance with the requirements of JAR 145 and the audits of the JAA appeared to be the main criterion of achieving an acceptable safety standard.

The objective of assessing standards in the study was to consider the extent organisations adopted an independent internally generated standard for evaluating their safety performance. During the course of the research this notion of having an internal standard of safety against which the successful implementation of policy could be judged was quite problematic for two reasons in particular. Firstly the model did not provide enough clarity on what exactly was meant by creating an internal standard. The model separated strategy and policy from implementation of policy and setting standards and as the research progressed the boundary between strategy and implementation and setting standards became less clear. However the literature did indicate that safety standards should be set at a strategic management level and continually monitored in practice.

The second problem encountered in relation to setting internal standards was that important aspects of the systems for ensuring safety and reliability do not work as they are supposed to do. In so far as they do work as an effective system, it is because of unofficial and informal mechanisms which are neither recognised nor valued in the way in which the system is commonly understood by those responsible for it. In many ways these informal mechanisms run directly counter to the expressed goals and values of the system and those who set company policy and strategy. Therefore an internal standard that does not take into consideration a realistic appraisal of what actually happens in practice will not be able to effectively judge how effectively the organisation is performing from the point of view of safety and reliability.

Overall in relation to the second element of the model many managers in the different companies expressed frustration that they or their company were unable to implement plans of work or allocate resources in an optimal manner either from a commercial or a safety point of view or that the quality of communications was not always timely, open and clear. Established practice, demarcations, industrial relations and the disciplinary climate were variously cited particularly in Companies B and D. It was also worth noting that Company A's organisational change programme was unable to fully realise its plans to operationalise the Fully Engineered Task (FET). On the other hand the system for the planning and organisation of work in Company C appeared to be relatively technologically sophisticated, flexible both to changing demands of production and individual requirements, and existed within a collaborative industrial relations atmosphere.

Planning systems were not one of the focal aspects of the model but the importance of planning and the organisation of work became apparent as the interviews progressed. This would suggest the inclusion of planning within the model in order to represent a more comprehensive overview of the planning process in aircraft maintenance.

One of the major contrasts between the companies was in their policy and practice concerning management training and development. Company C had the most comprehensive programme of management training and while Company A was very committed to providing training and managers tended to have undertaken one or more courses but the evaluation of these was mixed. Many managers in Company B had received some management training, some had not, but it was a minority who saw the value in this training in informing and developing their practice. Company D's policy did not value management training at all.

While all the companies were subject to the standards of compliance with JAR 145 as audited by their national CAA, to what extent did they adopt an independent internally generated standard for evaluating their safety performance? That is how do they effectively monitor their own performance and learn from the lessons of the past in ways that support safety? The notion of having an internal safety standard is quite

problematic particularly in light of the findings of this study where it was found that an effective standard of safety could only be effective if informal ways of working and normal operational practice could be systematically evaluated.

Normal Operational Practice

Another focus of the model was to measure important aspects of behaviour in normal operational practice and to compare this with how work is formally planned, prescribed, supported and monitored. The particular objective of this study was to assess what extent maintenance manual procedures are complied with. The analysis of the survey of task procedures showed that overall 34% of respondents reported not following the official procedure for the task. No significant differences were found between the four organisations despite different practices for supporting procedure compliance across the four organisations.

Thus, in over one third of tasks aircraft engineers report that they do not follow the procedure according to the maintenance manual. Lack of clarity in the task or procedure is strongly associated with not following the procedure having consulted the manual, while knowing a quicker way to do the task is strongly associated with neither following the procedure nor consulting the manual.

These findings give rise to some concern. The official position is that all the tasks in aircraft maintenance are required to be performed according to the procedures laid out in the maintenance manual and in the maintenance organisation's Exposition Document. This is one of the major pillars of quality and safety in the industry. The premise is that there is a correct way to undertake the task and that if the prescribed procedures are not precisely followed this may lead to mistakes and unsafe situations. The certifying aircraft engineer has to sign off that the work has been performed according to the procedures. What confidence can we have in a fundamental safety principle of the industry if it is routinely violated?

There is thus a radical disjuncture between the logic of practical experience and the logic of the formal safety system. This effectively amounts to a double standard

between two parallel systems of work – an official system and the way it is actually done. Therefore what confidence can we have in a fundamental safety principle of the industry if it is routinely violated? It may be tempting to conclude that the problem would be solved if everyone followed procedures, or in the words of one manager, if '...there was a pill that could be prescribed to follow task procedures...' However this is much too simplistic. On the one hand there often are better, easier and smarter ways of working than are laid out in the documentation. On the other hand aircraft engineers sometimes do deliberately and wilfully persist in undertaking tasks in a manner which violates procedures which are essential for safety.

The unofficial and illegal status of these informal work practices means that they tend to be hidden and unavailable to scrutiny. It is thus impossible to know how much of this informal work practice represents better ways of doing things than following the manual to the letter, or how much might increase risk because important safe-guards contained in the documentation are being ignored.

The implication of this is that the system relies on the professionalism of the aircraft maintenance engineer to manage the boundaries between unofficial informal work practices and the officially specified requirements of the task. This study found that while some aspects of the organisational safety culture (safety management system, safety climate, expectations of response to incidents) are strongly differentiated between and within organisations, other aspects (the behaviour and safety attitudes of aircraft engineers) are not. This analysis would seem to suggest that there is a strong professional sub-culture, which is relatively independent of the organisation.

One implication of this finding is that this professional sub-culture mediates the effect of the organisational safety system on normal operational practice. Arguably, this professional sub-culture provides the flexibility to deal with situations which are not fully anticipated or planned, and to make the judgement to do what it takes to get the job done. On the other hand, when this divergence between the management system and subculture becomes routine and institutionalised, then the difference between the "official" way of doing things and the "actual" way of doing things becomes impervious to scrutiny. When this happens it becomes very difficult to have an objective standard of safety as a great deal of knowledge lies in workers' hands. Yet

the gap between prescribed work and real work is a fact. One has to find ways to constantly reconcile and adjust the two in order to support maintenance operations in their constant dilemmas with unplanned situations. Otherwise the deviation from formal documented practice (which will take place anyway) may oblige workers to take great responsibilities and sometimes even greater risks (Bourrier, 1997).

Monitoring

The monitoring function extracts information from the overall effectiveness of policy implementation, the pre-determined standards and from what actually happens in practice. This information is obtained, for example, from internal and external audits, quality investigation reports, incident reports, and analysis of trends in incident and quality indicators. Those organisations which had extensive and well-used quality reporting systems and systems for investigating incidents in depth, frequently had difficulty in dealing effectively with the information generated by the quality or incident investigation reports. This difficulty could be because of the sheer volume of reports, the difficulty of knowing where responsibility for action should lie, or the nature and complexity of the report itself, which makes its implementation difficult.

Audits and inspections

All the companies were subject to the annual audit under the JAA regulations. However within this there were a number of differences between the companies in the manner in which auditing and inspection were carried out. Company C had a substantial auditing department which carried out system and process audits. System audits had the organisation and infrastructure as their subject; process audits were concerned with following a particular work process from initiation to completion. This could involve observation of the work being carried out. The results of audits were presented to the managers responsible and it was up to them to devise a plan to address any deficiencies that had been identified. Implementation was then monitored in future audits. The auditing process was not as comprehensive in the other three organisations. It appeared that auditing in the other organisations included both the auditing of documentation to ensure compliance with regulatory standards and site visits to audit the physical resources and infrastructure. However it did not include observation or sampling of the

work actually being carried out and the actual implementation of audit recommendations was usually not monitored.

There were also differences between the companies in relation to the inspection and certification of maintenance tasks. In both Company C and D there was a separate cadre of licensed aircraft engineers, or inspectors, whose job was to certify that the work had been carried out according to the procedures. In Company C it was emphasised that the role of these inspectors was frequently an advisory and supportive role making use of their seniority and experience. In Company D they were perceived to have more of a policing role. In both Companies A and B licensed engineers could themselves sign off, or certify, work which they had been responsible for carrying out.

Quality reporting

While all of the organisations had some form of quality discrepancy reporting system, which enabled aircraft engineers to report problems and deficiencies in the production system, these systems were at various stages of development. Company A had the most extensive system for quality discrepancy reporting which generated several hundred reports per year. However there was a large backlog of work in the system for dealing with these reports and many months usually elapsed before reports were dealt with. This risked undermining the credibility of the system. Part of the problem was getting departmental managers to accept responsibility for the problems identified rather than passing on responsibility elsewhere.

Company D's system of quality reporting was not so extensively used as that in Company A but had similar problems in achieving systematic follow through. Company B had recently introduced a quality discrepancy reporting system; it had not been extensively used and it appeared that many aircraft engineers were not aware of its existence. Some areas in Company C had a paper-based quality reporting system, which was unable to keep up with the volume of paperwork generated, compromising the credibility of the scheme. There was also a pilot scheme in one hangar, which could provide a model for a more comprehensive scheme. The scheme was centred on a PC database; it was actively promoted by the manager responsible and this had met with a positive response from line management to the extent that one manager had appointed a

deputy to deal exclusively with the outputs from the quality reporting system. In addition cost analysis was also carried out in connection with the quality discrepancy and Company C's quality inspectors rather than central quality dealt with the discrepancy reports.

Incident investigation

Arrangements for incident and accident investigation also varied between the companies. Company A had developed their own version of the MEDA investigation methodology. The methodology had been used in major incident investigations, and there had been reports of some of these investigations in the 'Human Factors' magazine. Company C had formed a team of experienced persons qualified to undertake accident and incident investigations wherever in the company they arose. An appropriate investigation team was put together from the team depending on the nature of the incident. In Company D the quality department conducted incident investigations though without any explicit human factors based methodology. Company B had also recently adopted a MEDA type methodology in its investigation protocols but this did not seem to have been extensively used.

Overall Company C displayed a much more open policy to incident management where they were significantly more likely to report impartial investigation, discussion of incident and verbal reprimand compared to the other organisations. On the other hand Companies B and D showed a much more closed and controlled approach to managing incidents within the organisations. Company B were, for example, significantly more likely to report suspension of licence and they had the lowest level of incident discussion. Company A reported similar outcomes to Company C although they were also more likely to report suspension of job compared to the other organisations. When these outcomes were compared across job types within each of the organisations it was found that different groups of personnel had very different perceptions. Operational staff in Company C were found to report significantly higher levels of impartial investigation compared to their management and support functions. This can be compared to the very similar perceptions on impartial investigation that were reported across all job types in Companies B and D. Likewise operational staff in Company B were significantly more likely to report suspension of licence compared to their

management and support functions, while similar perceptions on suspension of licence were reported across all job types in the other companies.

These results would seem to indicate that certain aspects of the incident management process are understood quite differently among different groups of personnel. So the question has to be asked why do operational staff in Company B perceive suspension of licence as a more likely outcome compared to their management and support staff functions? Or why do operational staff in Company C perceive impartial investigation as a more a more likely outcome compared to their management and support staff functions? On the face of it, it would appear that each of these organisations have not been successful in either communicating their policies on incident management involvement, or that they have displayed inconsistent practices in relation to dealing with incidents. These findings raise a number of issues, particularly in relation to disciplinary action. Because the disciplinary code and how it is enforced is so influential in the reporting of incidents and governs the manner in which companies respond to incidents, it is important that a consistent message on the disciplinary code is communicated and understood by everyone in the organisation.

This study found a number of differences across the four organisation in relation to their disciplinary policy. In Company D there was a strong emphasis on the importance of discipline and the enforcing of disciplinary standards, from senior management. A disciplinary response to involvement in incidents, which could be interpreted as negligence, appeared to be normal. In Company A there was a corporate "no blame" safety policy, which existed side by side with the disciplinary code. However Company A were significantly more likely to report suspension of job (the most serious disciplinary response) compared to the other organisations. Company A did recognise this problem and were working on a proposal to integrate these two policies in a coherent way in order to remove the contradictions between them. In Company B there was an informal policy described by managers as seeking not to blame individuals involved in incidents where serious negligence was not involved. In fact, it was pointed out that it was frequently the most conscientious workers who became involved in incidents through taking the initiative in order to overcome some deficiencies in the organisation of a particular task. However at the same time the policy was routinely to suspend the license of those involved in incidents and to put them through a half day

training programme - which can be seen as being a "blame and train" policy. In Company C the issue of discipline was not seen to be problematic with a strong preference being expressed for dealing with issues by discussion rather than punitively; in the case of serious incidents the issue of suspension of approval may arise but nothing would be decided without consultation with the union.

Feedback

Effective feedback has been described as a vehicle to facilitate organisational learning (Toft, 1992). It was felt that feedback can influence all levels of the system from strategy and policy, the mechanisms for the implementation of policy, setting standards, behavioural norms of the operation and external influence. The interviews looked at how the operational management received feedback from routine processes like auditing and from incident and accident reports and the manner of the response to this feedback.

There were great differences between the companies in the way they handled information from incident investigations and quality reports. These differences were reflected in how the companies addressed the possibility of change as a response to the incidents and reports. Company A disseminated much information from incident and quality reports in two internal company magazines. The scope and depth of the 'human centred' investigations raised issues which were difficult for managers to deal with because of their organisational implications. In Company B, incident reports were highly confidential. Managers usually received a verbal briefing, which they were meant to 'cascade down' to their subordinates in a sequence of briefings at increasingly junior levels. There was a strong reluctance to discuss details of incidents within the company. A routine response was to temporarily suspend the licence of an aircraft engineer involved in an incident. In Company C the investigation reports were normally available on demand throughout the organisation. In Company D managers were given reports of incidents including the level of detail deemed appropriate to their role and seniority (full investigation reports were treated as highly confidential). It appeared that the response to recent incidents had been to emphasise the importance of discipline.

Feedback from the various quality reporting systems also differed between the organisations. In both Companies A and C, quality systems appeared to be clogged with too many reports leading to long delays in dealing with the reports and providing feedback to the originator. In Company A, part of the problem appeared to be difficulty in getting management to take responsibility for the problem, rather than passing it on to someone else. In Company D, the low level of spontaneous reporting may be due in part to the disciplinary climate - people felt that they would be blamed for raising problems. Managers whose department was the subject of discrepancy reports felt that the finger of blame was pointing at them, which obviously led to a somewhat defensive attitude.

The way in which people would expect to hear about incidents that may have occurred in their company was one of the questions in the incidents questionnaire. It seems plausible to suggest that the way in which people hear about these events would strongly influence what they learn about the event and what preventive messages are contained in that learning.

Word of mouth was the most frequent method identified in all companies, with the exception of Company C where a written alert was the most frequently identified method. It was interesting to note that despite Company B's policy of conducting verbal briefings with staff about incidents Company B reported the second lowest response for verbal briefing in the incident survey. It would seem that the practice of cascading briefings down through the management hierarchy was not working as it should. The important role played by the Human Factors magazine and Tech News in disseminating incident information in Company A was reflected in the significantly higher percentage who would hear about an incident from a company magazine in Company A (33%) compared to all the other companies, who were all 7% or less.

Therefore it appeared that both Companies A and C operated a much more open and formalised policy in feeding back information from incident investigation. Both of these companies relied on discussion of incident and more formal documented means (e.g., alert bulletin, procedure change, human factor magazine) in order to systematically disseminate incident information. This can be compared with the closed

and cautious approach in Companies B and D where there was a high reliance on word of mouth as the source for disseminating incident information and where all documented information was kept under tight control.

The comparative analysis highlighted a number of key differences and strengths and weaknesses in the safety managements and safety cultures across the four organisations. A number of key underlying issues critical to the role of quality and safety became evident:

Who is the customer for quality and safety information?

A major function of quality and safety departments is the production, analysis and circulation of information. Some of this is required by external agencies such as the Aviation Authority, but who are the "internal customers" for quality and safety information and what do they do with it? In each organisation the researcher spent time identifying the various types of quality reports, where they originated and the committees and personnel responsible for dealing with the findings from these reports. While these different quality reports (e.g., audits, quality discrepancy reports, incident reports) adhered to the standards set by JAR 145 they were ineffective in feeding back outcomes through the organisation. Rather the systems were largely characterised by backlogs, outstanding discrepancy reports with no closure or corrective action, no effective follow-up of recommendations, no effective analysis of trends and little circulation of reports and findings through all levels in the organisations. Therefore are these reporting systems just a means to establishing and sustaining JAR 145 approval? Or should they be seen as a mechanism for enabling organisational learning?

Independent standards of safety performance

Most of the organisations compiled periodic statistics of incidents and quality reports. Some of the organisations went to great lengths to compute trends (e.g., Company A). Such trends were subject to reporting biases, and in some cases acted as a homeostatic mechanism oscillating around a mean preferred rate of reporting. The problem arose in reviewing and interpreting the trends - how does one know how safe one is? And how confident is one that these trends reflect the true state of affairs? Therefore is it possible

to go beyond compliance to develop an independent, internal standard of safe performance? An internal safety standard should be one of the core elements of an effective safety management system. It comprises the criteria on which to judge how effectively the organisation is performing from the point of view of safety and reliability. However this study has highlighted the difficulty in formulating and actually measuring internal standards. In order to formulate an internal standard it would mean that one of the core tasks of strategic management would be to base a programme of work on a realistic appraisal of what actually happens in practice. Without that basis it is difficult if not impossible to evaluate current performance, or to plan or achieve better performance from the system as a whole. But how do strategic management achieve this realistic appraisal of what actually happens in practice when there is an ever-widening gap between practice and official rules? Virtually everyone close to the industry knows that procedures are not strictly complied with, but there is a reluctance to formally admit it because of the legal implications. The issue is thus driven underground - it cannot be admitted, it cannot be studied, it cannot be changed, all of which is required in formulating and sustaining an independent, internal standard of safe performance.

What disciplinary regime is appropriate?

In most organisations there was a disciplinary procedure to cover cases of infringements of rules and regulations. These procedures existed alongside other methods of dealing with non-deliberate or less serious transgressions (human error). The differences between the organisations in their disciplinary policy appeared to have implications for the implementation of effective quality reporting and human factors programmes. While in Company C there appeared to be little conflict concerning the disciplinary code because there was a concern to resolve even fairly serious matters by discussion, with recourse to suspension of authorisation as a last resort, and consultation with the trade union. In Company A there was a serious attempt to resolve the contradictory aspects of the disciplinary process and the human factors inspired "no-blame" policy, but this had not yet been fully implemented. Company B had an informal "no-blame" policy but fairly routinely suspend authorisations and required retraining which appeared to send contradictory messages creating ambivalence about the system. Company D placed a strong emphasis on discipline, which was perceived to inhibit the development

of more human factor oriented policies. So how can the relationship between disciplinary action and reporting systems be effectively aligned or managed?

How to audit performance?

The review of the auditing practices of the different companies constantly threw up the question of what was audited and how. This led to a contrast between auditing practices which were concerned to ensure that the documentation was complete and in order, auditing static facilities (tools, material, environment), and auditing which was concerned to directly sample how work was performed. While the first two types of audits were routinely done, the third was undertaken relatively rarely, and only Company C claimed to include sampling and observation of behaviour as part of its auditing methodology.

Human factors and organisational investigations

Company A had pioneered the development of a methodology for the investigation of human factors and organisational aspects of maintenance incidents and accidents, through involvement with MEDA and its development in the investigation tool. However, this was still at a pilot stage. Company C had formed an investigation team, which was available to investigate maintenance incidents in depth. These investigations played a critical role in identifying how human and organisational factors contributed to accidents and incidents. Frequently, though, generating an in-depth analysis of the precursors of an incident led to preventive recommendations that may have been challenging or difficult to implement. Therefore a lot of attention needs to be given to the follow through of implementation and evaluation of these recommended actions.

Providing feedback to stimulate learning

If it is the case that controlling both human and organisational error is one of the core issues in enhancing safety in aircraft maintenance, then one of the key preventative mechanisms must be learning from one's mistakes and those of others. This presumably applies at all levels of the organisation. In order for this to happen there has to be systematic and structured feedback about errors and the factors that give rise to errors, otherwise no learning will occur. Company B were alone in having devoted an entire publication - "Human Factors" - to reporting on the human factors of maintenance

operations and how they can go wrong, and this was backed up by another magazine, "Tech News". Company C had a policy of openness on their incident reports, whereas there was a strong culture of secrecy in both Companies B and D, so much so that in the former case a proposed air safety magazine was to feature incidents, which occurred anywhere other than in Company B.

The issues identified above have major implications for how current safety management systems promote continuous improvement and organisational learning. It appears that the current weakness in safety management systems risks losing a major leaning opportunity, as there is a lack of transparency and collective knowledge on what actually happens in practice and how current performance can be systematically monitored and evaluated in order to plan or achieve better performance from the system as a whole.

Implications for the Safety Management Model

The model was defined in terms of those explicit organisational processes which had an impact on safety. As such it was deliberately wider than those organisational functions explicitly dedicated to safety. The model was also kept conceptually simple in order to facilitate mapping onto diverse organisations. Company documentation was the starting point in outlining the main structural features of each organisation and the roles and responsibilities of key managers and their departments. This was then supplemented by discussion and interview in order to confirm current roles and responsibilities and how these mapped onto the generic organisational processes in the model. While the framework adopted was applicable to all aspects of safety, a particular emphasis was placed on how the human social and organisational aspects of safety were managed.

Using the major dimensions of the model and employing different measurement and descriptive techniques it was possible to provide a coherent description of safety management systems and safety culture. One of the remarkable things about this study has been the way in which the quantitative results have been quite congruent with the results from the interview studies. Furthermore, this study has demonstrated that it is possible to differentiate between different organisations' safety management systems in

systematic ways. This also provides a starting point for an evaluation of the strengths and weaknesses of different real operational systems.

In general the model received substantial support from the study in describing and differentiating organisational aspects of safety across the four organisations. Analysis of the interview results in particular did, however, lead to a slight reformation of the model in order to emphasise other critical features of a safety management system.

The critical importance of the planning and organisation of work became apparent as the interview studies progressed. Because it was not an issue that had been explicitly highlighted in previous analyses of organisational safety culture, the role of planning and the organisation of work was not one of the focal aspects in the original model. Nevertheless sufficient material was elicited from the interviews to comment on the planning and organisational process engaged in by the participant organisations. Three issues emerged as important dimensions influencing the way planning and the organisation of work was described in the organisations. The first concerned the extent to which the planning and organisation of work was seen to be constrained by the industrial relations system and demarcations based on custom and practice. Secondly, several companies had been actively engaged in, or were considering, systematic 're-engineering' of their operational processes. While some of the focus of this activity concerned the restructuring of organisational departments and their relationships, activity was also directed at systems for the provision of materials, documentation and personnel to fulfil the companies' operational requirements. The third factor that appeared to be influencing the way in which production was organised concerned the use of information technology in the planning process. All of these factors were perceived to have implications for the safety and reliability of the production process. These considerations suggested that a more systematic representation of the planning and organisation of work was needed in the model.

It also became apparent during the study that while the model did address the various feedback mechanisms that should influence all levels of the system, the evidence as to whether change (particularly change in organisational issues) resulted was not explicitly highlighted in the model. This became particularly clear in the context of the quality reporting systems, which purport to be a major engine of change in the quality and

reliability of productions systems. In none of the organisations were these systems fully functioning and routinely delivering improvements in the way in which work was organised and performed. Either such systems had not been fully implemented or else they tended to be backlogged. Again, one highly problematic area appeared to be transforming information about specifically human aspects of failures and deficiencies into implemented programmes for change. For this reason it was decided to make change an explicit stage in the model, that is to further explore how effective change actually occurs following recommendations from the numerous information sources (e.g., incident investigation, quality reporting etc) and how that change is reviewed within the organisation.

As a result of the findings on the critical importance of planning in the overall safety management system and because of the somewhat challenging nature of implementing organisational change in order to continually improve safety management systems the safety management model was further developed. Figure 27 provides a schematic representation of the revised model. The revised model consists of six key elements rather than the five elements proposed in the initial model. The elements of the revised model are as follows (see figure 27):

- Safety Policy and Strategy- how safety is represented as an organisational goal and the organisation's strategy and standards for achieving its safety goals. This should provide a framework for identifying the specific standards which govern particular areas of operational practice.

