FLIGHT SAFETY FOUNDATION

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