  In the initial model setting standards was represented as a separate element to safety policy and strategy. However the results of the analysis would indicate that specific standards should be set at a strategic management level and continually monitored in practice. As a result setting standards was included as part of the overall safety policy and strategy.

- Planning and Organisation of Work – how the various activities are planned and organised to ensure the implementation of the safety strategy and safety standards, and to ensure the provision, for example, of resources in the areas of

methods/documentation, personnel, parts and facilities, in order to carry out the organisation's functions.

Planning and organisation of work was included as a key element in the model as it was felt that a much better understanding of the planning process was required in order to understand the issues involved in implementing strategy and policy and how the effectiveness of the planning systems are reflected in normal operation practice. For this reason it was decided to replace the second element of the initial model (Implementation of policy and setting standards) with planning and the organisation of work.

- Normal Operational Practice – how the effectiveness of the organisations strategy and policy and planning systems are reflected in normal practice or behaviour in carrying out the organisation's everyday functions.

- Monitoring – how all the activities of monitoring, feedback and review of operations, including auditing, incident investigation, quality reporting effectively assess the overall safety of the operation and how recommendations for improvement are acted upon.

- Implement Change – how recommendations for improvement as a result of the organisation's monitoring functions are implemented as programmes of change.

  The actual implementation of change was not systematically addressed in the initial model. Again the analysis highlighted some of the difficulties in addressing problems, particularly problems of a human and organisational nature and the complex nature of implementing programmes of change. As a result implementing change was also included as a key element in the model.

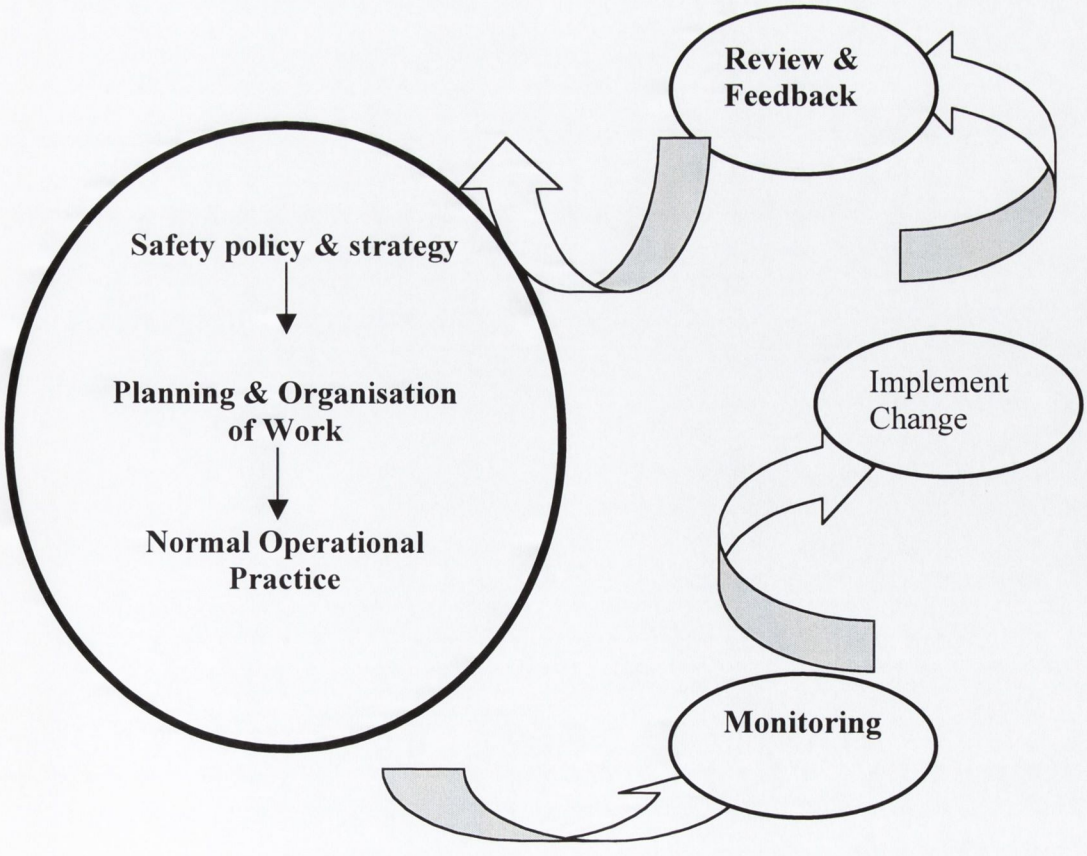
- Review and Feedback – how effectively the proposed change and its implementation has dealt with problems or deficiencies in the system and has this change been systematically fed back into organisational activities.

  In the initial model the process of feedback was considered a key output of the various monitoring functions and it was inferred that this feedback should impact all levels

within the organisation. However it became apparent that continuous review and feedback is required in order to ensure improvements and change in the overall safety management system.

The revised model emphasises the sequential nature of safety strategy and policy, planning and normal operational practice and the idea is that all these activities are subject to continuous monitoring and review. If such a review is to be influential, the recommendations from the monitoring functions need to initiate effective change, which can be systematically fed back into key organisational activities. Any changes that have been implemented should also be continually reviewed because without effective monitoring of change it is impossible to know whether or not recommendations have been effective. Following the review of any change, if that review has not effectively dealt with the problem or additional problems have surfaced then this should be fed back through the system so that the organisation can learn and continually improve its operations.

Figure 27. Revised safety management system model



Overall Summary

The chapter provided a discussion on the main characteristics of the safety management systems and safety culture across the four organisations. The discussion highlighted strengths and weakness in each of the organisations. However a number of key underlying issues critical to the role of safety management across all the organisations became evident. For example:

- What role should safety play in an aircraft maintenance company's overall strategy?
- Is it possible to go beyond compliance to develop an independent, internal standard of safe performance?
- Explicit human factor initiatives – is it advisable to set up a human factors programme in a separate administrative unit? Do responsible managers and organisations have the competence to respond to human factor problems?
- Who is the customer for quality and safety information?
- What disciplinary regime is appropriate?
- How to provide feedback to promote organisational learning?

Based on the key findings the safety management system model was also revised in order to better represent core elements of safety management and highlight the critical importance of planning and the challenging nature of implementing organisational change.

Chapter 7 - Managing Safety; Planning Systems and Implementing Change

Introduction

A wide range of organisational problems have been identified in accident enquiries, many of which occur again and again in different accidents and in different modes. Different combinations of these factors have been found in accidents as far apart as the Clapham Junction Rail accident, the Hatfield rail accident, the explosion of the Space Shuttle Challenger, the sinking of the Herald of Free Enterprise, the Kegworth air accident, the air incident near Daventry, the air accident at Gottröra, the King's Cross Underground fire. Similar contributory factors have been found across all these transport modes including:

- Lack of sufficient appropriately skilled or qualified personnel to undertake the operation satisfactorily
- Inadequate systems for personnel planning and rostering, leading, for example, to excessive hours of work or overtime
- Poor management of parts or equipment leading to the unavailability or poor availability of suitable parts and equipment
- Inadequate or inflexible planning and scheduling of operations and maintenance
- Inadequate monitoring of operational performance
- Inadequate procedures and procedural documentation
- Routine non-compliance with operational and safety procedures
- Incompatibility between procedural requirements and normal operational practice
- Lack of feedback of operational problems and safety concerns
- Lack of response to feedback on operational problems and safety concerns
- Inappropriate management and investigation of incidents and accidents
- Failure to implement recommendations from incident and accident investigations and enquiries
- Management pressures to achieve operational goals.

Virtually all aspects of the organisation and its systems and processes have been implicated in one way or another in the failure to ensure safety. For this reason safety

cannot be regarded as a separate organisational function that sets standards, monitors and controls – safety is implicated in everything that the organisation does. The critical issue is how the safety requirement influences, or fails to influence sufficiently, the whole range of activities for which the organisation is responsible.

To further elucidate the safety management model two separate case studies were undertaken in order to further understand the core issues (from a human and organisational perspective) in planning and organising work and implementing effective organisational change in aircraft maintenance. The objective of the in-depth case studies was not only to illustrate the importance of these two aspects but to further understand the core issues involved in maintenance planning and in achieving organisational change or learning.

Theoretical accounts of the planning process in relation to overall safety management have largely been overlooked in the literature except for some practical guidance material by the HSE's - Successful Health and Safety Management[4] (1991) and from some segments of the safety management literature (e.g., Waring, 1996; Hale at al., 1998). While these contributions highlight the importance of planning to 'minimise risks and setting performance standards' (HSE) and 'setting safety criteria for the planning of personnel, materials, equipment and documentation' (Hale at al 1998), there appears to be very little systematic analysis of the organisational and management processes that should support effective planning and organisation of work.

In addition the analysis of aircraft accidents (e.g., BAC 1-11 over Dicot, 1992; Boeing 737-400, near Daventry, 1996) have highlighted some of the problems in planning and organising the human aspects of aircraft maintenance (particularly in relation to managing manpower and workload and co-ordination between different working groups). Results from this study also found that many of the managers in the different companies expressed frustration that they or their company were unable to organise work or allocate resources in an optimal manner either from a commercial or a safety point of view or that the quality of communications were not always timely or clear. As

[4] Now recognised as HS (G) 65 'Successful Health and Safety Management', 1997. Also forms the basis for chapter 4 COMAH SRAM regulations (Control of Major Accident Hazards – Safety Reporting Assessment Methodology).

a result it was decided to include planning and the organisation of work as one of the key elements in the model.

The planning case study presented here provides a comparative analysis of the planning systems in Companies B and C. It was decided to compare these two organisations, as very different issues were emerging from both organisations in the preliminary analysis of planning in the previous study. It was also felt that interesting differences might emerge comparing Company B (a 3rd party maintenance organisation) and Company C (an airline).

There is also a lack of good guidance and case study material on achieving effective organisational change and learning. Organisational learning from incidents, which ensures prevention, for example, is perhaps the most difficult task in safety management. It also became apparent during the first study that it was very difficult to obtain concrete evidence of effective organisational change (as opposed to technical modifications). Quality reporting systems should be a major engine of change in the quality and reliability of production systems. However in none of the organisations were these systems fully functioning and routinely delivering improvements in the way in which work was organised and performed. Either such systems had not been fully implemented or else they tended to be backlogged. Again, one highly problematic area appeared to be transforming information about specifically human aspects of failures and deficiencies into implemented programmes for change. As a result the implementation of change was also included in the model and an in-depth case study was conducted in Company C with the objective of assessing how this organisation responded to recommendations from a series of incident investigations.

This chapter consists of three main sections. The first section provides a descriptive overview of the planning process in each of Companies B and C, a comparative analysis and outlines implications and core issues in the planning and organisation of work. The second section concentrates on the implementation of a set of recommendations following a series of incident investigations in Company C. Again the case studies provide a descriptive overview of the organisation's attempt to implement effective change following the incidents, outlines the implications and some preliminary recommendations for effective organisational change. The final section of

this chapter provides an overall summary and discusses the overall development of the safety management model.

Planning and the organisation of work – an overview

Planning and the organisation of work in aircraft maintenance involves a number of key departments responsible for the various aspects in planning, organising, scheduling and dispatching the aircraft in the most safe, the most efficient and most cost effective manner. Therefore almost every department has a role to play in the overall planning process. For example the Marketing, Finance and Contracts departments are involved at a very high level in not only securing existing contracts but also improving the overall business strategy of the organisation and planning for future contracts. Engineering, Planning and Operations departments are responsible for devising, scheduling and implementing aircraft maintenance schedules and liasing with customers, vendors and the manufacturer at the point of production. The various departments involved in the supply chain process are responsible for planning of parts, materials, equipment and tools. The Quality department has responsibility for planning that all monitoring functions are conducted in order to oversee effective compliance, and the Human Resources and Training departments have responsibility for planning manpower levels and appropriate certification levels.

Therefore overall planning in aircraft maintenance is a complex process spanning across the whole organisation, involving different departments and external organisations at different stages with very different issues and problems. Rather than focusing on the overall planning process, the particular focus of this case study was to provide an overview of the planning process involved in developing, dispatching and receiving the scheduled maintenance work-pack. This particular planning process was selected as the work-pack is the culmination of detailed planning involving inputs from a wide source of documentation and personnel including the manufacturer, the regulatory body, customers and various departments within the maintenance organisation. The output of this is the complete package of all the work-cards for scheduled maintenance for a particular check from which work at the operational level is planned and organised.

The complete work-pack for each check contains all the items relevant to the particular check including routine work, routine inspection, repairs, modifications, component changes etc. The inspection and work items on the work-cards are written strictly in accordance with the relevant item in the approved Maintenance Schedule for the appropriate aircraft type and the pack may also contain the relevant maintenance manual procedures attached to each of the job cards. In some cases a work-pack can contain up to 5,000 documents, and in the word of one shift manager 'the actual work-pack can be heavier than the aircraft itself'.

The overall objective of this section was to systematically analyse and compare this planning process (development, dispatch and delivery of the work-pack) across two of the aircraft maintenance organisations. This analysis will focus particularly on the role of the engineering, planning and production departments within the maintenance organisation in order to more fully understand the planning process and to identify the main human and organisational issues for effective planning and organisation of work.

Description of Planning in Company B

The description of planning in Company B traced the process from the engineering department, through to the planning department and finally the planning of daily activities on the hangar floor. A total of 6 semi-structured interviews were conducted, each interview lasting approximately 1 hour (See Appendix 8 for Interview Schedule).

The following personnel were interviewed:

- Production - Chief Scheduler, Shift Manager
- Planning Department - Planning Manager, A330 Planner
- Engineering Department - Chief Engineer, Systems Engineer

Relevant documentation across each of the departments was also analysed. This primarily consisted of the Company Manual Procedures and the Maintenance Organisation Exposition Document (MOE). Following each interview a synopsis was sent back to each interviewee in order to ensure the accuracy of the interpretation of the information, to clarify any ambiguous issues and to provide the opportunity to add any additional information.

Engineering Department

In Company B 75% of the work was derived from Third Party Maintenance and 25% of work from their airline. The engineering department had the responsibility for over-seeing the higher order planning of all the fleets (the airline fleets and third party work) and producing the Maintenance Program for each aircraft type. In relation to Airbus aircraft, for example, the starting point for a maintenance program was the Maintenance Planning Document (MPD) which provided guidelines as to exactly what tasks should be done and at what intervals. However, these guidelines were just a starting point. The engineering department could add or remove tasks from the schedule and/or intervals of checks could be extended or reduced. This revised program was then referred to as the Maintenance Schedule (MS) from which the maintenance planners prepared and produced all the work-cards and documentation necessary to complete a check. In some cases the customer defined their own maintenance schedule and produced their work-cards, which were sent directly to the relevant production area

Additional information could be added to the maintenance schedule at any time of planning. Additional inspections or modifications, for example, could result from airworthiness information (whether mandatory or recommended), or could result from manufacturers information, such as Service Bulletins.

Once planning receives notification of an additional inspection they have the responsibility for notifying other departments (e.g., materials and stores) to ensure materials and parts are in stock. Planning continues preparing the work-pack until it is ready to be sent to the shop floor.

Prior to the commencement of a check the engineering department have the responsibility for preparing the maintenance programme for each check and assessing any additional work that should be incorporated into a check, all of which should be completed prior to the arrival of the aircraft. During the actual check the role of the engineering department shifts from one of a planning nature to more of an advisory role.

Query notes are the primary means of communication between the engineering department and production during a check. A Query Note can be raised from the production to request from the engineering department any additional information or clarification on a particular task. Query notes are always technical and reactive in nature and feedback to the originator can either be in written form or of a verbal nature. It was reported that there is always prompt feedback from the engineering department on Query Notes as an aircraft or component, which is subject to a query note, cannot be released to service until a response has been received from Engineering. Query Notes are also used to advise the engineering department of inspection defect findings for information purposes only.

The engineering department had overall responsibility for creating the Maintenance Schedule for each aircraft type and check. This primarily involved communicating with different sections within their own department, customers, the airline's engineering department, the regulator and the manufacturer. All of these inputs were considered when compiling a maintenance schedule. It was interesting to note that at this stage of planning the production department were not involved even though this is where the maintenance schedule was actually implemented. The engineers did comment that they were not always aware of the overhaul maintenance schedule and did feel 'removed' from what actually happened in practice. They also reported that communication could improve between themselves and the planning department and sometimes they felt that the planning department did not always understand the technical aspects of planning maintenance work. While Query notes were treated as priority within the department, sometimes there were delays in responding effectively to them, as the information was not always adequate or correct. Therefore considerable time was spent chasing key information required to respond to the query. All of these issues had been raised on a number of occasions in the Company, however very little had been achieved in addressing them.

Planning Department

Based upon the maintenance schedule items (accessed via an IT based system) the planning department plan which particular aircraft is due for which check and prepare and produce all job cards and documentation necessary to complete the check. The

accomplishment of the maintenance schedule covers all sequential tasks which must be done before the task in question can be carried out and all other tasks which are dependent on the accomplishment of the task in question. This involves, for example defining the tooling, equipment, materials, man-hour content and relevant trades required to complete the check.

This type of detailed planning was obviously only done for those 40 per cent of tasks which were scheduled prior to the input. The remaining 60 per cent unscheduled defect items were usually raised as non-routine cards during the check. For line or ramp maintenance, task resourcing and work allocation was different. Line maintenance was broken down into two separate departments each operating independently from the other – wide-bodied operations and narrow-bodied operations. A co-ordinator assigned aircraft engineer(s) to certain aircraft as they arrived and their activities typically involved the transit checks (e.g., inspection, wheel changes, refuelling, replacement of faulty units). Therefore less detailed planning was required for line maintenance activities.

The Planning department in Company B were known as the "score-keepers" – in that they controlled all the planning documentation for aircraft maintenance and had overall responsibility for:

- Ensuring that all requirements for maintenance as issued by engineering/customers are planned and controlled.
- Producing, certifying and dispatching detailed work-packs required to accomplish scheduled maintenance during line maintenance and overhaul operations.
- Maintaining and auditing the work pack on completion of checks on the aircraft.
- Maintaining the current records for aircraft, engines and shop test equipment.
- Acting as co-ordinators for all queries of a maintenance planning nature which arise from customers in respect of a/c maintenance plans and interacting with engineering, Quality Assurance Maintenance and Overhaul, Finance, Marketing and Sales etc.

All of this required regular communication and negotiation with all customers, with aircraft overhaul, materials, stores and engineering. For example all work-packs should be evaluated for material specifications and these specification should be notified to the

materials section prior to a check. However because of time constraints and delays in developing the work-packs, the materials notification was not always presented prior to a check.

The planning department in Company B were not involved in the planning of manpower. The responsibility for planning manpower was with the sales and operations department who received their information on manpower availability from aircraft overhaul managers. However it appeared that manpower availability was not a consideration at this stage of planning, rather it was the responsibility of the shift managers at the operations level to manage manpower requirements.

Various meetings were organised throughout the lifecycle of a check, including the pre-check meeting, various progress meetings and the post-check meeting. While planning and engineering representatives attended the pre-check meeting, they were not involved in any of the progress meetings and did not have ongoing participation throughout the check until all the signed work packs were sent back to planning following the completion of a check. Within the work-packs there were usually a number of extra planning cards that the aircraft engineers could return if they had any problems with any of the work cards. Planning reported that very few of these cards were returned, however it appeared that very few of the aircraft engineers knew they existed.

It was strongly felt within the planning department that the IT systems currently in operation needed to be upgraded in order to link some of the existing systems. For example, while the forecasting system was effective for overall planning it was not linked to any of the Document Control Systems. Therefore the planners printed the job cards from the Document Control Systems and printed the required documentation from the microfiche and then stapled the documents to the work cards.

The planning department received the maintenance schedule from the engineering department and produced, certified and dispatched work-packs required to accomplish maintenance operations. Their role in many ways was largely an administrative role in organising maintenance compared to the highly technical role of the engineering and operations department. Over 80% of the personnel in the planning department did not have a technical background and it was reported that they did not always understand all

the maintenance schedule items that they were responsible for producing. One admitted that they knew 'the stores were located somewhere between hangars 1 to 5, although I am not too sure where they are located as I have never been actually down there'.

One of the planners had just taken responsibility for looking after components on the shop floor. The task involved checking and updating an IT-based report covering about 30 components every week from stores. However in many instances vital information was missing. One particular problem was highlighted in relation to the escapes slides. For example if a slide was over a certain age then the overhaul life was less, but planning did not know the date of manufacture, as it was not included in the report sent up from stores. Also, the battery on the slide, according to the documentation in planning, should be scrapped every 4 years. However the documentation from the shop showed that it should be scrapped every 5 years. Planning contacted engineering to clarify this situation but no corrective date had been issued. It was reported that the flow of information and documentation from engineering was always very slow and the whole process lacked any visibility. These types of problems were reported to have been prevalent for years and the solutions to date had been quick fixes and very short term solutions.

It was also reported that the department was very short staffed ('too much paperwork and not enough staff') and while some new people had joined a lot of time was devoted to on the job training.

Production - Check Scheduling Group

The check scheduling group were based in the production area and they received the aircraft work packs from the planning department or directly from the customer airline planning department. Initially the Check Scheduling group was under the control of the engineering department and became a sub section of the planning department. As the scheduling section was mainly an operations unit based on the hangar floor, problems developed when the schedulers were reporting to the management of a different department. It was felt that the management in the Engineering Department were using the scheduling section as a means of gaining hands-on information on the day-to-day problems experienced by the overhaul department and it was strongly felt that

'..sometimes this was used against aircraft overhaul for the wrong reasons...' Eventually this led to a mistrust of the schedulers by the operations people that in turn hindered the level of co-operation and communication between these two groups. As a result the check scheduling section was re-organised and at the time of this research reported directly to the Operations General Manager for Aircraft Overhaul.

There were 7 Product Lines in Company B and a typical Product Line team consisted of about 60 people for the small to medium sized aircraft and about 120 people for the maintenance of the bigger aircraft (e.g., B747 or the A330). Each Product Line had a support team consisting of 2 schedulers, 1 materials co-ordinator and 1 clerical administrator. The company had only recently introduced a materials co-ordinator within the support team.

The schedulers were responsible for supplying all the paperwork and documentation both prior to and during a check. They were responsible for organising the work-pack into controllable work. The work packs were broken down into 7 zones (e.g., cabin, wings, engines) of the aircraft and were then organised into a sequence of events (from pre-check to the test flight). At this stage the scheduler also drafted 'highlights'. The 'highlights' were a shortlist of the major jobs to be executed during the coming visit, which were used as a discussion document for the pre-check meetings. These 'highlights' allowed the supervisor to delegate work and allowed time for removal of vital parts prior to the work cards being placed on the rack. The work was broken down into different task cards and the tasks were distributed on the racks according to the different zones of the aircraft and the work teams associated with that zone.

The check scheduler was also responsible for a daily walk-around where he inspected the progress of completed work-cards and assessed any work outstanding. Work-cards were also audited about twice during a check, which involved comparing work-cards finished/outstanding with the tally list, and making sure that all work was signed off and stamped properly. At the end of a check the scheduler collated the cards and took responsibility for sending the work-pack back to the internal planning department or to the customer planning department.

Check Scheduling personnel met for about 15-30 minutes each morning with the contract manager, crew managers, materials personnel, and the customer. It was reported that this meeting was a vital part of the day-to-day work as each of the parties were brought up to speed on the current situation. In particular, the supervisors were able to report back on what was actually happening on the shop floor.

The returned work-pack was used as a feedback mechanism by the planning and engineering departments. Planning used it to update the aircraft data, for example, to update the time due and time remaining for certain parts as a result of modifications. The engineering department could also audit the work packs, however due to time constraints this very rarely happened. Specific programmes were usually observed, like the Corrosion Prevention and Control Programme (CPCP) and non-routine work. If certain task cards raised exceptional amounts of non-routine cards this situation would be examined. However this type of work was done manually and only when time allowed. Therefore the time span between the conclusion of the work pack and the use of the information by the engineering department was usually quite lengthy.

Another aspect of retrieving information from work already performed, either by means of concluded work packs or, for example, from reported defects, was that it was highly dependent on the memory of the investigating engineer as this type of work was not (yet) automated or based upon automated database information. For example, in order to trace a repeated defect, the investigating engineer would have to remember a previous occurrence of the same or comparable situation. It was reported that this was impeded by poor problem descriptions and incomplete information by the aircraft engineers (e.g., use of only two digits of the ATA reference instead of 3 or 4). Over a few days or maybe a week it may be feasible for the investigating engineer to remember occurrences but for longer periods of time the information could easily be forgotten.

The key role of the schedulers was to break down the work-pack into a controllable and manageable set of tasks. Therefore they relied a great deal on the delivery of the work-pack on time from either the planning department or from the customer. However it was reported that in over 50% of cases there was usually insufficient lead-time prior to a check to effectively organise and plan for maintenance tasks. A number of reasons were put forward for this, including delays in receiving the work-pack, or delays in

completing the previous check ('work pack delivered on time but delays in completing previous check').

It was reported that Company B were very short of manpower (especially in relation to aircraft avionic engineers and schedulers) and, as a result there was a heavy reliance on contracting staff in the company to make up the deficit. However contract schedulers do not exist therefore there was little or no back-up in terms of extra manpower. In the words of one scheduler, 'it is a job that no one wants to do as you are always under pressure with limited support from other work-groups in the organisation'.

In addition to controlling the work-card documentation during a check (including non-conformance reports as well as the scheduled work-cards), the scheduler also had responsibility for overseeing approximately 90% of the total customer invoicing. It was reported that in some cases it could take over a year or more to complete the invoicing for a customer for a particular check. Again this was felt to be a result of the inadequate planning systems and the poor communication between departments in finalising the maintenance contract.

Summary

In Company B each department took responsibility for their own aspect of the planning process and passed it on to the next department. The engineering department had the responsibility for overseeing the higher order and long term planning and producing the maintenance schedule (MS) for each aircraft. The planning department received the MS from the engineering department and produced, certified and dispatched work-packs required to accomplish scheduled maintenance. The scheduling section in the production area then received the work-packs from the planning department and organised the packs into the manageable tasks. At no stage in the overall planning process was production involved.

Production consisted of a team of aircraft engineers, supervisors, crew managers and shift managers who were supported by a separate team made of up schedulers, materials personnel and clerical personnel. However the schedulers were not seen to be fully integrated into the maintenance operation and were seen as a separate function rather than as a team member working towards a final goal. In addition the scheduler and

materials personnel only worked the day shifts and therefore provided little support for the evening and night shifts. There were also contrasting viewpoints reported between managers and aircraft engineers in relations to issues of manpower. The managers' perceptions were that the hangar and line were "over-manned and over resourced". This can be compared with comments from the aircraft technicians and the schedulers ("lack of manpower has caused endless problems"; "a lack of usable equipment at peak demands creates frustration and stress"; " there is a shortage of schedulers which is creating many problems"). Again this was reported to be a result of a number of factors. It was also felt to be a reflection of the industrial relations reported to be prevalent in Company B.

The IT systems in the organisation were not fully integrated. However there were plans to upgrade the systems and in particular to introduce automated systems with built in query possibilities that could assist in analysing trends and re-occurring defects.

Planning in Company B – an update

A subsequent study on the planning process was conducted two years after the above study as part of a larger project[5] concerned with implementing a continuous improvement initiative. A dedicated survey focusing on potential human factor problems was carried out across a number of key departments within Company B (including engineering, planning, quality, aircraft overhaul and line maintenance) to determine the nature and frequency of human factor type problems. A wide range of both potential and actual human factor based problems were identified.

One recurring problem concerned the planning, development and dispatch of the scheduled maintenance work-pack. Two specific problems were highlighted, one from the planning department, and the other from a project planner (formerly known as the scheduler) from the shop-floor.

As already explained, the engineering department were responsible for notifying the planning department of any additional inspections that required inclusion in the work-pack prior to its dispatch to aircraft overhaul. However planning reported that

[5] AMPOS – Aircraft Maintenance Procedure Optimisation System. Funded under the ESPRIT Programme, 1999-2001

engineering were not giving them sufficient notice for incorporating these additional inspections into the work-pack and therefore these additional inspections were causing delays in finalising and dispatching the work-packs to aircraft overhaul.

As a result the work-packs were arriving late to aircraft overhaul on a very regular basis. The project manager now accepted as the norm that he would receive the complete work-pack only 2 days prior to the arrival of an aircraft (rather than the 6 weeks as stated in the company procedures manual). Indeed on a number of occasions the aircraft had arrived in the hangar but there was no accompanying work-pack. An additional problem in Company B concerned the work-packs sent directly from the customer to aircraft overhaul. While it was reported that their in-house work-packs were prepared to a very high standards, there was no standard format for customer work-packs which were usually of a much lower standard. This also resulted in delays, as additional work was required before the work-cards could be allocated.

In order to further explore the issue, further discussions were conducted with the engineering and planning managers and a project planner from the shop-floor. Firstly, it was established that these problems were ongoing and had been highlighted to management on a number of occasions. In order to improve communication between the departments, bi-weekly meetings were set up between the different departments in order to initiate feedback regarding the different problems and attempt a more proactive approach to rectifying the problems. Even though these meetings took place over a 12-month period, '…they came to little or nothing and they just fizzled out without improving anything'. In addition as a result of a number of organisational changes both engineering and planning departments also reported to the same accountable manager. However none of these initiatives addressed the fundamental problem of delays in developing and dispatching the work-packs.

Based upon the findings of the survey, a team was established to further explore these issues. The team was made up of an engineering and planning manager, a reliability engineer, an aircraft planner and a crew manager from the shop floor. A number of meetings were conducted where each department could present 'their side' and a range of suggestions were put forward in order to deal with the problem. The engineering manager explained that when a Service Bulletin, for example, came into the

organisation it was first sent to the Technical Library and it was reported that documentation could '...sit in the library for weeks before it was sent up to engineering.' It was often the case that engineers had to go looking for information themselves. When the engineering departments received a Service Bulletin it had to be thoroughly assessed and this assessment could involve the manufacturer, another operator, the customer, their own finance and contracts department as well a wide variety of documentation sources. Therefore it could take weeks from when the organisation received a Service Bulletin until it was incorporated into a work-pack.

The output from these meetings was a list of five suggestions including:

- Re-establishing the bi-weekly meetings in order to improve communication and co-ordination between departments.

- Planning were to provide engineering with a copy of the winter overhaul so that the engineering department were informed which aircraft were scheduled for what hangar.

The objective of the second suggestion was to inform the engineering department of scheduled aircraft checks so that inspections, modifications and repairs could be issued at least two to three months in advance. This would allow planning to perform their function in producing the call-up for estimating and also to provide the work-pack to Project Planning six weeks before the aircraft check was due in the hangar for its check. The only exception to this would be airworthiness directives or other documentation received in the lead up to the check with a short compliance time.

Further suggestions were to:

- Improve manpower levels in the engineering and planning departments and assess the allocation of work in each department.
- Utilise the Training Project Group.

A training project group had just been set up in order to assess training needs within the organisation. It proposed that training within the organisation must 'create internal awareness' to enable each department to understand other department's objectives and workloads.

- Finally it was suggested to map out each stage in the paper/documentation trial. This would involve mapping out the process of receiving, reviewing and incorporating various documents (e.g., Service Bulletins, Airworthiness Directives) into the maintenance work-pack.

While these recommendations were put forward there seemed to be little or no follow up (e.g., no bi-weekly meetings were established). One of the planners did start mapping out the paper trail, however, while it became apparent that this was quite a major undertaking for one person, it was felt to be a vital task in order to fully understand the process and the barriers to its effective utilisation. As a result it was decided that this task should involve the dedicated process team within the organisation. This team was set up in order to systematically map out key processes and implement recommendations for understanding and improving the overall workflow with the organisation. However it was reported that even though this team had spent considerable amount of time and resources in looking at the overall 'pack to plane' process and had implemented a number of changes primarily at procedural level little or nothing had changed and one project planner reported that in the two previous checks the work-pack was considerably delayed resulting in subsequent delays in commencing the check.

Even though maintenance planning is a process that spans a number of key departments and requires a high level of communication and co-ordination, the process team within the company focused on overall planning as three separate processes:

- Pack-to-plane: pre-planning of aircraft input, identify tooling/equipment/materials, commercial and contractual issues.
- Check: meetings, card control, invoicing, check preparation, check close etc.
- Supply Chain: planning materials, purchasing, inventory management, logistics etc.

Local procedures for each of these processes were developed and separate training courses were organised to introduce changes within each of the processes, but it appeared that at no stage was there any consideration given to the level of integration and visibility between processes that appears to be vital to ensure efficient planning and co-ordination of work.

In summary the development, dispatch and delivery of the aircraft work-pack were assessed in two separate studies in Company B. The objective of the first case study was to gain a better understanding of this particular planning process and to highlight any limitations to its effective utilisation. A number of problems were highlighted, most notably, poor communication between key departments (e.g., planning, engineering and production), segregation of the key departments, lack of manpower, a poor IT infrastructure all of which contributed in some way to the constant delays in developing, dispatching and delivering the work-pack. A second study two years later established that similar problems were still affecting the overall planning process. The company initiated a number of strategies in order to improve the situation, however these met with limited success. The company opted for changing procedures and re-training (somewhat short term strategies) rather than assessing the overall picture and focusing on the key problem areas such as poor communication and co-ordination. As a result the development, dispatch and delivery of the work-pack in Company B was largely characterised by constant delays, much frustration and inefficient planning at all levels within the organisation.

Description of Planning in Company C

The description of planning in Company C focused on the changes introduced into the organisation as a result of the Total Quality Management (TQM) initiative. It was felt that the first attempt at introducing TQM within the company failed largely because they 'tried too much too soon'. As a result the company re-orientated their approach and decided to focus on key processes and gradually introduce change. The approach adopted within the company was described as ' systematic and structured approach to analysing, improving, controlling and managing processes with the aim of improving fundamental activities'. From the outset it was recognised that the existing organisational structure would be a barrier to further improvements and that a more matrix or cross-functional type of structure would be required. Both overall and day-to-day maintenance planning were seen to be key factors and, as a result, the planning functions were amongst the first processes to be re-organised, particularly planning at the operational level.

Planning within the company was composed of three primary levels:

Level 1 – Long Term Planning.

Level 2 – Short Term Planning.

Level 3 – Planning and co-ordination of daily work.

The overall planning process was a complete series of activities, which provided Traffic Related Maintenance (TRM), Heavy Maintenance (HM) and Component Maintenance (CM) with sufficient information in order to prepare and accomplish defined work within a particular time frame. Several functions were responsible for ensuring accomplishment of all planning tasks, including production, materials, engineering, planning and the business control unit.

A total of 7 semi-structured interviews were conducted, each interview lasting approximately 1 hour (see appendix 8 for interview schedule). The following personnel were interviewed:

- Engineering Manager
- Technical Engineer
- Process Manager/Duty Production Manager
- 2 Planners (responsible for printing job cards)
- Quality Investigator (seconded to TQM team)
- Engineer (seconded to TQM team)

Relevant documentation across each of the departments was also analysed. This primarily consisted of the Company Manual Procedures and the Maintenance Organisation Exposition Document (MOE). Following each interview a synopsis was sent back to each interviewee in order to ensure the accuracy of the interpretation of the information, to clarify any ambiguous issues and to provide the opportunity to add any additional information.

Overall, there were 6 key inputs across the three levels that contributed to the various planning activities in Company C. Table 14 provides an overview of these inputs.

Table 14 – Planning Inputs in Company C

Input	Period	Contents
FARP (Resource and Planning tool)	3-1.5 yrs	Prognosis of traffic programme. Including number of aircraft/type, maintenance volume. Modifications, tools/equipment/facilities etc
MMP (Maintenance Master Plan)	1.5-0.5 yrs	Reflecting FARP in respect of prognosis for next coming and estimate for the two next coming traffic programs. Including number of aircraft/type, total maintenance volume, modifications, third party work, tools/equipment/facilities.
HVP (Hangar Visit Plan)	1-0 yrs	Production adjusted maintenance volume reflecting the MMP, including modifications, number of checks according to resources versus capacity
MS Maintenance Schedule)	12-0 weeks	Detailed plan reflecting the HVP with job contents, information per identified maintenance check according to resources versus capacity per skill
PP (Production Plan)	10-0 days	Detailed plan reflecting the MS with all planned maintenance checks. Special planned job and needs of special skills, materials, tools per aircraft registration
Job Selection	24-0 hrs	Actual work load per A/C registration versus capacity

Level 1 – Long Term Planning

A level 1 planning on a long-term basis was carried out based on the company's planning and resourcing tool (FARP). This was a 'rolling' type IT based planning tool, forecasting the volume of maintenance work and other relevant conditions for the coming three-year period. Typically the planning tool reflected the requirements for all types of maintenance work in order to fulfil the traffic programme and highlighted the different types of resources, (e.g., the number of maintenance personnel, tools, equipment, facilities etc) needed during a 3 year period. This tool created a level of visibility for all the key departments in that each were aware of the maintenance schedule and could continually update this based on information from each of their functional activities.

The next step involved the development of the Maintenance Master Plan (MMP) for the coming year. The MMP document was the basis for agreement between planning, engineering and production, with respect to the volume of the maintenance work to be accomplished within the present traffic program period. As a result of the planning

forecast the need for material, tools/equipment and manpower specifications were identified and assessed. Also at this stage Engineering assessed inspections and modifications (e.g., Service Bulletins). When the MMP was developed an assessment against business goals was carried out before a budget was agreed upon between the planning and the business control departments.

The engineering, planning, business control and production departments were all involved at this first level of maintenance planning. Therefore all departments had the same knowledge base, a high degree of visibility and a high level of co-ordination and involvement at the strategic level of longer term planning.

Level 2 –Short Term Planning

The engineering, planning and production departments were also involved in the second level of planning. This step in the planning process was to determine in detail how production could manage and accomplish the maintenance work. A Hangar Visit Plan (HVP) based upon the MMP was undertaken. This usually involved a team from production including material planners, production planners and personnel from the planning and engineering departments. The HVP covered maintenance of the complete aircraft, including components, equipment, materials, and evaluation of job data, production resources and hangar facilities. The objective was to convert the MMP into intervals related to each aircraft thereby controlling and monitoring all scheduled maintenance applicable to the specific aircraft.

Based upon the HVP, a detailed plan (Maintenance Schedule, MS) with job contents information per identified maintenance task, according to resources versus capacity per skill, was developed by the planning department. The plan was the guideline for the overall planning programme of a particular aircraft on a particular check. The MS was then further broken down into a production plan (PP). The shift manager and production planners developed this plan, which could be up-dated and adjusted depending on resources available and delivery of materials, parts and tools. After a production plan (PP) for a certain period had been determined, production planning started producing job cards. In general the quality of job cards was seen as very high. However some management and staff did feel that more aircraft engineer input was

necessary. Company C had just recently introduced a paper based "Job Card Feedback" form where aircraft engineers could make suggestions for improvements in the task documentation. The form was sent to the engineering department who were responsible for replying to the originator and implementing changes.

At levels 1 and 2 flexibility was inbuilt into the planning process. It was recognised that due to the complexities of aircraft maintenance, it was impossible to plan for every contingency. Therefore the company's strategy involved building in what they called 'a buffer' at the early stages of overall planning and long-term maintenance work. For example, if it was planned that a particular check or task should take 5 days to complete depending on x amount of personnel, correct equipment, materials and tools, the planning and business control departments would allow for and budget for at least an extra two days in order to cope with unpredicted faults or snags. So even though the production plans would specify 5 days to complete a task there was some 'leeway' and 'flexibility' to cope with the occurrence of unpredicted faults or snags which had to be corrected.

Information technology was strongly developed and embedded throughout the organisation. All the planning documentation was highly visible and integrated and was automatically updated. For example, BOWAC (Bill Of Work for Aircraft) was a computerised system for planning tasks for maintenance work. This system contained all the information on the state of each aircraft, available manpower, scheduled checks etc. RELS (Reliability System) was also part of the BOWAC system. It allowed for a follow up on faults and trends that had occurred in the system. Results from this system could affect the maintenance programme (which the manufacturer and airline plan together). For example a follow up on a particular problem may result in reducing the time between inspections (i.e., from 500 hours to 300 hours).

Level 3 – Planning and co-ordination of daily work

The planning and co-ordination of daily work took place at level 3. At this level the planners produced, certified and dispatched the detailed work packs required to accomplish scheduled maintenance but they were also present and actively involved during the checks. The planners at this level worked in the Production Control Centres

alongside material personnel/planners, technical engineers, maintenance supervisors, and production managers.

Production control centres had been set up in a number of the hangars in Company C. The production control centres were physically located in the hangar and the team worked shifts to support local production shift patterns and produced fully planned and resourced tasks to the production area. The make up of the production control centre reflected the core team and brought together functions previously carried out in Planning, Materials Management, and Production Engineering. The following description concerned one of the hangars in the company where this new way of working had been in operation for almost two years.

Prior to the introduction of the production centres, the planners and the materials personnel were all in their own departments that were removed from the daily production. It was reported that they did not "...really understand or indeed appreciate what the other did." Now it appeared that all the key players in the production process had a holistic picture and worked as a team in order to meet the operational demands and complete the work on time.

The planners at this level also had daily contact with the aircraft engineers both on day and night shifts. It was reported that the planning process was very reactive to short term demands and any deviations. It was an objective within the company that planning could not be seen to be isolated from what actually happens in reality. Rather the planning and organisation of work must be an integral and flexible support to the demands of the daily operation.

The aircraft engineers and the personnel in the production control centre had a number of daily, weekly and fortnightly meetings to help them all keep abreast of work planned, work completed, work outstanding and any other issues that had come to the fore-front. For example, three weeks prior to a check the aircraft engineers, planners and materials personnel met and between them they decided on what manpower resources and materials were available, and together negotiated when tasks can be completed. It was reported that everyone felt that they participated in all areas of their work and therefore assumed more responsibility for day-to-day operations.

In addition there were weekly meetings that concentrated on general facilities, aircraft, and computer systems. Every second week the aircraft engineers and personnel from the production control centre meet in order to come up with suggestions on how their work and conditions could be improved. Outcomes of these meetings had resulted in, for example, a new media room where the aircraft engineers could educate themselves in the new computer systems and digital manuals. They also arranged a number of social activities within working hours together (e.g., the crew of aircraft engineers attend the gym). There was also a feeling of "pride in one's work" and responsibility for general housekeeping. The aircraft engineers power hosed the facilities at the end of each day, and as a result staging equipment and the general facilities are in very good condition.

Bringing together in the production control centre all the functions, which were previously spread around the organisation, had resulted in more effective planning that could cope with the uncertainties of normal operational practice. It had also resulted in improved communication as the person you need to speak to was sitting beside you and part of the team, not in another building or in another part of the company. Other areas of improvement cited by Duty Production Manager, Material Personnel and the aircraft technicians as a result of this new way of working included:

- More overall control
- More production
- Daily contact with reality
- No labour barriers
- Improved efficiency
- Better commitment.

The changes that had been implemented from 1994 were summarised by one manager as follows. The " culture in the production area is one of high involvement of all employees and they are consulted on every major change in process or work design… there are regular team meetings to discuss any problems in achieving targets and ideas for further improvements…"

Summary

The planning process in Company C involved the integration of planning, engineering, production and business control to oversee the planning of long term and day-today maintenance activities. For example, the entire key planning activities and support documents were developed, validated and implemented by all the key departments. The overall planning process was also supported by a fully developed and integrated IT system.

It was also recognised that TQM was about changing the culture of an organisation and therefore it was clearly communicated to the workforce from the outset that this focus on continuous improvement should not be seen as 'a quick fix' or something that could happen 'over-night'. Overall, it appeared that the changes had been a success because the changes had been incremental. In addition, the person who spearheaded the new way of working was committed to making it work. In addition, the foreman and middle management received training on this new "participatory" style. It also appeared that they were under no illusions that changes would happen over night but realised that they would happen slowly and over time but that they would happen. The commitment of management was seen to be real and this was backed up with actual resources. Above all, the same messages were communicated company wide. There was "...no confusion by us on what the company wanted to achieve and what our role was going to be." At all levels within this company everyone was "speaking the same speak".

There were, however, a number of problems at the initial stages of the introduction of this new way of working. Management focused entirely on those staff that were enthusiastic about the changes rather than trying to bring on board those that were more scepical. It was reported that management did manage to win almost everyone over. It was reported that other problems similar in other airlines still existed within this hangar, for example;

- Aircraft engineers refused to admit gaps in their own knowledge
- Aircraft engineers did not believe that there was a "no blame policy" and cynicism still existed about reporting individual mistakes etc.
- The availability of parts was not all that well managed in the stores
- Time pressures still existed (there was the recognition that you cannot plan for every single contingency)

- An "us" and "them" mentality existed to a certain extent even though flexibility between line and hangar was a one of the key elements in the new way of working.

The new way of working had not worked as satisfactorily on the night shifts. It appeared that it had only been recently introduced on the night shift. A number of suggestions were put forward for this lack of success. It was felt that the move to a process organisation was successful during the day shifts as the person "spearheading" the change was actually physically present and could personally oversee the day-to-day operations. The night shift also worked on much shorter shifts and it appeared that there wasn't the same focus on team working as aircraft engineers could find themselves working with different colleagues on different shifts. Therefore the consistency in team working during the day did not exist on the night shifts.

Comparison of planning in Company B and Company C

The overall planning of maintenance activities spanned three functions (engineering, planning and production) at varying degrees of integration and involvement in each of the organisations.

In general terms, while Company B still existed in the traditional functional organisation, Company C was in the early stages of moving to a more process-based organisation that in effect called for the break-down of traditional departmental barriers. In Company B each department took responsibility for their own aspect of the planning process and passed it on to the next department. The engineering department had responsibility for the higher order and long term planning and produced the Maintenance Schedule (MS). The Planning department received the MS from the engineering department and produced, certified and dispatched work-packs required to accomplish scheduled maintenance. The scheduling section in the production area then received the work-packs from the planning department and further organised the packs into the daily work. On completion of the checks on the aircraft, the planning department then audited and maintained the work-packs and any other records for the aircraft.

In Company C the overall planning process was moving to a more cross-functional way of organising work. So while the engineering, planning and material departments still

existed within the company, the planning process involved the integration of these to oversee the planning of long term and day-to-day maintenance activities. The Maintenance Master Plan (MMP), Maintenance Schedule (MS) and the Hangar Visit Plan (HVP) were developed primarily between planning and engineering. After a production plan for a certain period had been determined, production planning produced the job cards. The planning and co-ordination of daily work took place within the production control centres located in the hangars. The make up of the production control centres reflected the core team and brought together functions previously carried out in planning, materials and engineering.

Core issues in planning and organising work

Four issues in particular emerged as important dimensions influencing the way planning and the organisation of work was described in the two organisations.

- The first concerned the integration of functions in order to support the planning process. This activity concerned the restructuring of organisational departments and their relationships. Activity was also directed at systems for the provision of materials, documentation and personnel to fulfil the companies 'operational requirements'.
- Second was the degree of role support for the integration of previous distinct functions and the high level of visibility and co-ordination.
- Thirdly, this integration of functions, particularly at the operational level, allowed for validation of plans, as the people who had first hand knowledge of the operation are involved in monitoring and reviewing the day to day plans.
- Finally, this resulted in much more flexibility in the organisation both for higher order planning and for what actually happens in practice.

A number of factors were also highlighted that appeared to constrain the overall effectiveness of the planning process.

- The first concerned the extent to which the planning and organisation of work was seen to be constrained by the industrial relations system and that changing the "way we do things around here" (i.e., culture) was a difficult task and one that has to be addressed from the outset.
- The second factor concerned the use of information technology in supporting both the overall and day-to-day planning process.

- Another factor concerned the constraints imposed by 3rd party maintenance as opposed to internal maintenance.
- The final factor concerned the approach adopted in introducing and sustaining change in order to improve the overall planning process.

Integration of functions

Both companies had systematic and fairly comprehensive overall planning systems in place for their higher order planning. The critical difference was in how they planned and managed the uncertainties of the normal operational practice in aircraft maintenance in order to organise work and allocate resources in an optimal manner. While both companies had production support groups on the hangar floor, the production support roles in Company C had been facilitated by changes in the organisation structure to align indirect functions with the product groups they supported. A defining feature of the company was the integration of previously distinct functions. Company C were moving away from the traditional hierarchical methods of ensuring that work is completed (e.g., departmentalisation, command and control) with the introduction of team working. More information passed between previously distinct functions therefore creating a much shorter feedback loop for adjustment and change. This facilitation for communication was essential for supporting not only production targets but also employee development goals.

Role Support

With the introduction of team working at all levels in the organisation different roles provided support for each other. For example production planners worked similar shifts to their other team members (aircraft engineers, shift manager etc). All of this was supported by dedicated training courses emphasising the importance of the complementarily of roles in achieving overall goals. Even though some barriers still existed (e.g., between line and overhaul) considerable progress was made in the company in diluting role barriers and boundaries. Implicit in all of this was the high degree of visibility and co-ordination in Company C. For example all the planning documentation was highly visible and integrated. There was also the physical visibility of key personnel working together at all levels.

Validation of daily plans

With the integration of previously distinct functions attention was also paid to several job features. Two in particular stand out. One of the key aspects of job content is that of production responsibility. A common characteristic of Company C was that it increased the visibility and significance of the individual's contribution to production. Its particular emphasis on quality and the pursuit of such principles as "right first time" highlighted the role of the individual in the production process.

Another job content was that of work interdependence (i.e., degree to which employees collaborate with and are dependent on others in the execution of the work). For example in Company C planning, engineering and production were involved in all levels of both developing and validating the overall planning of the maintenance schedule. TQM practices emphasised the importance of meeting the requirements of both internal and external customers, thus increasing employee awareness of their interdependence. The problem solving aspect of the new way of working also linked the aircraft engineers more directly with the support staff. The production strategies were also designed to make production problems more highly visible so that efforts were exerted in problem prevention rather than rectification.

Flexibility

The integration of previously distinct functions, the introduction of team working and the high involvement approach to work in Company C had allowed for much more flexibility in the organisation both for higher order planning and for what actually happened in practice. It was an objective within the company that planning should not be seen as a process isolated from what actually happens in reality, rather the planning and organisation of work must be an integral and flexible support to the demands of the daily operation.

Industrial Relations

In Company B many aspects of the planning and organisation of work appeared to be an unresolved issue from the management point of view. While many managers remarked that there was less than optimal allocation of resources with plenty of slack

and a heavy and routine reliance on overtime, on the shop floor the comment was that problems were frequently caused by a lack of adequate personnel resources at the right time and place. The scheduling group was also re-organised in order to improve relations and foster some degree of trust between this group and the production team. There was the strong impression that the industrial relations climate was inhibiting effective mechanisms for the planning and allocation of resources. This can be compared with the highly collaborative nature of the industrial relations in Company C. This had led to the development of a system that was both highly flexible to short term variations in operational demands and appeared to optimise the use of human resources without significant recourse to overtime. Therefore it appeared that Company C were able to organise their work and allocate their resources in a more optimal manner both from a safety and a commercial point of view.

Information Technology

Information technology was strongly developed and integrated throughout Company C. The system for planning and the organisation of work in the company appeared to be relatively technologically sophisticated, flexible both to changing demands of production and individual requirements. In Company C the IT supported the integration and the flexibility and made it possible to meet operational demands. The IT system in Company B was not integrated which posed the question as to whether this lack of integration and visibility was a barrier to developing more flexible and validated planning.

Third Party Maintenance

Third party maintenance accounted for 75% of Company B's work, therefore planning maintenance tasks not only involved co-ordination and communication within the company but also required a high level of negotiation and co-ordination with their customers. Working with external organisations also placed a number of constraints on effective planning as different organisations had their own value systems, their own standards of work and their own demands. One particular problem highlighted concerned the work-packs sent directly from the customer to aircraft overhaul. While it was reported that their in-house work-packs (although always late) were prepared to a

very high standard, there was no standard format for customer work-packs and these were usually of a much lower standard. This also resulted in delays, as additional work was required on the customer work-packs before a check could commence.

Introducing Change

Both organisations had undergone various change initiatives. The re-organisation of the planning process in Company C was a key goal of the TQM programme. Quite a lot of resources both in terms of training, manpower, time, and investment in IT were devoted to bringing about improvements. These improvements were represented not only at a procedural level but also at the level of the organisational infrastructure (integration of functions, introduction of team working etc) and supported by dedicated training courses and commitment at the operational management level. Company B introduced a dedicated team to assess the problems with their current planning systems and introduced recommendations to improve the problems. Even though the team assessed the overall planning process that spanned across a number of departments, their recommendations were very localised rather than taking a more centralised approach. For example new local procedures were developed for each of the key departments (production, planning, engineering), therefore the changes further reinforced the segregation of these functions rather than their integration and co-ordination. Therefore it appeared that improvements in maintenance planning required focus not only on the integration and co-ordination of different functions at all levels but also in emphasising the complementarily of roles and functions in achieving improvements.

In summary, documentation control and, in particular the development, dispatch and implementation of the work-pack is one of the key processes in maintenance planning. It is a process that spans across different internal functions at different stages and also involves inputs from external organisations (e.g., manufacturer, regulator, customers etc). Only around 40% of maintenance tasks can be planned from the outset, therefore the planning of the remaining 60% of tasks are managed at the production area.

The case studies presented a comparative analysis of two organisation's approach to planning the aircraft maintenance work-pack. Company C had embarked on a

continuous improvement initiative and the planning process was one of the first to be re-organised. This primarily involved:

- Greater reliance on effective co-ordination between planning, engineering and operations departments to ensure that plans could be adjusted to meet operational requirements.
- Real-time validation and review of plans (at all levels) conducted systematically to ensure that the way in which operations are planned and organised does effectively address the way in which they are carried out.
- Development of a highly flexible system and a highly flexible work force.
- Integration of 'user friendly' IT support systems.

As a result delays in developing and dispatching the work-pack were the exception rather than the norm. While a number of problems still existed, most notably on the night shift, availability of parts, time pressures etc, it was reported that the planning process within the company was very effective and that the organisational processes supporting maintenance planning was improving all the time.

Company B on the other hand were continually reacting to the long-standing problems in developing and dispatching the work-pack. Over a number of years various changes had been introduced into the organisation in order to improve the overall planning process. The changes included for example, the re-organisation of the check scheduling section, the introduction of one accountable manager for engineering and planning, bi-weekly meetings between the various departments and the introduction of support teams on the hangar floor made up of schedulers, materials personnel, administration support and shift management. While it was reported that the support teams were a successful intervention, this team did not receive the relevant support from the other planning functions and changes at the production level were not reflected at other levels within the organisation. This was compounded by constraints imposed by third party maintenance and the prevalent industrial relations. Even though a dedicated team had been set up within the organisation to improve planning processes, very little progress was made as fundamental issues like integration of functions, existing structural barriers, validation of maintenance schedules, line management involvement, overall visibility and accountability were never seriously addressed.

In many ways Company B could learn from the experiences of Company C even though Company B had a number of constraints imposed by third party maintenance. While managing the planning process involves the co-ordination of tools, tasks, parts, equipment, personnel, etc, the culturally and structurally embedded processes of the organisation which support this must also be systematically addressed in order to effectively improve the organisational system that harbours potential problems for the effective planning and organisation of work. The deficiencies in planning systems that have been implicated in incidents and accidents are often most enduring and persistent characteristics of the organisation, rather than being short-term problems in otherwise efficient systems. The implication of this is that unless we are able to change the more deep-seated and enduring characteristics of organisations, there is the danger of repeating the same general types of safety and quality lapses time and time again.

Organisational Change following An Accident Investigation

Introduction

In the initial model while change was an implicit assumption particularly in the context of quality monitoring and feedback functions, the actual process of effectively implementing change was not explicitly considered. For this reason it was decided to make change an explicit stage in the model to further explore how effective change actually occurs following recommendations from the numerous information sources (e.g., accident/incident investigation, quality reporting) and how that change is implemented and reviewed within the organisation.

There was very little evidence either in the academic or practitioner domain regarding the effectiveness of the diagnosis or an assessment of the effectiveness of the recommendations following an accident or serious incident. The incident investigation appears deemed complete once the report had been submitted and there appears to be little or no follow up on the impact of the recommendations or on whether organisational learning and change occurred as a result of the investigation.

When a serious incident or accident occurs the organisation is mandated to conduct an investigation to determine what went wrong, why it went wrong and what needs to be addressed or changed in order to reduce the likelihood of a similar incident or accident occurring in the future. In addition, external bodies may also conduct their own investigation (e.g., Regulatory Bodies, Board Of Accident Investigations) again to determine what went wrong and why it went wrong. All of these investigations culminate in reports, which include a set of recommendations, some of which may be mandatory which the organisation is required to consider or actively implement. However the focus of the incident investigation is largely on the diagnosis of the problem with little or no consideration given to the actual implementation and assessment of the recommendations. For example in a number of internal company accident reports assessed, the average length was anything between 80 and 120 pages out of which one or two at the most was dedicated to the actual recommendations. In most cases while the recommendations of a purely technical nature were very specific, the recommendations with a human factor or organisational focus (e.g., 'seek to ensure the company improve their system of quality assurance') lacked specificity, guidance

and support on how such recommendations should be effectively realised by the organisations. For these reason it was decided to conduct a case study on how Company C responded to a series of incidents involving what turned out to be a particularly difficult and intractable problem.

The case study described the air traffic accident on 27th December 1991 at Gottröra and a similar incident five years later. The accident involved deficiencies in line maintenance activities which are a core function of overall aircraft maintenance. The case study provides a synopsis of both events, identifies contributory factors and tracks the organisations response to the findings of the investigations. The case study identified a number of core issues in effectively implementing change, most notably that effective change takes a long time, it takes many attempts and requires continuous review in order to assess the adequacy of the improvements in dealing with the identified problems.

The investigation of the Gottröra accident was based largely on the analysis of a number of investigation reports, including the report from the Board of Accident Investigation and the company's internal investigation report. Interviews were also conducted with two members of the company investigation team and a quality inspector. The analysis of the second incident was again based on the company's internal investigation report and interviews with one member of the company investigation team, a quality inspector and a quality manager.

The Aircraft Crash at Gottröra

On 27 December 1991, an aircraft (DC-9-81) crashed at Gottröra 4 minutes after takeoff from Arlanda airport, Stockholm, Sweden. According to the Board of Accident Investigation, the obvious reason for the crash was that clear ice broke off from the wings and caused damage to the engine fan stages, leading to engine surges that destroyed the engines. The pilots succeeded in getting the 129 people on board safely to the ground. The aircraft was destroyed. (Märtensson, 1995)

The aircraft landed at Arlanda airport on the night of the 26th of November at 2209 hours. During the night a flight technician inspected the aircraft where he noticed that

ice had formed on the upper surface of the wings. The flight was scheduled for departure on the morning of the 27th of November at 0830 hours. The mechanic responsible for handing over the aircraft in the morning in question noticed frost coverage on the underside of the wings. He therefore checked whether there was ice on the upper side of the left wing by climbing a ladder, putting one knee on the wing and feeling the forward part of the wing with his hand. He found no ice, but did find slush. Using a ladder he checked the air inlet of the left engine and found nothing abnormal.

The aircraft was refuelled and was ready for de-icing at 0830 hours. The mechanic had after consultation with the captain ordered de-icing of the underside of the wings also, because of the frost he had seen there. There had been no discussion of clear ice. After de-icing the mechanic did not check whether there was any clear ice on the upper side of the wings, since he had previously found none. After engine start up the captain taxied the aircraft to the runway. The engine de-icing systems were 'on' for both engines and there was no indication of any malfunctions in the system.

It was reported that three passengers saw ice coming off the upper side of the wings as the aircraft took off.

Approximately 25 seconds into flight the right engine started to surge. The captain throttled back on that engine but without the surging ceasing. The surges continued until the engine stopped delivering thrust 51 seconds after the surges had started. Two seconds after the right engine had failed the left engine also began to surge. When both engines had failed the crew prepared for an emergency landing. During the approach to the selected field the aircraft collided with trees. In the collision, the major part of the right wing was torn off. The tail of the aircraft struck the ground first. After the impact the aircraft slid along the ground for approximately 110 metres before stopping. The fuselage was broken into three pieces on impact and during the subsequent braking on the ground. No fire broke out but the aircraft was totally destroyed on impact.
(Account adapted from Board of Accident Investigation (SHK) Report C 1993:57)

According to the Board of Accident Investigation the accident was caused by the company's 'instructions and routines being inadequate to ensure that clear ice was

removed from the wings of the aircraft prior to takeoff. Hence the aircraft took off with clear ice on the wings. In connection with lift off, the clear ice loosened and was ingested by the engines. The ice caused damage to the engine fan stages, which led to engine surges. The surges destroyed the engines.

The Clear Ice Problem

Several cases of 'soft' Foreign Object Damage (FOD) had been reported on a number of DC-9 aircrafts. In 1981, both engines of a Finnair DC-9-51 were damaged by clear ice, which came off the wings at takeoff and was ingested by the engines. This event was reported to the authorities, manufacturer and operators. After a number of cases where clear ice had been found remaining on the wings following de-icing, Finnair summarised its experience in a report in 1985, in which the problem of undiscovered, unremoved clear ice as 'the most difficult systematic threat to flight safety today'.

The Clear Ice Problem in the Company

The problem of clear ice on this aircraft type had been known within the company since 1985 (6 years prior to the Gottröra accident) when Mc Donnell Douglas gave extensive information, including several "All Operator Letters" (AOL) that dealt with the clear ice problem following the Finnair experience. In May 1989 the National Authority urged the company to examine the need for corrective action following a flight occurrence report on an engine surging as a result of ice being ingested. As a result of this the company circulated bulletins on current de-icing procedures to both flight operations and technical divisions, produced Swedish-language de-icing instructions for winter operations 1991/1992 and included information in their Line Maintenance Handbook (LMH) on the discovery and removal of clear ice. This was judged to be an 'entirely satisfactory basis for the production of detailed regulations in solving the clear ice problem by the National Aviation Authorities.

Contributory factors

It was ultimately the captain's responsibility to ensure that de-icing was done with sufficient care. It was however, the technical division that were accountable for de-

icing being performed and checked. Apart from the bulletins issued within the technical division during the course of the year, training was organised before the start of the winter season for all personnel concerned and each mechanic was provided with a checklist.

The following provides a summary of some of the contributory factors identified in the accident report and from the analysis of the research interviews.

De-icing Procedures

The company's instructions and procedures were insufficient for ensuring the discovery and removal of clear ice. For technical personnel, the Line Maintenance Hand-Book (LMH) contained the following as regards checking for clear ice: "...When there is doubt as to whether clear ice has formed on the wing upper surface, the wing upper surface has to be checked using suitable means of access in order to detect the possibility of clear ice." The (Swedish-language) Line Maintenance De-icing Instructions Winter 1991/92 for the base contained the following statement about clear ice control: *"Physical hand contact with the wing upper side and the tapping with the back of a screwdriver are the only reliable methods of discovering clear ice. If external conditions give reason to suspect clear ice, the upper sides of both wings must be inspected even if the wing inspected first is free of clear ice".*

Technical personnel were familiar with the clear ice problem through training and information. However the clear ice problem as dealt with in LMH, which is the formal governing document for direct work, had "...an obscure position and lacked detailed instructions on how the check for clear ice was to be carried out. Nor was there any follow-up on how the check was performed in daily practice..."

In the MD-80 study guide that pilots used when training on the MD-80, clear ice was not mentioned. Also in the de/anti-icing chapter in the RM (Route Manual), there was nothing on the clear ice problem. After the accident the first officer stated that he had never known the extent of the clear ice problem during his training on the MD-80. Therefore it appeared that the flight operations manuals and procedures were also inadequate.

De-icing Equipment

The company's equipment was insufficient for ensuring the discovery and removal of ice. To reach the critical area on the upper side of the wing without risking an accident, either special tools or specially built ladders would have been required. The technical personnel had no access to suitable aids for checking clear ice effectively.

Reporting Procedures

There was no routine for reporting on observations regarding clear ice. The technician who inspected the aircraft during the night noted the presence of clear ice, however, there were no instructions obliging him to report this to the aircraft technician who was to carry out the departure the next day.

Pilot Training

The pilots had insufficient knowledge and training to enable them to identify the risk of clear ice and take action. In various bulletins over the years the clear ice problem was described and the AOM (Aircraft Operations Manual) bulletins to pilots mentioned that the problem was considered the greatest current threat to flight safety. However in the training of MD-80 pilots the clear ice problem had not been specially dealt with nor was there any special written instructions for the pilot's actions if there was a risk of clear ice.

Inadequate Self-Monitoring

The company's monitoring activities had been inadequate regarding the handling of the clear-ice problem. Even though they had received different warning signals over the years on the risks associated with clear ice, this had not led to any effective action. As has already been highlighted, there was "no routine in place for reporting on observations regarding clear ice". It also emerged that the Civil Aviation Supervisory Agency was not aware of the deficient system of quality assurance. Following Gottröra the Board of Accident Investigation recommended that the Aviation Authority ensured that the company possessed a well functioning system of quality assurance.

What changed after the accident?

The following summarises some of the changes adopted by the company.
as a result of the company's internal investigation and other investigation reports from the National Aviation Authority and the Board of Accident Investigation.

Establishment of a Working Group

A working group made up of pilots and personnel from the engineering department was established in order to redesign the procedures and the equipment for the clear ice checks.

Revised Procedures

The working group revised the procedures and tools for inspection and detection of clear ice on the wings. Prior to the accident, there were no detailed instructions in defined nomenclature that described how to check for the presence of clear ice, how the ice should be removed or how the follow-up check and the report to the captain should be affected. Redesigning the procedures was problematic. The procedure of climbing on the wing to do the check presented a personal injury hazard. Several iterations of procedure change were tried before the company were satisfied. Initially the company installed tufts for easier detection of wing ice and then they replaced the tufts with non-skid stripes to ease the maintenance of the detection system.

Detecting clear ice was also a difficult perceptual task, and it was obvious that checking from the ground was not sufficient. The procedure was changed to require the aircraft engineer to climb up to the level of the wing to inspect.
This change used two senses to detect the ice:

- Visual based check by colour contrast
- Tactile based check of rough-not rough-rough perception when moving a pole or hand over the covered area

Changes in Equipment and tools

At the same time there were changes in equipment and tools. New access equipment was made available to enable aircraft engineers to climb over the wing without walking on the wing, which could result in a personal injury hazard. Several tools (poles) were also developed after Gottröra to ease the ice detection procedure. The working group were actively involved in the development and testing of the tools. After testing, a heavy, stiff pole used to scrape FWD and AFT was selected. The ice detection tool consists of a telescopic pole, on one end of the pole is a circular scraper and in the centre a flashlight can be mounted. However the detection pattern and method in the Mc Donnell Douglas Manual and the company AMM were based on a light flexible pole to swipe sideways and not on the heavy stiff pole. Consequently the tool and procedure described in the AMM did not match.

It was also recommended to install heating blankets. The purpose of the heater blankets was to prevent ice in the critical cold corner. A built-in thermostat should via a warning light in the cockpit indicate if the heating was insufficient to keep the heater blanket free from ice and therefore alert the need for de/anti-icing.

The role of the pilot

Prior to Gottröra it was ultimately the captain's responsibility to ensure that de-icing was done with sufficient care and the technical division would answer for de-icing being performed and checked. Following Gottröra it was decided that, as there would be problems for the pilots with the procedures for de-icing at different stations that the aircraft engineers would take complete responsibility for the clear ice check.

Authorisation and Training

As a result of Gottröra there were also changes in training. Prior to Gottröra any certified aircraft engineer could carry out de-icing and clear-ice checking. Subsequently, it was made a task which required authorisation. This authorisation was based on initial training along with annual brush-up training. They also introduced renewal training (aircraft engineers would receive update training if there had been any changes in procedures and a brush-up course before entering anti/de-icing work). It

was recognised that problems with clear ice occurred very rarely but in order to counter-act complacency it was recommended that the problem would be highlighted in the aircraft engineer's brush-up training courses.

Quality Assurance System

Based on the Internal Control Concept, the company began to further develop their Quality Assurance System. The purpose of the Quality System is "… to control the processes and task to ensure that they are performed satisfactorily with continuous improvements…"

All of the above changes were implemented after the accident and it was felt within the company and with in regulatory authorities that the problem with the detection and removal of clear ice was effectively addressed.

However five years later the company had another serious incident due to the clear ice problem.

MD-80 Wing Ice Incident, 1996

On Sunday the 14th of January 1996 the MD-80, SE-DIB departed Arlanda for Geneva at 0855 hours. Prior to departure the aircraft engineer found 2-3 cms frost on the under side of the wings, but no ice was detected on the upper side using the approved tool and procedure. After consulting a supervisor, the aircraft engineer ordered under wing de-icing only. The aircraft was thereafter dispatched in a normal manner. One hour into the flight a passenger informed the captain, that approximately 0.5m piece of clear ice had fallen from the left wing of the aircraft – and that a piece of ice was still remaining on the wing. This was confirmed by both cabin and flight crew. The remaining ice left the aircraft during descent to Geneva.

Contributory Factors

The following presents some of the contributory factors highlighted by the incident investigation.

Inadequate tooling

During the investigation it was revealed that the ice detection method used was not adequate to detect the ice under all conditions. This concerned both the tool used for detection and the non-skid strip pattern to check upon. Both wings had been checked for presence of ice according to LMH (Line Maintenance Handbook). No ice was detected on the upper surface of the wing using the approved tool and method.

De-icing Procedures

As the ice check, performed according to the procedures specified by the company, did not reveal the presence of ice, the ice detection procedure in use was unsatisfactory. Again there was inconsistency between the clear ice detection procedures in the LMH and the AMM. In the LMH, clear ice check specified the following procedure for ice detection:

"**Physically check** for possible **ice within entire clear ice critical area** by using touch or tool as stated below on forward-aft direction".

"Important for MD-80: The clear ice critical area is identified with the red line surrounding the grey or white non-skid stripes. Only a rough-smooth-rough-indication from the non-skid stripes assures an ice-free surface. Any other indication will demand further checking or de-icing".

The Aircraft Maintenance Manual (AMM) for MD-80 stated in the section concerning "Checks for Need to De-ice": …wing upper surface has to be checked using suitable means of access in order to detect clear ice (feeling with hand preferred)". The AMM further states in the section concerning "Check of Complete De-icing: CAUTION: INSOME CASES PRESENCE OF ICE CAN ONLY BE DETERMINED BY TOUCH.

In addition there was no maintenance requirement to check and maintain the non-skid stripes.

Duties and Responsibilities

There were also inconsistencies in the company documentation in relation to duties and responsibilities. For example, according to the TDH (Technical Department Handbook), the departure check personnel has to inspect the aircraft and provide a verbal report indicating that the aircraft was free from frost etc. However in the LMH it stated that the departure check personnel had to report the condition of the aircraft. Therefore these different descriptions of the same procedure inevitably led to misunderstandings.

Training

It was also found that there was no training in detection of real ice during the de/anti icing course. As the de/anti-ice training contained no practical training on real ice, the approved personnel had never touched clear ice with the ice detection tools and had to rely on expectations of how to feel it.
Other findings included:

- Related Service Bulletins, Alert Service Bulletins and AD notes were not administered correctly
- The paint used for non-skid stripes was not the one specified in the SB, and thereby not approved for the AD
- The contrast and roughness of the non-skid stripes was not adequate
- The aircraft was not equipped with Wing Heater Blankets
- No fuel transfer was performed (the fuel transfer reduces the amount of cold fuel in the wing tanks by transferring it into the centre tank. With low quantity of fuel in the wing tanks, the possibility of clear ice accumulation is greatly reduced).

What Changed after the Incident?

The recommendations concentrated on improving the detection tool by using the "hands on" method and the detection pattern, by improving the non-skid stripe roughness, colour contrast and maintenance requirements.

Establishment of a project group

The investigation of this incident led to the establishment of another project group to redesign the clear ice check procedure yet again. This project group, significantly, included aircraft engineers who performed the check on a daily basis as well as pilots and engineers. The findings of this group was that the only way an aircraft engineer could be sure there was no clear ice on the wing was to check it with his hand.

New Procedures for Clear Ice Check

The following outlines the new procedures for the detection and removal of clear ice for the MD-80 as redesigned by the project group. The key to the development of the new procedures was the step involving the aircraft engineers in re-designing the procedure. See next page for the revised procedure.

Line Maintenance Procedure - Departure Check/De-icing Check Procedures

Clear Ice Check (Ref MD-80 AMM 05-22/12-30 and MD-80 Airworthiness Directive):

A Clear Ice Check shall be performed:

- If there is frost or ice on the underside of the wings
- If the OAT is below +15°C, and
    1. The dew point is within 3°C of OAT, or
    2. There is, or has been, visible moisture/precipitation

- After de-icing for whatever reason
- On P-I-C request

The clear Ice Check shall be performed as follows:

Physically with hands-on, check both wings upper surface for possible ice, at least within marked area
Depending on findings, the physical check shall be expanded as required

It must always be remembered that snow/slush can hide a Clear Ice layer, which is very difficult to detect. Check that parking area is clear of foreign objects and equipment

Verbally report to P-i-C 'Departure Check performed' and 'Clear Ice Check performed' (when applicable). Report any check findings or need to de-ice. Any reported check findings shall be confirmed by read-back by P-i-C.

The procedure also included a drawing of MD-80 wing Clear Ice Check Area that indicated the areas that required de-icing.

Annual Audit

The quality department also introduced a annual audit of de-icing procedures. The objective of this audit was to focus on the actual practice as well as the documentation.

Sum up seminars

Another practice that was precipitated by the Gottröra accident and the second incident was an annual meeting at the end of the anti-icing season in May, to review the effectiveness of the procedures during the season. This meeting included the station managers from Stockholm, Oslo and Copenhagen, as well as pilot representatives.

The AEA – Ice Group

The company was a member of the Association of European Airlines (AEA's) "Ice group". This was a major avenue for dissemination of their experience in anti-icing practice to the industry. In addition, close contact was kept with McDonnell-Douglas regarding appropriate procedures. At this stage the company's clear ice inspection procedures were more conservative than those in the manufacturer's airworthiness directive – they carried out inspections at higher temperatures, and also on DC9's, which the manufacturer does not require.

Summary

The problem regarding the detection and removal of clear ice was known in the company for 6 years prior to the Gottröra accident. During those 6 years the company issued internal bulletins highlighting the problem, de-icing instructions to deal with the problem and provided training for their aircraft engineers. All of which was deemed satisfactory both by the company and their regulatory authority.

However those technical instructions and procedures were insufficient and as the training was based largely on the procedures this inevitable proved to be inadequate also. The flight operations procedures and training was also found to be inadequate. For example according to one of the pilots. 'this is a situation that had not been simulated during training'(Märtensson, 1995) .

The de/anti icing equipment, the reporting procedures and the company's overall quality assurance system were all found to be deficient with regard to the clear ice problem.

Following the accident, the primary focus of both the company and the regulatory authority was on the development of a new procedure and improved de-icing equipment. Therefore a working group was established made up of pilots and engineers who had the responsibility of revising the procedures and the equipment. At the same time it was decided that the pilot would no longer have responsibility for ensuring that de-icing was done with sufficient care, rather this would now be the sole responsibility of the aircraft engineer. There were also a number of changes in relation to training and authorisation (de-icing and clear ice checking required authorisation). And in parallel with all of this the overall monitoring function (i.e., the Quality System) also underwent improvements. Therefore the company reacted to all of the recommendations from the various investigation reports and put in place new procedures, new equipment, improved training and an improved Quality System.

However it was evident that this set of recommendations was insufficient to prevent a further similar incident. Five years later another potentially serious incident occurred and again the procedures, instructions, equipment, training and the quality system were all found to be inadequate. Therefore even though at this stage the problem with the detection and removal of ice and clear ice was widely known within the company for 11 years and a major and highly publicised accident occurred the organisation had not appeared to learn and effectively change.

Again following the second incident the focus was largely on improving the technical procedures, instructions and equipment. Another project group was established, this time involving the aircraft engineers (who actually do the work). A new set of standards and procedures were established and disseminated, an annual audit of the procedures was introduced as well as other assessments for the effectiveness of the procedures and the equipment.

11 years after the first notification of the problem the company were confident that after two investigations and the implementation of recommendations that they had managed

the problem and that the organisation had a 'fool proof procedure' in place to enable the detection and removal of both ice and clear ice. Several months after the completion of the case study, it emerged that a new incident occurred. An aircraft pushback had been initiated while aircraft engineers were still on the wings checking for clear ice. Luckily no one was injured when they jumped clear of the aircraft.

The whole orientation of the company's strategy, the regulations strategy and this case-study had been on 'how the company developed an effective procedure for the detection and removal of clear ice' and the temptation was to draw a satisfactory conclusion under the 'final' procedure. This served to illustrate that there were still serious operational problems to do with the implementation of the solution, which needed to be tackled. Furthermore, achieving the successful resolution of this issue required a continuous process and this process must open up the normal conditions of the operation to more effective scrutiny and improvement.

Core Factors in Achieving Change

At least two separate accident investigations were carried out in relation to the Gottröra accident. One of which was by the company's own dedicated internal team of investigators, and one by the Board of Accident Investigation. An internal investigation was also conducted into the second incident. All of these investigations provided an excellent diagnosis of what went wrong and why it went wrong. Technical, documentation, management, and quality deficiencies were all highlighted in relation to the operation. However the investigations did not lead to effective actions for the prevention of a similar event occurring again. In fact the active role of investigation teams usually ends with the publication of their reports except in those circumstances where disciplinary action is invoked.

So this begs the question: what exactly is the role of an incident/accident investigation? Should we expect an investigation to lead to effective actions and recommendations, or is the investigation just a first step (the diagnosis)? What is the role of the other monitoring functions in supporting the outcomes of an investigation, or indeed the organisation as a whole in accepting and supporting the recommendations?

Many recommendations, particular those of a human or organisational nature are not quick fixes that can be illustrated by a 5-step procedure. Rather these types of recommendations need to be accepted and supported throughout the organisation if they are going to be effective. So of course one could argue that there are short-comings to incident investigations, but it is felt that these short comings should not only focus on the investigation itself but on what supporting mechanisms are required both from the Quality System and the organisation to effectively realise and implement recommendations from the initial investigation.

This case study raised a number of issues in relation to effective organisational change.

Effective change takes time

Effective change often takes a long time and many attempts to get an adequate solution. For over eleven years the company knew of the problem of clear ice before fully effective procedures were developed and implemented. While the company did make a number of attempts to solve the problem they failed to take the necessary steps to assess and continually improve the adequacy of their initial attempts to solve the problem.

The occurrence of several incidents

Sometimes several incidents have to occur before the problem is effectively dealt with. The company were first notified of the clear ice problem in 1985, they had their own flight occurrence in 1989, a major accident in 1991, a serious incident in 1996 and another potentially serious incident in 1997. Following an incident in which ice was ingested into an engine, the company produced de-icing instructions, which were judged to be good basic material for solving the clear ice problem by their national authority. However the introduction of the revised instructions was not enough. One year later an aircraft took off with ice on its wing and had to make an emergency landing. The investigation found that the company's instructions although judged to be good were still not sufficient. After this accident the company revised their clear ice procedures as well as a number of other changes in training, authorisation and the introduction of new equipment. Six years later another aircraft took off with clear ice

on its wings. Yet again the clear ice procedure was found to be inadequate and the company set about to redesign the procedures.

Involvement

To achieve effective change it is often necessary to involve the people who have first hand operational knowledge of the situation (e.g. those who do the work) in the making, monitoring and evaluating of the recommendations. The investigation of the 1996 incident led to the establishment of project group to redesign the clear ice check procedure yet again. This project group included aircraft engineers who performed the check on a daily basis as well as pilots. The findings of this group was that the only way an aircraft engineer could be sure there was no clear ice on the wing was to check it with his hand. Therefore this project group redesigned new procedures for the detection and removal of clear-ice.

Validation of Recommendations

The critical step in achieving a solution to the problem concerned validating the recommendations in terms of how the work was actually carried out in practice. Although the company was committed to continually making revisions, the question has to be asked why did the company not test and validate these changes (i.e., actually test what was happening in practice and validate these changes for all possible conditions)? It appears the company felt that to revise and implement the procedure and other changes was enough without any systematic follow up on their effectiveness.

Monitoring

Without an effective monitoring of recommendations (through quality reports, audits or other feedback) it is impossible to know whether or not recommendations have been effective. It was found that the company's quality assurance was inadequate and that there was a lack of effective routine quality reporting. Without an effective monitoring of recommendations (through quality reports, audits or other feedback) it is impossible to know whether or not recommendations have been effective.

Continuous Review

For problems that are particularly intractable it is necessary to have a focused process of continuous review of the effectiveness of the measures taken. One can never assume that the problem is fixed. A critical step taken by the company was the involvement of the aircraft engineers in the redesign of the clear ice procedures and the annual review of the effectiveness of the revised procedures. As a member of the AEA the company also disseminated their experience in anti-icing practice to the industry and they also kept in regular contact with the manufacturer regarding appropriate procedures.

Overall analysis of organisational change due to accident investigation suggests that in reality effective change is a step-by-step and evolving process. Effective change is not always meticulously planned or smoothly executed and tackling problems, which concern how people work and what they do (human factors) is particularly difficult. Arguably change as a result of an accident investigation can often be characterised by reactive and short-term solutions, and indeed evidence suggests that it may take further accidents or incidents to prompt the organisation into more long term and proactive solutions. However on the other hand what the problem history here may also show is the iterative approximation to an almost 'perfect' solution as we don't know whether the frequency of upper-wing de-icings changed after each implementation. What is clear from the case study is that just to implement recommendations is not enough. Recommendations and subsequent change have to be continually monitored in a systematic and focused way in order to ensure effective organisational change and learning.

Development of the Safety Management System Model

The Safety Management System Model was developed as a framework to systematically describe and compare safety management and safety culture across four aircraft maintenance organisations. In the initial model five key elements of safety management were identified; strategy and policy, implementation of policy and setting standards, operational norms, monitoring and feedback. A comparative analysis of each of these elements was undertaken across the four organisations and a number of salient differences emerged in each of the company's safety management systems. This analysis also highlighted a number of implications for the model itself.

The initial model was primarily descriptive in nature and it did not attempt to measure every key process and aspect in managing safety in aircraft maintenance, rather the model focused on a number of key elements. However the comparative analysis highlighted the importance of the planning process in the operation of everyday safety management practice, and in particular the impact human and organisational factors had on the overall effectiveness of planning and the organisation of work. As a result planning and organisation of work was included in the revised model and a comparative case study on the planning systems in Companies B and C was carried out.

While organisational change was implicitly addressed in the initial model, particularly in relation to the monitoring and feedback functions, no systematic analysis was carried out to describe and assess how actual organisational change is achieved as a result of the operation of a safety management system. Aircraft maintenance is a dynamic industry and its safety management system is required to address and adapt to the changing nature of the industry. Again, one problematic area appeared to be transforming information about specifically human aspects of failures and deficiencies into implemented programmes of change. Therefore it is inevitable that the actual implementation of change should also be included as a key element in the revised safety management model.

The case studies presented in this chapter provide substantial evidence and support for the inclusion of these two key processes in the safety management system model. Planning spans across the complete organisation from senior management level right

down to the operational level. All key documentation, tools, equipment, manpower and other key resources require effective planning and co-ordination to ensure a safe, reliable and efficient operation. This affects normal operational practice, safety standards, the implementation of safety policy and the overall quality of the end product. Therefore in many ways effective planning and the organisation of work is a core process in any management system. However the overall organisational infrastructure for supporting effective planning involves the integration of key functions across different levels within the organisation, a high level of visibility and flexibility at the different levels of planning and improved communication and co-ordination mechanisms to support inter-functional roles.

The organisations themselves admitted that some areas of their safety system required improvement and change, however achieving effective change is perhaps one of the most difficult tasks in safety management. This point was clearly illustrated by the Gottröra case study. The inclusion of the process of change in the model allowed for a systematic look at one company's attempt to introduce change following a series of serious incidents. As a result a number of key issues were identified as important considerations when implementing change.

In general, it is possible to distinguish between three types of models: (i) descriptive or empirical models, which attempt to summarise and describe findings from one or more organisations in a purely value neutral context; (ii) explanatory models, which seek to account for the efficacy of the system described by the model and provide the basis for evaluative comparison; and (iii) prescriptive or predictive models, which seek not only to describe and specify safety culture and safety management systems per se but also to set requirements and criteria for effective safety outcomes. The model presented in this thesis originated in a largely descriptive mode although the model also had significant evaluative elements (e.g., safety climate, safety attitudes). However, in many ways the two case studies have pushed the model much more towards an explanatory role in that the current model highlights basic principles underlying effective safety performance, which appears to distinguish between better performing organisations.

The importance of continuous improvement or self-regulation is an essential part of each stage of the revised safety management model. While the revised model is quite

hierarchical and sequential in nature it does recognise that none of the elements is static. For example strategy does not remain static but migrates as a result of changes in context (e.g., Johnson, 1996), and as a result each element as well as the overall system requires continuous monitoring and review. The model has evolved to represent a continuous improvement process where the human and organisational aspects of each of the elements are subject to continuous review. If this review highlights problems or deficiencies a programme of change should be initiated and this programme is also subject to continuous review, the output of which needs to be fed back through the system. The review and feedback of any proposed change is one of the key factors in enabling organisational learning and enabling any system to continually improve its operations. Therefore the various monitoring functions need to be working in an effective manner in order to highlight problems and initiate proposed recommendations to deal with these changes. In order to effectively implement change the monitoring function requires support from the wider organisation. The Gottröra case study highlighted that an effective accident investigation is not sufficient for initiating change but that the recommendations from such investigations require support not only from the various monitoring functions but also from wider organisational functions. The implementation of change itself and its implications also require continuous review as it is only through reviewing the outcomes that an organisation can establish if they have effectively dealt with any shortcomings in their safety management system.

Chapter 8 - Overall Conclusions and Discussion

Introduction

The overall objective of the thesis was to develop a model outlining the key aspects of safety management systems and safety culture and to use the model to systematically describe and compare organisational aspects of safety management and the underlying safety culture across four European aircraft maintenance organisations. The model highlighted the ability of organisations to establish strategies, goals and internal standards; to plan and organise production to an optimal standard; to determine what actually happens in practice; to monitor and adjust systems and procedures and to learn from recommendations. Empirical studies of the four aircraft maintenance organisations were undertaken, including analysis of documentation and qualitative interviews; surveys of safety climate; surveys of safety attitudes; and expected response to incidents and compliance with task procedures. The data from the management interviews, the incidents survey and safety climate survey exhibited a large measure of agreement in differentiating between the different safety management systems and safety cultures of the four organisations.

However the measures of compliance with task procedures and safety attitudes did not differentiate between the four organisations (though one organisation did differ from the others in safety attitudes), suggesting a strong relatively homogeneous professional sub-culture of aircraft engineers spanning the different organisations. A number of interesting differences as well as similarities in safety management practices and culture emerged within and between the organisations. The analysis of the data presented a very complex set of problems and issues both in relation to the model and methodologies developed as well as to the theoretical and practical considerations of safety management and safety culture. The analysis of the results provide a rich basis for further theory development in this area. The overall discussion of the thesis is organised around the following sections:

- Development of the Safety Management Model
- Development of the Methodologies
- Overview of key findings - theoretical implications
- Overview of findings - an operational point of view

- Overall Conclusion.

Development of the Safety Management Model

The objective was to develop a model that could be applied as a framework to systematically describe and compare safety management and safety culture in aircraft maintenance. The model underwent two key stages of development. The initial model was developed drawing both from the analysis of safety culture of Pigeon and O'Leary (1994) and from the Health and Safety Executive's 'Successful Health and Safety Management (1991[6]). From the outset the model was kept conceptually simple and focused on a number of key elements of safety management and culture rather than measuring a wider range of elements pertinent to effective safety management. The model highlighted five key elements: strategy and policy; implementation of policy and setting standards; operational norms; monitoring and feedback. The model was primarily descriptive and the test of the model was how well it was able to describe what was happening in practice from a human centred perspective and operational perspective rather than from a purely cognitive or occupational point of view.

The initial model received substantial support from the study in facilitating a clear description of organisational safety systems and culture in aircraft maintenance. However it became clear that while the model did address key elements such as strategy and policy, monitoring functions, communication and feedback functions, the model didn't systematically address two other key elements that came to light as the analysis progressed. The first two elements of the model included strategy and policy and implementation of policy and setting standards, however a key process linking these two elements was missing, that is how planning affects the overall management of safety. As a result planning and the organisation of work was included as an explicit element in the model. It also became apparent during the study that while the various monitoring and feedback functions were addressed, the evidence as to whether change (particularly change in organisational issues) resulted was not explicitly highlighted or addressed in the model and the subsequent analysis. Therefore implementing change was also included as a key step between the outcomes of the monitoring functions and

[6] Now recognised as HS (G) 65 'Successful Health and Safety Management', 1997. Also forms the basis for chapter 4 COMAH SRAM regulations (Control of Major Accident Hazards – Safety Reporting Assessment Methodology).

the feedback and review functions. As a result the revised model included the following elements:

- Safety Policy and Strategy- how safety is represented as an organisational goal and the organisation's strategy and standards for achieving its safety goals.
- Planning and Organisation of Work – how the various activities are planned and organised to ensure the implementation of the safety strategy and safety standards, and to ensure the provision, for example, of resources in the areas of methods/documentation, personnel, parts and facilities, in order to carry out the organisation's functions.
- Normal Operational Practice – how the effectiveness of the organisation's strategy and policy and planning systems are reflected in normal practice or behaviour in carrying out the organisation's everyday functions.
- Monitoring – how all the activities of monitoring, feedback and review of operations, including auditing, incident investigation and quality reporting effectively assess the overall safety of the operation and how recommendations for improvement are acted upon.
- Implement Change – how recommendations for improvement as a result of the organisation's monitoring functions are implemented as programmes of change.
- Review and Feedback – how effectively the proposed change and its implementation has dealt with problems or deficiencies in the system and how this change is systematically fed back into organisational activities.

The model developed in this study was derived largely from Pidgeon and O' Leary's model of safety culture, which was primarily based upon man-made disasters and high reliability organisational theory. Pidgeon and O' Leary's model suggested that safety cultures might both reflect and be promoted by four facets: location of responsibility for safety at strategic management level; distributed attitudes of care and concern throughout an organisation; appropriate norms and rules for handling hazards and on-going reflection on safety practice.

Recently this model has been criticised in that the above four facets are not aspects of culture per se but rather idealised operational objectives which can to some extent be normatively linked to safe performance. However one can argue that the model

developed in this study highlights more than just idealised operational objectives in that a conceptual distinction has been made between safety-related goals or outcomes (e.g., organisational learning and/or change), strategy, policy and procedures for achieving overall objectives (e.g., effective quality and monitoring system), and the social and cultural arrangements that support the overall objectives (e.g., addressing the double standard or the dilemma of blame).

The model developed here has moved from a purely descriptive or empirical to a more explanatory model, in that the revised model highlights a number of principles which logically underlie effective safety performance. The study also highlighted a number of problems in moving to a more prescriptive or predictive model given the complexity of the factors involved in safety management and safety culture and the difficulty of getting clear outcome measures, which relates to the problem of setting an internal standard.

The research was very much an exploratory study into assessing safety management and safety cultural issues in the domain of aircraft maintenance. Therefore at the onset of the research the model was developed very much as an exploratory research tool that would enable a first diagnosis and understanding of the organisational processes of safety management systems in aircraft maintenance. As already mentioned the model presented in this thesis was kept conceptually simple, however the model is largely compatible with the more detailed modelling of safety management systems carried out by a number of researchers most notably in the process and chemical industries (Hale et al., 1997; Hale et al., 1999; Bellamy et al., 1999). Much of this work has focused on integrating technical and management modelling so that predictions and assessments of total system risk and its control can be made.

Since the mid 1990's a number of research groups (e.g., DELFT University of Technology, Amsterdam; ERM – Four Elements, UK; SAVE Consulting Scientists, Apeldoorn) have developed structural models of safety management and auditing systems with the objective of providing a systematic and complete description of what elements should be present in an SMS and how they should be related to each other. In particular the research aimed to make explicit the links between risks and direct preventive and control measures on the one hand and the organisational and

management processes that ensure that the prevention measures are present and functional on the other hand (Hale et al., 1997). This has involved finding ways to link the detailed and deterministic techniques of technical risk analysis, such as fault and event three analysis, to the dynamic modelling of safety management. In their approach safety management is seen as a problem-solving process at three levels of on-line risk control, development of plans and procedures and development and review of the structure of a risk management system. Various methods have been tried to make these links in all the important phases of the life cycle (design, construction, operations, maintenance and modification). These focus on a number of generic parts of the management system which deliver resources and controls to safety critical tasks in operations, inspection and testing, maintenance and emergency situations. These generic parts include manpower planning, selection and training, motivation, incentives and training, documentation and planning, design and layout, purchase and issue, information and meetings and policy planning and leadership. The research has also developed highly structured audit and inspection tools and studied ways of using expert judgement to prioritise aspects of the management system (e.g., PRIMA - Process Risk Management Audit; I-Risk – Integrated Technical and Management Risk Control Monitoring Methodology).

Further development of the model presented in this thesis could further explore more detailed modelling in order to capture the complex and dynamic nature of managing safety and risk.

Development of Methodologies

The overall analysis did not rely on a single form of assessment (e.g., questionnaires), nor was it placed on any single part of the overall system (e.g., compliance with procedures). The standard methodologies developed for the study were systematically employed in each of the four organisations and as far as it was feasible similar procedures of data collection occurred in each of the organisations.

The overall results of the study indicated that the range of methodologies applied to measure the different facets of safety management and the underlying culture complimented each other and provided a wealth of information and understanding on the human and organisational aspects of managing safety in aircraft maintenance.

Indeed there is a growing view in the literature that these different approaches should be seen as complementary and should not be treated as alternatives. Taken together, and cross-referenced in this study, the various measures provided a holistic view of the safety management systems within the organisations, tapping different aspects of organisational structure, function, culture and behaviour.

The starting point for the analysis involved an assessment of key documentation in order to provide an overview of the structure, management and operation of each organisation. It was also interesting to compare how the official documentation compared with company personnel's perceptions of their overall safety management. The management interviews allowed for a more in-depth look at the key elements identified in the model and allowed for an understanding of the processes relating to management behaviour. So, while the importance of management commitment has been identified in the literature, the understanding of the processes relating to management activities, their perception by the workforce and the resulting impact on safety management and culture are rather less well established. The overall perception of the work-force's safety attitudes, their perception of incident management, levels of procedure compliance and their managers' commitment to safety were measured quantitatively which enabled an additional indicator of the underlying safety culture both within and between the organisations. The measures were also what Flin, (1998) refers to as 'leading measures' in that the study did not rely on retrospective data such as accident and incident rates, rather the measures provided a mechanism for understanding the 'normal' functioning of everyday safety management.

A total of 955 questionnaires were completed (e.g., safety attitudes, safety climate and procedure compliance), 61 interviews (including management, aircraft engineers, quality, planning and engineering personnel), documentation analysis, an ergonomic assessment and general observations across the organisations. While more or less equal numbers of interviews, similar documentation and similar procedures for the ergonomic assessment were conducted across the organisations, an unequal sample was represented in the Safety Attitude and Safety Climate Survey. In the survey of Safety Attitudes and Climate almost three times as many questionnaires were completed in Companies A (230) and D (222) compared to Company C (76) and twice as many were completed in Company B (141) compared to Company C. The procedure for

administering the questionnaire differed somewhat in Company's A and C in that key personnel in the relevant areas took responsibility for administering the survey and posting it back to the researcher rather than the researcher being on hand to administer the survey. Nevertheless it was felt that the sampling strategy in both of these organisations was satisfactory and the sample size in Company C even though small in comparison to the other organisations was still sufficient to conduct analysis and that the sample represented personnel from the key areas. A wide range of job categories across the organisations took part in the questionnaire and as it was not always possible to pre-plan filling job categories with equal numbers, a number of low responses were found in some of the categories. As a result the range of job categories were collapsed into three broad categories: operational staff; operational management and support staff.

In addition to the sampling strategy another issue arose in relation to the reliability of the Safety Attitude Scale. The reliability analysis showed an internal consistency (Cronbach Alpha) value of .56 on the Safety Attitude Scale. This was quite a low reliability value for the scale and was substantially lower than the (Cronbach Alpha) value for the original scale .78 (Cabrera et al., 1997). In any future study this survey would require some further development not only to improve its overall reliability but also to further develop the objectives of the survey. The Safety Attitude Survey developed in this study primarily concentrated on individuals' perceptions of compliance with safety standards, safety rules and safety procedures in relation to avoiding incidents and accidents and completing maintenance tasks in a safe manner. This is consistent with other research (e.g., van Vuuren, 2000; Lee & Harrison, 2000) that has concentrated on compliance with safety rules and standards, reliance on protective gear, risk taking, etc. These collective beliefs about thinking of safety in terms of protective gear, risk taking and the importance of following procedures and rules are important and the results indicated a high level of positive safety attitudes across the complete sample. However this study also highlighted that attitudes to safety involve a more complex mix than just agreeing or disagreeing with the value of safety standards, rules and procedures.

For example, the study found that while there is an official way of doing things, which is laid out in the official procedures, often this does not meet user needs. Then there is the way in which work is actually done, which is supported by unofficial

documentation and standards and which frequently diverges from the official way. It was also found (e.g., Biemans et al., 1997) that while managers see that the role of the aircraft engineer is to follow procedures as laid down, the aircraft engineer sees himself as being responsible for the safety of the aircraft, and to use his own judgement as to what is necessary to complete the task (even if it is not exactly as in the manual). So this raises the question how well does the formal system of safety standards, procedures and rules support safe and reliable ways of working? Therefore it seems quite paradoxical that a safety attitude survey should focus on the degree of compliance with safety standards, rules and procedures when the evidence indicates that these standards and procedures do not always support the actual operation. A future study could look at the development of a survey looking at professional attitudes towards safe working practices.

The Survey of Procedure Compliance found that in 34% of tasks respondents reported not following the official procedure because there was either an easier way, a quicker way or better way to complete the task than what was laid down in the manual. The survey also found a number of other interesting findings: for example, just under one third of respondents reported that it was necessary to use guesswork, trial and error and problem solving to complete a task. 11% of tasks were deferred either because of problems with parts or inability to identify the problem. The survey sampled a range of both planned and unplanned tasks as well as relatively simple, intermediate and difficult tasks. However, it was not possible to infer from the survey if there were particular types of tasks that were more susceptible to non-compliance compared to others. The survey did request a maintenance manual reference number and a work-card number, however many of the respondents were reluctant to provide this information because of the legal implications of admitting to not following procedures. Also a number of questions in the survey were unable to get to the underlying reasons for a particular problem. For example, for the question - 'was it clear from the work-card what had to be done' - almost all of the respondents answered that it was clear, however for those that responded that it was not, there was no way of finding out exactly what was not clear. While the survey did highlight a number of interesting findings a future study may consider a more interview type approach especially considering the sensitivity of the subject matter.

The objective of the safety climate measure concerned the way in which those who work in the organisation perceive the company's values, priorities and common practices concerning safety. This study identified two key dimensions of safety climate (i) management commitment to safety and (ii) communication and improvement. Management commitment to safety has been found as a key dimension of safety climate in almost all studies (Zohar, 1980; Brown & Holmes, 1986; Cabrera et al., 1997; Cooper & Philips; 1994, Dedobbeleer & Beland, 1991), while communication has only been found in a smaller number of studies (e.g., Glendon et al., 1994). However the importance of management commitment to safety and effective communication strategies has been repeatedly highlighted not only in the safety climate and culture literature but also as key elements in safety management. The four organisations all had a different safety climate ranging from positive to negative, representing the value and importance attributed to safety in the company's operational priorities. Differences between the organisations in expressed philosophy of senior management concerning the role and importance of safety were also reflected in a more or less consistent pattern of differences in safety climate throughout the organisation.

Overview of Key Findings - Theoretical Implications

Existing empirical attempts to study safety culture and its relationship with safety management outcomes have remained fragmented and under-specified in theoretical terms. This is despite the existence of a number of well-developed theories of organisationally induced accidents and disasters (Turner, 1978; Turner & Pidgeon, 1997; Perrow, 1984; Reason, 1997). This study focused on developing a deeper understanding of the organisational processes of safety management systems and how they are embedded in the culture of an organisation. The thesis has developed, and validated (to some extent) a more comprehensive model of safety management in highlighting, for example, the complexities and problems of effective planning, implementing and sustaining change and the role of the informal system in achieving operational goals. The study has also linked this model to the wider cultural context of organisations, through an assessment of safety climate and perceptions on incident management systems, which have demonstrated that one can differentiate between organisations. However, other cultural variables (e.g., safety attitudes and levels of procedure compliance) did not differ across the organisations, suggesting a relatively homogeneous professional sub-culture of aircraft engineers spanning the different

organisations. It was found that the data from this study raised many more questions than the established models in the literature have adequately addressed. While this study has not answered all the questions it has gone some way in highlighting the complexity of some of the theoretical issues of safety management and safety culture. The following outlines some of the key theoretical issues surrounding each element of the safety management model.

Safety Strategy and Policy

This study focused on three particular aspects of strategy and policy: (i) the impact of compliance with JAR145 regulations; (ii) company managers' expressed commitment to safety goals; and (iii) the role of human factor initiatives.

The framework for the JAR145 regulations is built around the philosophy of granting approval to maintenance organisations that have an adequate management to ensure safe operations. Therefore compliance with the regulations was a major factor driving safety strategy and policy. This study found that the strategy and goals of the organisations did not always adapt to the changing internal and external environment. Company C differed from the other organisations in the self-regulatory model of their safety system. This was designed to express internal goals and standards, which in many ways exceeded the standards set by the regulations, however it wasn't always clear how this internal standard actually worked in practice (although this could have been a result of the fact that the study did not clearly define exactly what was meant by an internal standard). Overall it appeared that a disproportional effort was going into ensuring compliance (particularly in Company B), compared to engaging in more direct methods of ensuring safety and adapting to both internal and external demands. This raises the possibility that the particular demands of the regulation itself could be distorting or impeding the internal organisational safety system.

The aircraft maintenance system itself is responsible for its own safety and operational performance under the JAR145 framework and it is the management system, both operations and quality, which are subject to audit. The quality system is dedicated to ensuring that both safety standards are maintained and that appropriate adjustments are made to correct deviation from that standard.

One of the objectives of this thesis was to assess whether or not aircraft maintenance organisations go beyond compliance with JAR 145 to develop their own independent, internal standard of safe performance. This question has proved a problematic issue for the thesis. From the outset the study did not clearly clarify what exactly is meant by developing an internal standard? However the findings from this study did provide an insight into the complexity of developing and sustaining internal standards for safety in aircraft maintenance.

Most organisations compile periodic statistics of incidents and quality reports and from their own assessments of their operational safety performance believe they are operating very safely, after all they have very few accidents. However, the assessment of these incident and quality reports reinforces the 'official' understanding of how the system works. These quality processes (and standards) are largely ineffectual in uncovering the informal and unofficial patterns of behaviour and normal operational practice. Therefore there is a lack of valid and effective monitoring and feedback to determine: (i) if current standards are adequate in measuring safety performance; (ii) problems which require correction; (iii) what change and adjustment is required to initiate improvements; and (iv) demonstrate the effectiveness of any improvement initiative or corrective action.

Clearly there are no absolute standards for measuring how effectively an organisation is performing from a safety point of view. There is a complex mix of factors in managing safety in aircraft maintenance which adds to the difficulty of getting clear outcome measures or setting standards. Therefore at the very least an internal standard has to incorporate a complex set of indicators representing a realistic appraisal of what actually happens in practice because without that basis it is difficult if not impossible to evaluate current performance, or to plan or achieve better performance from the system has a whole.

The importance of management commitment and, in particular the perceived priority accorded to safety strategy and policy, has been repeatedly highlighted in the literature (e.g., Waring, 1996; Cox and Flin, 1998). However while senior managers undoubtedly set the tone and tempo for organisational atmosphere, establish priorities and allocate

resources, there was little evidence in the literature that demonstrated how this actually worked in practice.

Significant differences were found both within and between the organisations in their perceptions of their managers' commitment to safety and on the effectiveness of the communication and improvement strategies in their organisations. Operational management were found to believe in management commitment to safety and the effectiveness of their communication and improvement strategies significantly more than operational staff. This finding was consistent with other research that found different perceptions between different groups of personnel. For example Mearns et al., (1997) found personnel working on offshore installations appear to concur on only one safety aspect of their environment, namely that the chance of 'catastrophe' occurring is extremely unlikely. The most common feature, which accounted for the majority of differences between the personnel groups examined was 'seniority', with managers reporting more positive attitudes and perceptions than non-managerial staff on almost all variables.

This study did go some way to highlighting the importance of senior management commitment to safety. However, in establishing what actually happens in practice and assessing organisational processes the study also raised an interesting issue. While two of the companies (A and C) were more likely to perceive that their company management were committed to safety and appeared to have quite an effective approach to their planning processes, both companies were still encountering problems at the operational level. The fully engineered task (FET) in Company A was not fully realised and a number of problems in relation to management of parts and planning issues on the night shift were reported in Company C. In general operational staff were significantly less likely to believe in their management's commitment to safety. Therefore it appears that the commitment of senior management to safety is equated with actual success of safety initiatives at the operational level.

The aviation industry is one which recognises the critical role of human factors in ensuring the highest level of safety (e.g., CRM, MRM, MEDA etc). This study found that while two of the organisations (A and C) had adopted a number of human factor based programmes, they both had a very different approach in their overall strategic

perspective. The human factor programmes in Company A, for example, were not systematically integrated into other programmes of work within the organisation. Even there human factor training appeared quite ad hoc in that it was developed as a separate initiative with no clear objectives. On the other hand while Company C had no clearly labelled human factors programme they had adopted a much more human centred approach to almost all of their programmes of work.

A number of problems in the management systems of operations and quality systems were highlighted in this study and this is an important first step in outlining a strategic agenda for what a human factors programme could contribute to their solution.

Overall the failure of many 'human-factors' programmes to live up to expectations betrays a lack of understanding of how principles of managing people effectively should be built into all aspects of the production and management system of aircraft maintenance. McDonald (1999) has summarised a number of the key reasons why human factor initiatives have failed to live up to their original expectations:

- Marginalised: human factors programmes can become marginalised in a separate department or specific 'champion' who has little influence when decisions are taken. A lack of perceived effectiveness leads to the weakening and ultimate end of the programme.
- One sided: many human factors programmes have a single focus, often on training for example. When people then return to their previous work environment after training, disillusion occurs if that environment has not changed and the old ways of working are still reinforced.
- Focus on diagnosis not change: human factors expertise has well-developed methods for diagnosing what went wrong. Often, there is too little focus on changing the situation to prevent it happening again.
- Lack of clear objectives: human factors programmes often have objectives that are not easily defined, for example, – what is to be achieved by increasing awareness? What does the prevention of error mean? Such programmes do not have a clear link between the focus of the intervention (usually people's attitudes or behaviour) and the outcomes that the organisation needs.

- No commitment to evaluation: few human factors interventions are accompanied by systematic evaluation of their effectiveness. Developing an effective human factors programme involves a significant investment. It is appropriate to measure the effectiveness of this investment.

The analysis of safety strategy and policy and management commitment to safety highlighted a number of important theoretical dilemmas:

- How to bridge the gap between the static regulations and the dynamic aircraft maintenance system?
- How to go beyond compliance to develop an independent, internal standard of safe performance?
- Is it possible to have an absolute internal standard of safety?
- What is required in order to implement and sustain an effective human factors programme? What sort of managerial and organisational competence is required?

Planning and the organisation of work

This study systematically compared and assessed the role of organisational processes in the planning and organisation of work in two aircraft maintenance organisations. A number of researchers have referred to the importance of effective planning, for example Grote and Kunzler (1996) found that more than 50% of respondents across four chemical companies and one transportation company felt that their planning systems required immediate improvements. However the theoretical accounts of planning and the organisation of work have been largely overlooked in the safety literature. Pidgeon and O'Leary's (1994) model of safety culture did not account for planning systems and Perrow's model of normal accidents prioritises the organisational consequences of 'complexity' and 'coupling' in the technical system rather than in the organisational system per se. This lack of theoretical consideration is surprising considering the evidence from major accident and inquiries which have highlighted the strong contributory role of organisational failures in the provision of the basic elements of production - personnel, documentation, tools and parts. In order to explain this apparent failure of organisations to provide for the basic elements of production in a

routine and reliable manner two case studies were undertaken into the maintenance planning systems of two contrasting maintenance organisations to help provide a deeper understanding of the organisational processes and dynamics of aircraft maintenance planning. The focus was on the planning of the maintenance work-pack and a number of core issues for effective planning and organisation of work was highlighted.

Planning the maintenance work-pack is a process that spans across a number of internal functions at different stages of development, dispatch and execution. One of the organisations (Company C) had moved to a more process-based organisation that in effect called for the breakdown of traditional departmental barriers in order to create an overall planning process, which was more integrated and cross-functional. The other organisation (Company B) operated under the traditional functional organisation system that had an established hierarchical structure and was horizontally divided between areas of specialisation - engineering, planning, quality, production, finance, personnel and other departments. This tended to dictate a top-down process of planning and organisation.

As a result, the issues that emerged as important dimensions influencing the way planning and the organisation of work were described were largely focused on the integration of functions, which allowed for more flexibility in the planning process and validation and review of plans by those who had to actually implement the plans. This approach primarily involved greater reliance on effective co-ordination between planning, engineering and operations, real-time validation and review of plans (at all levels) and the integration of an IT system to support the more flexible and team working approach to planning. In some ways this can be compared to the research from the 'high reliability group', in that they also highlighted the importance of flexibility in switching between different forms of structure depending on the situation. Under 'normal' conditions, high levels of formalised hierarchical control were found, whereas in 'crisis' situations a more team-like cooperation with local control was established. However their research did not explore potential or actual problem areas in switching between different forms of control and structure, apart from highlighting the 'importance of cultural factors in being able to perform these switches between control and more flexible structures' (LaPorte & Consolini, 1991).

This study also highlighted a number of issues that appeared to constrain the overall effectiveness of the planning process, particularly in relation to the organisation that operated under the traditional hierarchical and top-down process of planning. Both organisations had attempted a number of change initiatives in order to improve their overall planning process. The key difference was that Company C's change was not only represented at a procedural level but that actual physical change in the organisational infrastructure took place (e.g., integration of key functions, introduction of team working, etc.) which was supported by dedicated training courses and commitment from both senior and operational management. Company B, on the other hand were unable to sustain effective change beyond rewriting company procedures. However Company B had a number of problems unique to their organisation. The industrial relations climate was seen to constrain both the effective implementation of change and the overall planning systems and a number of specific constraints were also imposed by the fact that they were a 3rd party maintenance organisation as opposed to an airline. Therefore the assessment of the organisational processes in the planning and organisation of work requires a deep understanding of the social, cultural and structural embedded processes in order to both uncover and address potential problems for the effective planning and organisation of work.

Safety is embedded in everything an organisation does, whether it is at the level of decision making (Halpern, 1989); effective team working (Weick, 1979); or organisational design (Grote & Kunzler, 2000). Effective planning also influences the performance and outcomes of a safety management system in that all key documentation, parts and equipment require effective planning and co-ordination to ensure a safe and reliable operation. This study goes some way in highlighting possible constraints to effective planning and the organisation of work but it also raises a number of questions for future research, for example:

- In moving to a more process-based planning system, would this have to be part of a wider organisational change programme (as was the case in Company C)?
- Is it possible to 'switch' between different forms of control and structure (e.g., as exemplified in high reliability organisations), and what are the social and political considerations of this high degree of flexibility? Is this high degree of flexibility generalisable to other industries?

- Part of this study concentrated on the planning processes for the development, dispatch and delivery of the work-pack. Are the findings from this generalisable to other planning processes (e.g., line maintenance)?

Normal Operational Practice

A particular interest of this study focused on the area of aircraft maintenance procedures and the extent to which aircraft engineers routinely deviate from documented task procedures as accident reports suggest that violations of procedures are relatively widespread, and are not being identified and/or rectified under present systems. The analysis of the survey of task procedures found that 34% of aircraft maintenance personnel reported not following the official procedure for the task because in many cases there was an easier (either better and quicker) way to do the task and that the maintenance manual procedure was too complicated. No significant differences in the levels of non-conformance were found between the four organisations. Likewise no significant differences between organisations (except a slight significant difference between Company D and the others) were found on the safety attitude measure. So while some aspects of the organisational safety culture (safety climate) are strongly differentiated between organisations, other aspects (the behaviour and attitudes of aircraft engineers) are not. Therefore the conclusion from this thesis suggested the existence of a professional sub-culture amongst aircraft engineers who routinely perform their tasks differently from the way their company management expected them to.

Another interpretation is that this is simply an inevitable response to strictly imposed external task procedures because these task procedures are largely inadequate and that there is a universal discrepancy between formal and informal practices. However it is important to see these deviations from official procedures in a systemic context because they are often a response (whether deliberate or unintentional) to deficiencies in the operational system. Because these are violations of rules they are often illegal and thus they cannot be officially admitted even if everyone knows about them. Because such violations are so common but hidden from public scrutiny, when they are implicated in an accident, it is very easy to over-interpret the causal contribution of the violation to the accident. Therefore these routine unofficial patterns of behaviour are a major issue

for quality and safety systems in transport and need to be seen as more than just an evitable response to strictly imposed external procedures driven by regulatory and liability concerns.

One implication of this finding is that this professional sub-culture mediates the effect of the organisational safety system on normal operational practice. Arguably, this professional sub-culture provides the flexibility to deal with situations which are not fully anticipated or planned, and to make the judgement to do what it takes to get the job done.

It would appear that many of the steps outlined in any task procedure may include certain aspects that could be overlooked and would not impact on safety. The task procedures are written in such a way as to cover every eventuality and differing levels of experience. However task documentation does not have a close relationship with task performance. The official way of doing things is laid out in the documentation, which has a legal status, but objectively does not meet user needs. Then, there is the way in which work is actually done, which is supported by unofficial documentation and which frequently diverges from the official way. The unofficial and illegal status of these informal work practices means that they tend to be hidden and unavailable to scrutiny. It is thus impossible to know how much of this informal work practice represents better ways of doing things, or how much it might increase risk because important safe-guards contained in the documentation are being ignored and this may challenge the safety of the system.

In the maintenance area the philosophy is unclear. Are aircraft engineers supposed to exercise expertise and judgement, or are they to strictly follow the specified procedure? Engineering culture is such that engineers have traditionally been trained as professional problem-solvers, more so than instruction followers. The official management stance in aircraft maintenance is "always conform", but unofficially there seems to be room for discretion. Under time pressures or unavailability of relevant manpower is it routinely acceptable to take short cuts and not follow the procedure to the letter? There appears to be a double standard in operation where the aircraft engineer works under conflicting operating philosophies. Articulated policy is therefore also inconsistent. All companies studied, in accordance with JAR 145, have

absolute conformance with official procedures incorporated within their policy documentation. This does not (and perhaps could not) accurately reflect the "double standard" philosophy evident across all the organisations studied.

These issues also raise questions regarding the 'high reliability' findings where they advocate total compliance without surveillance when operations are centralised. Weick, (1987) argues '...before you can decentralise, you first have to centralise so that people are socialised to use similar decision premises and assumptions...it creates a homogeneous set of assumptions and decision premises...' However do similar premises and assumptions allow for professional expertise and judgement? How does one achieve an understanding of the informal practices that dictate operational decisions and assumptions and create a common culture? While one could argue that a common or homogenous culture is characteristic of high reliability organisations (e.g., disciplined approach to working and following rules and procedures), the findings from this study have indicated that achieving this common culture in aircraft maintenance is much more difficult than it is assumed in the high reliability organisations.

This also raises questions in relation to Weicks' (1987) problem of 'requisite variety', where he argues that humans who operate and manage complex systems are themselves not sufficiently complex to anticipate problems. This study found that it is the human complexity and professional practices that compensate for many of the deficiencies in the overall system. However the issue of the 'double standard' needs to be addressed as the gap between prescribed work and real work is a fact and if this divergence between the management system and the subculture is not addressed not only will an immense amount of operational knowledge not be captured but it also becomes very difficult to have an objective standard of safety.

These findings raise the question, is it necessarily a good thing to have a totally integrated safety culture or do cultures benefit from deviations from the norm? Surely, as Mearns at al., (1997) argue, subcultures bring new perspectives to the situation, perspectives that can provide a forum for learning, development and innovation. Indeed this thesis argues that the professional sub-culture provides the flexibility to deal with situations which are not fully anticipated or planned, and to make the judgement to do what it takes to get the job done.

Monitoring

The monitoring of safety performance and the effective feedback of that information is an integral part of any safety management system. In assessing the monitoring functions in aircraft maintenance the study focused on the Quality System and concluded that the quality systems were largely ineffective in dealing with the human and organisational issues.

The auditing practices in Company C differed somewhat in that they not only audited documentation but also audited particular work processes and it was the responsibility of the relevant area managers rather than the quality department to devise a plan for implementing recommendations from the audits. While all the organisations had some form of quality discrepancy reporting system which enabled aircraft engineers to report problems, Company A had the most extensive system for quality discrepancy reporting. However there was a large backlog of work in the system for dealing with these reports and many months usually elapsed before reports were effectively dealt with. In all of the organisations there appeared to be no ownership or accountability for dealing with quality reports and the process of implementing recommendations both from these reports and incident investigations was also problematic.

Quality discrepancy reporting, audits and incident/accident investigations do not always make a positive contribution to collective organisational learning. The Quality System, even though it is supposed to be an independent monitoring function, needs to be understood within the local, social, political and regulatory contexts of each organisation. In many ways quality investigators are faced with 'moral dilemmas' just as the aircraft engineer is in making a decision to not follow the procedure. The quality investigator is in the position where he has to monitor and report on the safety of the overall operation bearing in mind both the regulatory requirements and knowing the existence of the 'double standard'. In addition to monitoring safety the quality department also has the responsibility in many instances to oversee and verify the implementation of recommendations from incident investigations, audits and quality discrepancy reporting as well as deciding on appropriate disciplinary action following an incident or accident. However the effective implementation and follow-up of

recommendations involves the co-operation, co-ordination and acceptance of other departments who also have their own agendas and priorities.

The institutional dilemma of 'blame' also requires further consideration. One of the organisations in this study routinely suspended licences pending the outcome of incident investigation and senior management within the company supported this. As a result quality and incident investigations were seen as 'unfair' and 'unjust' as blame was assigned even before the investigation commenced. So, how can the relationship between disciplinary action and reporting systems be effectively aligned or managed? This study has highlighted that there are many barriers to collecting, analysing and disseminating information not only from incident investigations but also from other forms of reporting. Reason (1997), in his discussion of safety culture, has identified the need for a 'just culture', an atmosphere of trust in which people are encouraged, even rewarded, for providing essential related information. However, he also accepts that current disciplinary systems are a significant obstacle for encouraging reporting of essential safety information.

While this study did highlight deficiencies in the current quality systems in aircraft maintenance, these deficiencies cannot be seen in isolation to everything else that goes on in the organisation. As already mentioned the effective functioning of the quality system (from a human and organisational perspective) is highly dependent on the local, social and political contexts of their organisations and as a result these dimensions require deeper consideration and analysis in future research. This study also raised a number of other interesting questions in relation to the quality system:

- Why do audits, quality discrepancy reports and incident investigations operate as separate processes with very little trend analysis across these processes? Would a more integrated approach to the overall monitoring function be more appropriate?
- Who is the internal customer for quality information? Is it a mechanism to enable organisational learning? Or is it just a means to establishing and sustaining JAR 145 approval? While the different quality reports adhere to JAR 145 standards they are ineffective in feeding back outcomes through the organisation.

- Should we expect an investigation to lead to effective actions and recommendations, or is the investigation just the first step (the diagnosis)? The implementation and review of effective recommendations is a serious 'bottleneck' in current incident investigations, therefore how can an organisation ensure effective learning following an incident?
- What is the role of the other quality and organisational functions in supporting and implementing the recommendations from incident investigations?

Implementing Change, Review and Feedback

What is common to many accounts in the literature is the emphasis upon organisational learning as a key component of safety management. Feedback and review are essential requirements of organisational learning. There were great differences between the organisations in the way they handled information from incident investigations and quality reports. These differences were reflected in how the organisations addressed the possibility of change as a response to the incidents and quality reports. One of the organisations discouraged disclosure and formal communication of their own internal incidents. Pate-Cornell (1993) has pointed out that in such an environment, the fact that a severe accident did not occur seems to be sufficient proof that the system works well. The possibility that several minor problems could occur at the same time does not seem to be considered. In two of the other companies, the quality reporting systems appeared to be clogged with too many reports leading to long delays in dealing with the reports and providing feedback. A number of reasons were put forward for these delays, including the lack of commitment from management and lack of clear channels of accountability.

A case study was also carried out which tracked the implementation of change in one of the organisations following a series of similar type incidents. The case study identified a number of core issues in effectively implementing change, most notably, effective change takes a long time and many attempts. It took the organisation over six years, one accident, one serious incident and three different investigations before they implemented change to effectively deal with the problem. Continuous review is also required in order to assess the adequacy of the improvements in dealing with the identified problems. This is something the organisation did not undertake after the first

accident as following the development of a new procedure they felt the problem was solved. This reflects Gephart's argument (1994) that few changes actually occur even after a major disaster except for the formalisation and adjustment of procedures already known to be inadequate. After the second incident the organisation took a much broader analysis of the problem and involved the aircraft engineers in redesigning the procedure as well as introducing a number of organisational initiatives to continually review the particular problem.

So if the preventative measures (e.g., audits, quality discrepancy reports) are not capturing potential problems in the system and it can take a long time for the more reactive mechanisms (incident investigation) to solve the problem, what makes safety systems in aircraft maintenance work? One conclusion of this study is that it is the reliance on the informal systems of control and safety performance that compensates for deficiencies in the more formal systems. Therefore any organisational change or learning has to address the informal systems and processes and be aware of the different 'subcultures', their interaction and the network of power relations that help to define them.

Arguably 'subcultures' are increasingly important considerations in the safety field. This study found that different groups, for example, the aircraft engineers and management all operated within the framework of their own safety 'subculture' rather than sharing a total view of safety. While all individuals in an organisation may be committed to safety, the perceptions of this commitment by others differs and very different beliefs emerge in relation to some of the fundamental mechanisms of safety management (e.g., procedures, incident management and management commitment) largely based on past experiences within their own group. Thus is culture more associated with similar roles or professions or with an 'overarching organisational entity'?

Culture associated with similar roles and professions may contradict many of the definitions of safety culture put forward where organisations are supposed to hold 'shared meanings and beliefs' about safety and a collective commitment to safety (e.g., HSE, 1991). In Martin's (1992) discussion of the 'differentiation' perspective on culture, she does explore the viewpoints of subcultures. Martin's 'differentiation'

perspective agrees that culture is defined as that which is shared, but it is the group, rather than the entire organisation, that is doing the sharing. Other definitions on the 'differentiation' perspective vary in the extent to which they admit the possibility that subcultures may co-exist with some form of organisation-wide consensus. Trice and Morand (1993), for example assume the existence of an overarching, 'common' organisational-wide culture, in which subcultures are embedded. Therefore it may be the case, as Denison (1996) has put forward, that it is the organisational context that must be viewed from different perspectives. For example, it is important to determine what is common to the overall organisational culture and what is common to the various subcultures. Assessing safety culture, therefore, is not an issue of determining whether an organisation does or does not have a safety culture, rather safety culture of an organisation should be viewed from different perspectives with an assessment of what these different perspectives contribute to the overall safety operation, rather than choosing one perspective over the other. Only when the underlying safety culture is understood is it possible to effectively diagnose and improve safety operations.

Overview of findings - An operational point of view

In comparing and differentiating between different organisations' safety management systems this study has enabled an evaluation of the strengths and weaknesses of different real operational systems. As a result the objective of this section of the discussion is to draw on the evidence from the key findings of the thesis to identify the implications from an operational point of view.

The key findings of this study can be summarised as follows:

Quality Reporting Systems

The main safety assurance mechanism of maintenance organisations (the quality system) cannot deal effectively with human factors issues. No quality reporting system investigated was fully effective. For example, some systems were only partially implemented, others overburdened with reports that were not dealt with. It was very difficult to find examples of consistent and effective change in maintenance operations in response to identified human and organisational problems (whether from quality discrepancy reports, audits or incident investigations).

Auditing

Auditing practices varied widely between different maintenance organisations. While all organisations placed emphasis on effective auditing of documentation, some audit fixed facilities and resources, but few attempted to audit how work is actually done. There appeared to be no common auditing standards.

Learning from Incidents

Organisations are not learning from their incidents. Following incidents or accidents, it is critical to future safety that organisations learn from what has happened and implement change to prevent similar incidents occurring. This is particularly true of the human and organisational factors that contribute to incidents. The analysis of the Gotrörra incident demonstrated that despite focused efforts to solve the problem, incidents may have to occur several times before effective change happens. Organisations are rarely systematic in their follow-up to non-technical aspects of incidents, specifically the implementation of recommendations, the monitoring of their effectiveness in addressing the problems they are designed to change and ensuring that knock-on problems are avoided.

Disciplinary Code

The disciplinary code is very influential in the reporting of incidents and governs the manner in which companies respond to incidents. There were also differences in the organisations' policies on discipline following incident involvement. One company maintained its disciplinary procedures alongside its 'no blame' policy. While another company showed a high reliance on suspension of licence and a routine response of retraining following involvement in incidents. Different groups of personnel within the organisations also had different perceptions and understanding of the incident management process and their company's disciplinary policy.

Maintenance Planning and the organisation of work

The planning and organisation of operations lacks the flexibility to address the fluctuating pressures and requirements of production. Two case studies were undertaken into the maintenance planning systems of two contrasting maintenance organisations. One dominant theme concerned a tension between constraints on planning through traditional industrial relations practices and attempts to re-engineer the production process. In one of the organisations in particular, maintenance planning frequently did not sufficiently take account of actual variations in manning, availability of appropriately qualified staff, or availability of parts or equipment. Thus, instead of the plan being adjusted to the realities of production, those responsible for production were routinely adjusting the way they worked to compensate for lack of adequate resources in order to fulfil the plan.

Task Documentation

The quality of task documentation and usability of documentation technology in many maintenance organisations is quite inadequate from a user's point of view (for example, the ergonomic standard of many microfilm reader-printers and the quality of their print is poor; there is no training in use of CD ROM). On the other hand, 'Black Books' are universally accepted to exist. These are illegal and unofficial manuals in which the technician records useful information for their own reference – making it more likely that an aircraft engineer will be using information that is not current and accurate. Moreover, it was found that in over one third of the tasks aircraft engineers reported that procedures were not followed and that there are easier and quicker ways than the official method.

The role of the aircraft engineer

Aircraft engineers and their managers frequently have a contradictory understanding of what the job of the maintenance technician involves.

- The aircraft engineer sees himself as being responsible for the safety of the aircraft, and to use his judgement to do what is necessary to ensure this (not always exactly as in the manual – sometimes more).
- The manager sees the primary role of the technician to follow procedures as laid down – if this is done, safety will be ensured. On the other hand it is often stated

that if work was done strictly according to the written procedure, nothing would get done on time.

In summary the two main mechanisms of safety and reliability in the aircraft maintenance system are the documentation system which specifies the required procedures for carrying out work and the quality system which seeks to ensure that it is done to the highest possible standard. In neither case is the system functioning effectively, particularly when dealing with human and organisational aspects of safety and reliability. This does not mean that the system is inherently unsafe. It manifestly is not. It does mean that it is impossible to assess how safe the system is and where its vulnerabilities are. The system lacks the transparency that is necessary for confidence. The fact that human factors problems are so pervasive in the industry leads to the conclusion that significant improvements in safety and reliability can only be achieved by a systematic approach to managing the human factors of aircraft maintenance.

In assessing the practical and operational implications of this study, the following discussion will be organised around four key findings:

- There is a double standard of task performance in aircraft maintenance – an official way and the way in which work is actually done.
- Quality reporting and auditing do not systematically address how work is carried out, and there is evidence that organisations are not learning effectively from the incidents they have had.
- Planning systems do not always work effectively. Planning systems lack the flexibility to address the pressures and requirements of production.
- Regulatory bodies have a huge influence on safety management systems in aircraft maintenance.

The double standard of task performance

Professionalism

This study has highlighted that organisational systems are complex and dynamic – they are made up of different professional groups, with distinctive sub-cultures. Therefore one important task is to understand the nature of the professional mix in the

organisation and to enable different professional groups to work towards a common organisational goal despite divergences of interest and role. There are a number of features of the professional consciousness of an aircraft engineer: a strong sense of responsibility for the overall safety of the aircraft, which goes beyond simply performing a technical task to a set standard; a belief in professional judgement – that it is the role of the aircraft engineer to use his own judgement, based on experience, knowledge and skill in carrying out the work, rather than blindly following a set of procedures; and a practical concern to get the job done, but to have it done safely. This professional consciousness can conflict with how management perceive the role of the aircraft engineer, and sometimes management expectations can be quite contradictory. Thus, many managers will assert that if the job is done strictly according to the procedures, then it will be done safely. It is not the job of the aircraft engineer to go beyond the way the job is prescribed. However, often in the same conversation, it is strongly stated that it is also essential for work to be done on time and that if every task is done by following the letter of every procedure then unacceptable delays will be inevitable. The aircraft engineer thus has to reconcile the technical requirements, which have to be fulfilled, with the demands of production – getting the job done on time. Sometimes this requires compromise (the double standard). Those who manage this compromise best are highly valued by the company as being people on whom one can rely to get the job done (the 'right stuff'). However the nature of the compromise is never made explicit or acknowledged.

Task Documentation

The standard mode for presenting aircraft maintenance task procedures for many years has been the microfilm reader/printer. The quality of display and documentation production using this technology in most organisations surveyed falls far short of basic ergonomic standards. On the other hand, the ergonomics of more modern CD-ROM displays are far superior. Nevertheless many aircraft engineers prefer the familiar microfilm technology, and do not feel comfortable with the new technology, perhaps because so little training has been given in the use of this new technology.

What this suggests is that the provision of user-centred documentation, which will optimally support maintenance task performance, has not been considered critical in normal maintenance operations in many companies.

It is likely that the legal status of official aircraft maintenance documentation provides a strong controlling influence over the way it is produced. The documentation has to provide the basis for the certification that maintenance tasks have been done correctly and appropriately. The logic of the system requires that if the task has been done correctly according to the maintenance manual then it will be done safely. The quality system and feedback to the manufacturer are there to ensure that any deviations from this rule are corrected. This would seem to dictate the priority requirement that the documentation produced by the manufacturer is comprehensive, accurate and up to date. However, this study has found that this requirement is not compatible with producing documentation which is fully user friendly.

Lack of transparency

These conflicting requirements have led to a complete lack of transparency in the way in which work is undertaken. It follows from this that a priority in the management of safety and reliability must be to find effective measures which will address the double standard of an official and an actual way of doing things. The core of the double standard is that the logic which drives the design of technological systems and their documentation, the planning and organisation of production and quality systems is different from the logic which drives the way in which maintenance (and other) operations are actually carried out.

What is the implication of the double standard for change and learning? The fundamental premise of safety systems is that faults or problems which were implicated in the causation of incidents and accidents can be rectified. How does this work when the problems concern the human side of the system - how people behave and act, and how they are affected by the situation and environment in which they work? A substantial part of normal operational behaviour exists in a partially hidden world, where professional judgement is more important than following procedures to the letter, and compromise is required to cut through the day-to-day problems of less than adequate resources of parts, tools, personnel and environment.

When an incident or accidents occurs all internal (e.g., quality personnel, management) and external (regulatory bodies) stakeholders are reassured that the issue is being properly dealt with. However, underlying many incidents is a routine and normal

pattern of unofficial behaviour which cannot be formally admitted and which the quality system cannot get to grips with. Quality Assurance recommendations do not always address the relatively normal occurrence of informal work-practices. Thus it is likely that nothing substantial will change to prevent similar incidents happening again. The issues to do with routine procedural non-compliance appear to be far too big to be dealt with through the internal quality process alone. The solution is to reinforce the intention to follow procedures more assiduously – through exhortation and threat – and to improve the clarity of the documented procedures through rewriting. What this response does, however, is to shift responsibility for compliance clearly onto the shoulders of those at the front line of the operation rather than addressing the wider system of accountability both from a legal and regulatory point of view and from an internal company point of view.

Quality Reporting Systems

One of the core tasks therefore of safety management is to base a programme of work on a realistic appraisal of what actually happens in practice. Without that basis it is difficult if not impossible to evaluate the predictive safety of current performance, or to plan or achieve better performance from the system as a whole.

Every organisation must seek to assess and to continually improve how it is achieving its overall strategy and goals. One immediate concern for organisations is to learn to improve its quality system operations and to prevent incidents and accidents.

Organisations are frequently condemned to making the same mistake again and again. More seriously, it is often the case that several serious incidents have to occur before effective preventive measures are taken. How can an organisation learn to reduce the risk of similar incidents happening again? The safety management model outlined in this study here is one in which internal processes of monitoring and review (including audits, quality reporting, incident investigation) should lead to changes in the way in which the operation is conducted to ensure greater levels of safety and reliability in the future. However there appears to be a number of issues, which have to be resolved if effective learning is to be achieved.

Disciplinary Systems

One of the most difficult issues to resolve is the conflict between the disciplinary system and the goal of prevention of individual error and system failure. The differences between the organisations in their disciplinary policy appeared to have implications for the implementation of effective quality reporting and human factors programmes. The disciplinary policy was also understood differently by different groups of personnel in the organisations. In one company, for example significantly more operational staff believed that suspension of licence was the result of incident involvement compared to operational management and support. Because the disciplinary code and how it is enforced is so influential in the reporting of incidents and governs the manner in which companies respond to incidents, it is important that a consistent message on the disciplinary code is communicated and understood by everyone in the organisation. Arguably disciplinary systems can be more effective in their role of influencing the general climate of acceptable behaviour than in changing the individual who is the object of the disciplinary process. In order to achieve this the disciplinary system at the very least needs to be seen to be transparent and fair, universally understood by all in the organisation and with agreement on a set of principles between acceptable and unacceptable behaviour.

Establishing Accountability

A second issue concerns the system of accountability. All aircraft maintenance organisations operate in a framework of accountability under the law. This accountability of the organisation to external authority is reproduced by an internal system of accountability, some of which directly reflects external legal requirements (signing for work done), some of which derives from company regulations (including discipline, job descriptions, performance reviews and promotions procedures). Directly and indirectly this system of accountability is a major motivating factor on how people behave. Accountability provides the motivation amongst those whose responsibility it is to take action (at whatever level) to change whatever needs to be changed to lead to more effective performance. This motivation has to overcome resistance from the inertia born of established practice, and the pressure of immediate deadlines. All management systems operate through a system of accountability and responsibility.

How are management accountable for safety? This study has highlighted various ways in which this frequently goes wrong:

- When it is difficult to get ownership of a problem arising from a quality discrepancy report. Responsibility for action gets shifted around and in the end nothing gets done.
- When there is no follow up on the implementation of recommendations from audits or incident investigations.
- When there is follow up on the implementation of recommendations, but there is no systematic assessment of the effectiveness of the recommendations in correcting the original problem.

Effective systems of accountability involve reporting relationships and periodic review. This involves effective reporting channels up the chain of responsibility to one's immediate superior; down the chain of responsibility to those for whom one is responsible and horizontally to those with whom one has to co-ordinate in order to achieve overall objectives. The company has to be seen to be dealing effectively with the problem and taking appropriate preventative measures.

Implementing Recommendations

One of the most challenging tasks is actually closing the loop from audits or investigations in actually implementing and reviewing corrective actions and recommendations. The point of conducting an investigation is not just to find out what happened but also to try and prevent similar incidents occurring in the future. Recommendations thus have a critical role in any investigation report. The recommendations or corrective action for change must be demonstrated to be valid in addressing the real day-to-day operational situation. Normally it is essential to involve those who are directly involved in the operation and those who may be effected by any change. However recommendations are of little use unless:

- They are accepted, implemented and reviewed.
- Their implementation is effective in changing the factors causing the incident.
- Their implementation changes the whole situation for the better and does not create additional or compensatory problems.

Organisational Learning

Organisational learning from incidents, which ensures prevention, is perhaps the most difficult task of safety management. There is a scarcity of good guidance and case study material on achieving effective change following an incident investigation. The case study conducted as part of this study concerned procedural and organisational change as a result of accident investigation and provided an account of how one organisation responded to a series of incidents. This case demonstrated that organisations need to have a system for monitoring the implementation of recommendations and evaluating their effectiveness in addressing the problems which gave rise to the incident. There must be review of the effectiveness of the implementation of the recommended changes, including the knock-on effects of these changes on other parts of the system. Where appropriate this review should be periodic and continued at least until the system is demonstrably stable over a period of time. In many cases this requires a determination to get it right despite attempts which are only partially successful, or not successful at all, or which produce in turn a new set of problems to solve. Indeed some problems are so intractable it is necessary to have a focused process of continuous review of the effectiveness of the measures taken. This focused process of continuous review must involve more than just quality personnel, all key stakeholders (particularly those with first hand knowledge of the practical requirements) must be actively involved in formulating and reviewing effective solutions.

Planning Systems

Finally the overall planning and design process in an organisation cannot be a static function. Organisational plans must be an integral and flexible support to the demands of the daily operation. Identifying and applying regulatory standards and codes of best practice is the first stage of design of a system or planning an operation. The JAR framework of regulations makes certain general requirements about how a maintenance organisation should operate. However an effective safety management system needs to spell out in more detail how the human aspects of these general requirements can be fulfilled, and point to areas where there is need to develop better regulation and codes of practice. Ensuring that plans work in practice requires good co-ordination and communication, but this in turn requires that the way in which departments are

structured and linked with each other actively support the carrying of maintenance plans into practice. This study identified a number of aspects to effective planning:

- Building in flexibility to allow for variation in demand,
- Co-ordination between planning, engineering and operations departments to ensure that plans are adjusted to meet operational requirements,
- Real-time validation and review of plans to ensure that the way in which operations are planned and organised does effectively address the way in which they are carried out.

The Role of the Regulator

A word should be said regarding the relevance of the suggested approach to safety management. Although the focus of the approach was clearly on organisational safety management, it is linked to institutions beyond a single organisation. Regulatory bodies, for example have a huge influence on the safety management systems in aircraft maintenance. The regulators are in the particular position to act as one of the most effective defences against organisational incidents and accidents. They are 'located close to the boundaries of the regulated system, but they are not it'. This grants them the perspective to identify how the work is done and how the Safety Management System is functioning. However the JAR 145 lacks human factor specification for guidance for a company' s Safety Management System and for auditing practices. In many cases the granting of JAR 145 approval focuses on ensuring that the documentation is complete and in order and less emphasis is placed on how work is actually performed. The question has to be asked how can one regulate a "self-regulatory management system". There is a need to establish a framework of regulation that can support the aircraft maintenance organisation in their efforts to address organisational aspects of safety management. Regulators have been trained and are highly experienced in identifying technical inadequacies and many of them have been recruited from the airlines. However, what regulators often lack are the tools, training and the resources to monitor and action the all-important human and organisational factors. Arguably the eventual role for the regulator could be one of facilitator and advocate, with little or no need for direct regulation. Future research is required to further explore the role of the regulator in supporting a 'self-regulatory management

system', which recognises the need for an internal standard of safety, complete transparency and the right kind of human factor competence.

In conclusion an organisation which ignores, or feels threatened by, quality reports, or which cannot take effective action in response to serious incidents, which reacts punitively when people make well intentioned mistakes, or which makes unrealistic or inappropriate demands, will see the skill and professionalism of its people go towards protecting themselves and not towards improving the organisation. On the other hand an organisation that openly recognises and values how their systems function in practice and how people commonly behave in them, operates a transparent disciplinary system; systematically monitors actual operational practice, and maximises learning from quality reports and incident investigations, will see all parts of the safety management system directed towards the same goal – improving safety, quality and reliability in maintenance operations.

Overall Conclusion

How is safety culture embedded in an organisation's safety management system? This study highlighted the complex and subtle interaction between the structure and functioning of a systematic safety management system and the underlying safety culture. The study went beyond the directly visible characteristics of formalised technical and organisational safety programs and practices to establishing a first account of the organisation's safety values and priorities.

A safety management system is made up of explicit organisational processes (policies, reporting structures, quality and planning systems etc) all of which are deeply rooted in and influenced by the organisation's safety culture. This study highlighted that fundamental aspects of the various systems for ensuring safety and reliability are not working optimally. That these systems do work, is largely because of the unofficial and informal subsystems. While these informal systems are known in the organisation they are not always valued or acknowledged and in many ways these informal mechanisms run directly counter to the expressed goals, priorities and values of the overall management and regulatory systems. An assessment of the formal structures and systems of safety management alone would not have provided an adequate

explanation of these normal characteristics of operational systems. In this study the analysis of the underlying culture provided the explanation. The analysis of safety culture provided an account of how different personnel understood their role in the overall safety management system and thus provided the context for understanding different value systems, behaviours, beliefs and the subsequent actions and safety outcomes.

In addition this study did not rely on the analysis of accident and enquiry reports in assessing deficiencies in the overall safety management system. In assessing the normal operational and management practice the study advanced both the theoretical and practical considerations of safety management. Rather than just offering generalised prescriptions or key components to ensure effective safety management, this study in exploring the underlying organisational and cultural processes enabled a much more systematic and thorough explanation of some of the fundamental dilemmas in safety management.

Overall the systematic and comparative analysis undertaken in this study has had a considerable influence in explaining some of the fundamental problems and dilemmas of ensuring effective safety management. As well as explaining some of these fundamental dilemmas, the study also raised a number of very important theoretical issues, which require further consideration in future work in order to better inform safety management practices, most notably:

- The role of the regulations in supporting safe practice
- The role of an internal standard of safety
- The role of the Quality System and reporting systems
- The role of management training and development
- The role of informal systems of control and safety performance
- The role and contribution of 'subcultures' to overall safety practice
- The underlying organisational processes for effective planning
- The current role of human factor practice
- Organisations inability or resistance to 'change' or 'learn'.

All of the findings and conclusions from this study have been reviewed by each of the participating organisations, who have recognised and confirmed the observations and

interpretations offered. While many features of these different organisations will have changed since the research was undertaken, this does not undermine either the validity or generalisability of the findings, for two reasons. Despite change, organisations display considerable continuity in their structures, processes and patterns of interaction – much detail may be different but the overall pattern displays overall stability, or gradual evolution. Secondly these organisations are of interest not only to themselves and their own particular history. To a greater or lesser extent they represent organisations in this type of industry and in this geographical area. The issues they face are common to a wide range of organisations. The way in which they cope with them may be more specific to their own history and culture, but by contrasting a number of different approaches to these problems it will help us to see what the possibilities are in a way that transcends the specificities of each organisation.

We do not know exactly how typical or representative these organisations are – this is an issue for further research. Replication studies, for example, may enable confidence in both the validity of the overall findings and in relation to independent replications of questionnaires. But for the time being we can use them as examples, providing us with some insight into the complexity of managing the human aspects of safety and reliability.

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Appendices

Appendix 1 – Management Interview Schedule

ORGANISATIONAL SAFETY SYSTEMS
Interview Schedule

- **All views expressed are confidential and non-attributable**
- **All informants will receive a draft synopsis of the interview for their comments/confirmation**

Section 1 – Background Information
Length of time in the company/current job
Professional qualifications
Key responsibilities and job description
Responsibility and experience in relation to managing safety issues

Section 2 – Safety Policy and Strategy in the Company
Impact of compliance with JAR145 regulations
Development of the MOE/Safety Statements etc
Priority of safety goals and strategies
Reconciling safety with commercial and operational considerations
The role of human factor initiatives in achieving overall safety policy and goals

Section 3 – Implementing Policy and Setting Standards
Maintaining an adequate set of measures or standards of performance
Internal safety performance standards
Review of internal safety performance
Organisational issues that impacted implementation of policy
    Human Resource Planning
    Role of Information Technology
    Industrial Relations Climate
Effectiveness of the current system in achieving safety goals

Section 4 – Training
Participation in Management Training Programmes
Participation in Safety Training Programmes
Participation in Human Factors Training Programmes
Availability of such training courses/Organisation's commitment to training
Effectiveness of such training programmes

Section 5– Quality System
Quality Assurance Vs Quality Control
Monitoring functions in place
    Quality Auditing
    Incident Investigation
    Quality Reporting
Effectiveness of quality reporting systems in dealing with human factor issues
Effectiveness of overall quality reporting systems, audits and incident investigation in terms of: length of time to completion; satisfaction with investigation outcomes; review and feedback on outcomes; the disciplinary code.

Section 6 – Communication Strategies/Flow of Information

Internal communication strategies to ensure safety policy is understood
Formal and informal channels of communication on safety issues
Role of safety committees
Feedback from monitoring functions

Section 7 – Role of Regulations
Formal and informal communications strategies with the National Aviation Authority
Disseminating information and reports on incident and accidents
Nature of the working relationship

Appendix 2 – Survey of Safety Attitudes, Safety Climate and Incident Management

SURVEY OF SAFETY ATTITUDES, CLIMATE AND INCIDENT MANAGEMENT

The Aircraft Dispatch and Maintenance Safety (ADAMS) project is a [7]European research initiative concerning the role of Human Factors in safety in aircraft maintenance, with the aim of developing better safety systems in the European maintenance industry.

This survey is aimed at assessing safety attitudes and climate across the organisation. Some form of identification is necessary as we plan to administer the survey to you at a later date so we can measure if there have been any changes in safety attitudes and climate over time.

The survey is completely CONFIDENTIAL.

Access to the completed questionnaires will be restricted to the researchers only and you can be assured that your answers will not be traced to you personally.

Please;

- Answer all questions
- Give your first natural answer
- Work quickly and efficiently through the questionnaire
- Unless otherwise stated, tick the appropriate response to each question

Could you please place the completed questionnaire in the envelope provided, seal it and return it as requested.

Scales developed by Universidad de La Laguna, Tenerife.

General Information

In order to analyse the data it is important that we have some background information so that we can group opinions together.

Remember all responses are completely CONFIDENTIAL

Please complete the following:

Personal Data

Roll Number _____ Sex: M [ ] F [ ]

Time in the company: ___ years

Time in your current job: ___ years

Highest level of education:

A3 [ ] A2 [ ]

A1/University [ ] Technical qualification [ ] (Please Specify)

Job Data

Job Title _____

Do you usually work in the hangar; Yes [ ] No [ ]

Do you usually work on the line; Yes [ ] No [ ]

My present job situation is: Full-time Permanent [ ]

Part-time Permanent [ ]

Contract [ ]

Other (Please Specify) _____

Note: This section was customised for each of the organisations

Attitude to Safety Scale

1. I think that if safety standards were complied with, most maintenance accidents could be avoided.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

2. I believe that to have an accident is a matter of chance.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

3. Those colleagues who ignore safety procedures and standards make me angry.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

4. Using personal protection equipment is uncomfortable while working.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

5. In my opinion I can smoke in the workplace if I am careful.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

6. Complying with safety standards is more important for me than the results of my work.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

7. I think that reporting accidents and incidents is a way of preventing them.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

8. A good standard of safety makes a company more competitive.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

9. When the job requires it, the most important thing is to finish it on time.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

10 Safety rules only provide a means of penalising you.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

11. I am so familiar with my work that sometimes I forget the precautions I should take.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

12. I think that safety would improve considerably if unsafe behaviour was penalised.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

13. Personal protective equipment is useful in a hazardous situation.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

14. I find working with a certain amount of risk exciting.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

15. I can do my job perfectly without so many safety rules.

Absolutely Agree	Agree	Indifferent	Disagree	Absolutely Disagree
( )	( )	( )	( )	( )

Organisational Safety Climate Scale

1. My Company invests sufficient funds and resources in the prevention of accidents.

agree ( ) disagree ( )

2. My Company managers are strongly committed to full compliance with safety standards and procedures.

agree ( ) disagree ( )

3. My co-workers respect safety standards and procedures.

agree ( ) disagree ( )

4. When my Company management becomes aware of a safety problem arising at work, it quickly takes corrective action.

agree ( ) disagree ( )

5. In my Company, productivity is more important than safety.

agree ( ) disagree ( )

6. My Company managers are really concerned about safety problems.

agree ( ) disagree ( )

7. Our managers take safety standard violations very seriously even when they do not result in accidents.

agree ( ) disagree ( )

8. It is just a matter of time before I find myself involved in an accident.

agree ( ) disagree ( )

9. We have a simple procedure for making suggestions to management in order to prevent accidents.

agree ( ) disagree ( )

10. Resources directed at safety training make a positive contribution to the functioning of our Company.

agree ( ) disagree ( )

11. My Company places great importance on full compliance with safety standards and procedures.

agree ( ) disagree ( )

12. The managers in my Company are willing to adopt new ideas in order to improve safety.

agree ( ) disagree ( )

13. Working safely is the top priority in my Company.

agree ( ) disagree ( )

14. Those in authority respect safety standards and procedures.

agree ( ) disagree ( )

15. In comparison with other maintenance facilities, this is one of the safest.

agree ( ) disagree ( )

16. My Company regularly reminds the workforce about safety standards.

agree ( ) disagree ( )

17. Management in my Company is continually informed whether work safety standards are complied with.

agree ( ) disagree ( )

18. My Company managers would like to invest more resources to improve safety levels.

agree ( ) disagree ( )

19. My job carries a considerable level of risk.

agree ( ) disagree ( )

20. Employees who are trained in safety perform their work better.

agree ( ) disagree ( )

Incident Management Survey (version A)

Please read the following scenarios:

Mechanics had performed a routine maintenance task which involved the removal of the horizontal stabilizer leading edges the night before the flight. The upper screws on the left leading edge were not re-installed by the next shift.

During a 'C' check engine pylons were checked for cracks which required the removal of the fuse pin bolt and clip. The job card was incorrectly marked as if the clip had been installed before hand over to a new mechanic. The aircraft was returned to service without the bolt and clip.

An engineer working on an engine had tightened nuts in the low pressure turbine only finger tight before going to lunch. On returning he had forgot he had not completed the torquing of the bolts as he had intended and continued with the next stage of the task.

Several functional checks were carried out on an aircraft which required the ground interconnect cable to be disconnected. Throughout the tests the warning device was not fitted as it could not be located . A non-routine work card was not raised to highlight this fact and the aircraft was returned to service with the cable disconnected.

All of these scenarios led to a reported flight incident which could have led to the loss of the aircraft or the death of those on board.

If any of these incidents occurred in your company, what would happen to the technician(s) involved? (please tick appropriate boxes)

Nothing ❑

Verbal reprimand and no further action ❑

The incident would be discussed with them so that they could learn from their mistake ❑

Impartial investigation to find out what factors gave rise to this incident ❑

Disciplinary hearing ❑

Suspension of license pending disciplinary hearing ❑

Suspension from job pending disciplinary hearing ❑

If any of these incidents occurred in your company how might you hear about it? (please tick appropriate boxes)

not at all ❑
by word of mouth from colleagues ❑
through a verbal briefing from a company official ❑
through a written alert bulletin from the company ❑
through a notification of a procedure change ❑
through a company magazine or newsletter ❑
through an industry magazine ❑
through the national or local media (newspaper, TV) ❑
other means (please specify) ❑

Incident Management Survey (version B)

Please read the following scenarios:

Mechanics had performed a routine maintenance task which involved the removal of the horizontal stabilizer leading edges the night before the flight. The upper screws on the left leading edge were not re-installed by the next shift.

During a 'C' check engine pylons were checked for cracks which required the removal of the fuse pin bolt and clip. The job card was incorrectly marked as if the clip had been installed before hand over to a new mechanic. The aircraft was returned to service without the bolt and clip.

An engineer working on an engine had tightened nuts in the low pressure turbine only finger tight before going to lunch. On returning he had forgot he had not completed the torquing of the bolts as he had intended and continued with the next stage of the task.

Several functional checks were carried out on an aircraft which required the ground interconnect cable to be disconnected. Throughout the tests the warning device was not fitted as it could not be located . A non-routine work card was not raised to highlight this fact and the aircraft was returned to service with the cable disconnected.

If any of these incidents occurred in your company and did not lead to a flight incident, would you expect incidents such as these to be reported? yes no

If so what would happen to the technician(s) involved?
(please tick appropriate boxes)

Nothing	❑
Verbal reprimand and no further action	❑
The incident would be discussed with them so that they could learn from their mistake	❑
Impartial investigation to find out what factors gave rise to this incident	❑
Disciplinary hearing	❑
Suspension of license pending disciplinary hearing	❑
Suspension from job pending disciplinary hearing	❑

If any of these incidents occurred in your company how might you hear about it? (please tick appropriate boxes)

Not at all	❑
By word of mouth from colleagues	❑
Through a verbal briefing from a company official	❑
Through a written alert bulletin from the company	❑
Through a notification of a procedure change	❑
Through a company magazine or newsletter	❑
Through an industry magazine	❑
Through the national or local media (newspaper, TV)	❑
Other means (please specify)	❑

Appendix 3 – Survey of Procedure Compliance

THE ROLE OF PROCEDURES IN AIRCRAFT MAINTENANCE

The following is a short and **COMPLETELY CONFIDENTIAL** questionnaire. It is part of a European funded research project aimed at enhancing safety in aircraft maintenance by improving task support for maintenance engineers such as MM procedures.

Your **HONEST** response to this questionnaire will help identify areas which need improvement.

Instructions for completing the questionnaire.

1). Please answer ALL questions that apply.

2). For questions where you are given a choice of answers, circle your answer, e.g.

[NO]

and if you change your mind then ...

3). For questions with "[_]" please tick in the box if the statement applies.

4). Please return the questionnaire with the work card.

5). Abbreviations used in the questionnaire **MM** -Maintenance Manual; **IPC** - Illustrated Parts Catalogue; **SRM** - Structured Repair Manual; **WDM** - Wiring Diagram Manual.

Thank you for answering this questionnaire. Your honest responses will help us improve the information sources, which support your work.

Background information

Certification Level _____ Years of experience _____

Maintenance Manual Ref. Number _____ Work Card Number _____

1. Did the task you have just completed arise as a result of (please circle your answer)

Planned M. task Entry | Unplanned M. Task/Non Routine Card | Tech. Log

Cabin Log Entry | Service Bulletin | Self Raised Card | Other

2. How difficult would you rate this task.
(from "0" quite simple to "5" extremely difficult). _____

3. Please CIRCLE your answers.

- Was it clear from the work-card exactly what the task was? **[YES]** **[NO]**

III. Was there a MM procedure for this task? **[YES]** **[NO]**

IV. Was the MM procedure attached to the work-card? **[YES]** **[NO]**

V. Was it clear from the start precisely what steps had to be taken? **[YES]** **[NO]**

VI. Did this job involve any 'vital' parts/processes? **[YES]** **[NO]**

VII. Would communication with flight crew have been helpful? **[YES]** **[NO]**

VIII. Did you have to use techniques such as problem solving skills, trial and error or guesswork to solve the problem? **[YES]** **[NO]**

IX. At the end of this job were any items on the work-card deferred? **[YES]** **[NO]**

X. If yes then why? **[UNABLE TO IDENTIFY PROBLEM]** **[TIME]** **[PARTS]** **[OTHER]**

XI. Did you have the aircraft's maintenance history available to you? **[YES]** **[NO]**

XII. If yes, did you use it? **[YES]** **[NO]**

XIII. If no, would it have been helpful? **[YES]** **[NO]**

XIV. Did you replace parts as a precautionary measure without being sure that they were the source of the problem? **[YES]** **[NO]**

XV. Did you take over this job from a previous shift? **[YES]** **[NO]**

XVI. If yes... was it clear what the current status of the job was at the hand-over? **[YES]** **[NO]**

4. Did you consult the MM procedure to complete this task? [YES] [NO]

4A. If yes ...why? (Tick ALL that apply).

1. I've done the task before but I needed to refresh my memory. [_]
2. I have never performed the task before. [_]
3. I needed a reference for the IPC. [_]
4. It is company policy to consult the MM. [_]
5. To check for any temporary revisions/ alerts. [_]
6. To ensure that I performed the task correctly. [_]
7. To determine the safest way to complete the task. [_]
8. Other. (Please Specify) [_]_____

_____

4B. If no ... why? (Tick ALL that apply).

1. I have done this task before and know the correct procedure. [_]
2. I couldn't find the MM. [_]
3. The MM was being used by somebody else. [_]
4. I was shown how to do the task by a colleague/supervisor. [_]
5. People would think that I didn't know my job. [_]
6. Reader printer was unserviceable. [_]
7. The MM is poorly laid out and takes too much time to find what I need. [_]
8. Did not require the MM to complete this task. [_]
9. The reader printers were all in use. [_]
10. Other. (Please Specify) [_]_____

_____

5. Did you follow the method for performing this task exactly as laid down in the maintenance manual (whether or not you actually consulted it)? [YES] [NO]

5A. If no... (Please tick ALL that apply)

- There is an easier way to do it. [_]

IV. Because the MM method is too complicated. [_]

V. Because there is a better way to do it than the MM method. [_]

VI. Because there is a quicker way to do it than the MM method. [_]

VII. It is not normal to use the MM method to complete this task. [_]

VIII. I didn't have time to follow the MM method completely. [_]

IX. The MM does not cover this task. [_]

X. There aren't enough staff to allow me to follow the official method. [_]

XI. The task was just too difficult. [_]

XII. It was a highly unusual task. [_]

XIII. I wished to try out other ways of doing the task. [_]

XIV. I was shown another way to do it by a colleague/supervisor. [_]

XV. Other_____

_____

6. If you have used any of these manuals in the past please circle them below. Read the list and indicate any problems you have experienced with the documentation you have used. (please tick)

	MM	IPC	SRM	WDM
1. Some information missing.				
2. Poor print quality.				
3. Not fully comprehensible				
4. Not fully accurate.				
5. Not completely up to date.				
6. Too much detail .				
7. Other(Specify)				

7. If there was other documentation that you should have referred to and didn't, why?

8. If you have any suggestions on the topic of maintenance support documentation and how it might be improved, or suggestions regarding this questionnaire please write them below.

Appendix 4 – Ergonomic Assessment Checklist

Ergonomic Checklist for the assessment of CR-ROM and Microfilm Reader Printers

This ergonomic checklist was developed in order to assist the researcher in assessing the CD-ROM and microfilm reader printers as supports to the aircraft engineers. This checklist was not meant to be a comprehensive analysis of all aspects of ergonomic requirements for visual display terminals. The checklist focused on the following areas:

- Workstations (work desks/stations, work chairs)
- Legibility of Displays
- Hardware
- Length and distribution of time operating the machine

Workstations

ISO 9241-5 deals with the design of workplaces for visual display users. Good workplace design should facilitate efficient operation of the visual display and encourage the user to adopt a comfortable and health working posture.

- Lighting conditions
- Size of the work surface in relation to the task (adjustable work surface)
- Location of frequently-used equipment controls, display and work surfaces
- The location of frequently-viewed displays within easy view
- Clearances under work surfaces
- Work chair (e.g., support for the back especially for the lumbar region)

Legibility of Displays

ISO 92451-3 deals with the characteristics of the visual display, which determine its effectiveness in presenting an image to the user. The user performance objective is that the user should be able to detect and recognise the image accurately, quickly and without discomfort.

- Quality of screen output
- Problems with illumination
- Problems with excessive flicker
- Problems with glare from the screen
- Quality of layout features on the screen

Hardware

- Keyboard layout
- Key travel
- Key force
- Quality of print-outs
- Frequency of breakdowns

Length and distribution of time operating the machine

- Speed at which information is obtained
- Flexibility (skim, search, look back, look ahead, look in detail)
- Training in the use of CD-ROM and Microfilm Reader Printer

Appendix 5 – Factor Analysis of Safety Attitude Scale

Factors for the items related to safety attitude in the total sample.

ITEMS	F1>.3)	F2 >.3)	F3 >.3)
Safety Rules			
15. I can do my job perfectly without so many safety rules	.666	.236	.104
10. Safety rules only provide a means of penalising you	.625	-.129	-.178
14. I find working with a certain amount of risk exciting	.541	-.195	.253
5. In my opinion I can work in the workplace if I am careful	.460	.217	.104
3. Those colleagues who ignore safety procedures and standards, make me angry	.434	.264	-.163
Compliance			
12. I think that safety would improve considerably if unsafe behaviour was penalised	.109	.699	.167
1. I think that if safety standards were complied with, most maintenance accidents could be avoided	-.105	.681	-.160
6. Complying with safety standards is more important for me than the results of my work	.273	.361	-.213
Personal Protection Equipment – PPE			
4.Using personal protection equipment is uncomfortable	.262	-.240	.607
11. I am so familiar with my work that sometimes I forget the precautions I should take	.158	.193	.561
13. Personal protective equipment is useful in a hazardous situation	.134	.211	.365
Percentage of variance explained	17.290	12.155	9.440
Cronbach Alpha	.51	.27	.09

Appendix 6 – Reported consequences of Incident Involvement

Reported consequences of Incident Involvement

Table 1. Percentage results for led to and did not led to incident

	Led to Incident	**Did not led to incident**
Nothing	2.2	3
Verbal Reprimand	6.3	12
Incident Discussed	28	36
Impartial Investigation	37	39
Disciplinary Hearing	35	31
Suspension of licence	25	17
Suspension of Job	16	8

Table 2. Percentage results on each response across organisations

	Company A	**Company B**	**Company C**	**Company D**
Nothing	3	4	0	3
Incident Discussed	37	21	50	28
Verbal Reprimand	10	10	15	6
Impartial Investigation	48	33	60	24
Disciplinary Hearing	42	22	33	31
Suspension of licence	14	48	7.9	16
Suspension of Job	18	8.5	2.6	11.3

Table 3. Percentage results across Job Types

	Operational Staff	**Operational Mgnt**	**Support Personnel**
Nothing	3	0	2
Verbal reprimand	8	13	7
Incident discussed	31	24	38
Impartial Invest.	36	52	51
Disciplinary	34	13	37
Susp. Of licence	22	24	17
Susp. Of Job	12	7	14

Table 4. Percentage results by job type by organisation

Verbal Reprimand

	A	B	C	D
Operat. Staff	8	9	10	5
Mgnt	1	1	1	1
Support	1	0	2	0.45

Incident Discussed

	A	B	C	D
Operat. Staff	30	16	32	17
Mgnt	4	1	8	4.5
Support	2	3	9	5

Impartial Investigation

	A	B	C	D
Operat. Staff	30	2	47	15
Operat. Mgnt	8	6	7	5
Support	4	6	13	5

Disciplinary Hearing

	A	B	C	D
Operat. Staff	35	18	30	20
Mgnt	4	1	3	6
Support	3	3	2	10

Suspension of Licence

	A	B	C	D
Operat. Staff	11	37	7	13
Mgnt	2	6	0	1
Support	1	6	0	2

Suspension of Job

	A	B	C	D
Operat. Staff	14	7	0	7
Mgnt	2	0	0	2
Support	2	1	0	2

Appendix 7 - Dissemination of Incident Information

Dissemination of Incident Information

Table 1. Percentage results for led to and did not led to incident

	Led to Incident	**Did not led to incident**
Not at all	4.5	5.3
Word of Mouth	57	62
Verbal briefing	18	16
Written alert	44	47
Procedure Change	23	22
Company Magazine	13	14
Industry Magazine	3	2
National/local media	13	7

Table 2. Percentage results on each response across organisations

	Company A	**Company B**	**Company C**	**Company D**
Not at all	6	3	4	5
Word of Mouth	67	65	54	51
Verbal briefing	21	16	12	15
Written alert	49	45	71	34
Procedure Change	29	15	29	17
Company Magazine	31	3	4	7
Industry Magazine	4	2	2	0
National/Local Media	16	11	13	3

Table 3. Percentage results across Job Types

	Operational Staff	**Operational Mgnt**	**Support Personnel**
Not at all	5	0	6
Word of mouth	61	50	57
Verbal briefing	15	24	21
Written alert	43	50	57
Procedure Change	21	11	32
Company Magazine	13	11	17
Industry Magazine	3	0	3
Media	12	0	6

Table 4. Percentage results by job type by organisation

Not at all

	A	B	C	D
Operat. Staff	5.6	3	0	4
Mgnt	0	0	0	0
Support	0	0	0	1

Word of Mouth

	A	B	C	D
Operat. Staff	52	51	35	36
Mgnt	7	7	8	8
Support	4	7	9	9

Alert Bulletin

	A	B	C	D
Operat. Staff	30	26	47	21
Mgnt	8	7	10	6
Support	3	2	12	7

Procedure Change

	A	B	C	D
Operat. Staff	23	12	15	9
Operat. Mgnt	4	1	7	3
Support	2	1	4	0

Company Magazine

	A	B	C	D
Operat. Staff	23	3	5	2
Mgnt	6	0	1	2
Support	2	0	0	1

Industry Magazine

	A	B	C	D
Operat. Staff	3	2	0	1
Mgnt	0	0	0	0
Support	4	2	0	1

National/local Media

	A	B	C	D
Operat. Staff	14	9	9	5
Mgnt	0	0	0	0
Support	0	0	1	0

Appendix 8 - Planning Systems Interview Schedule

Planning, developing and dispatching the work-pack

Interview Schedule

- **All views expressed are confidential and non-attributable**
- **All informants will receive a draft synopsis of the interview for their comments/confirmation**

The initial interview schedule was developed as a broad checklist in order to obtain an understanding of the overall planning process.

Section 1 – Background Information

Length of time in the company/current job
Professional qualifications
Key responsibilities and job description

Section 2 – Overview of the planning process (key departments)

Key departments involved in overall planning of the work-pack
The role of each department
Level of co-ordination within and between departments
The role of external organisations and customers

Section 3 – Overview of the planning process (key documentation)

Trace the key documents involved in both long-term and short-term planning
Source of documents
Co-ordination of documentation within and between departments

Section 4 – Planning and co-ordination of daily work

Who is responsible for planning and co-ordination of daily work?
What support is available for this task?
Planning of manpower, parts, materials, tools etc

Section 5 - Planning Systems and the IT infrastructure

The role of IT in supporting both long-term and short term planning
Future plans for IT support

Section 6 – Problems with planning, developing and dispatching the work-pack

Specific problems within each department/area of work
Specific problems between departments
Organisations' response to dealing with these problems

Section 7 – Influence planning has on overall safety of operations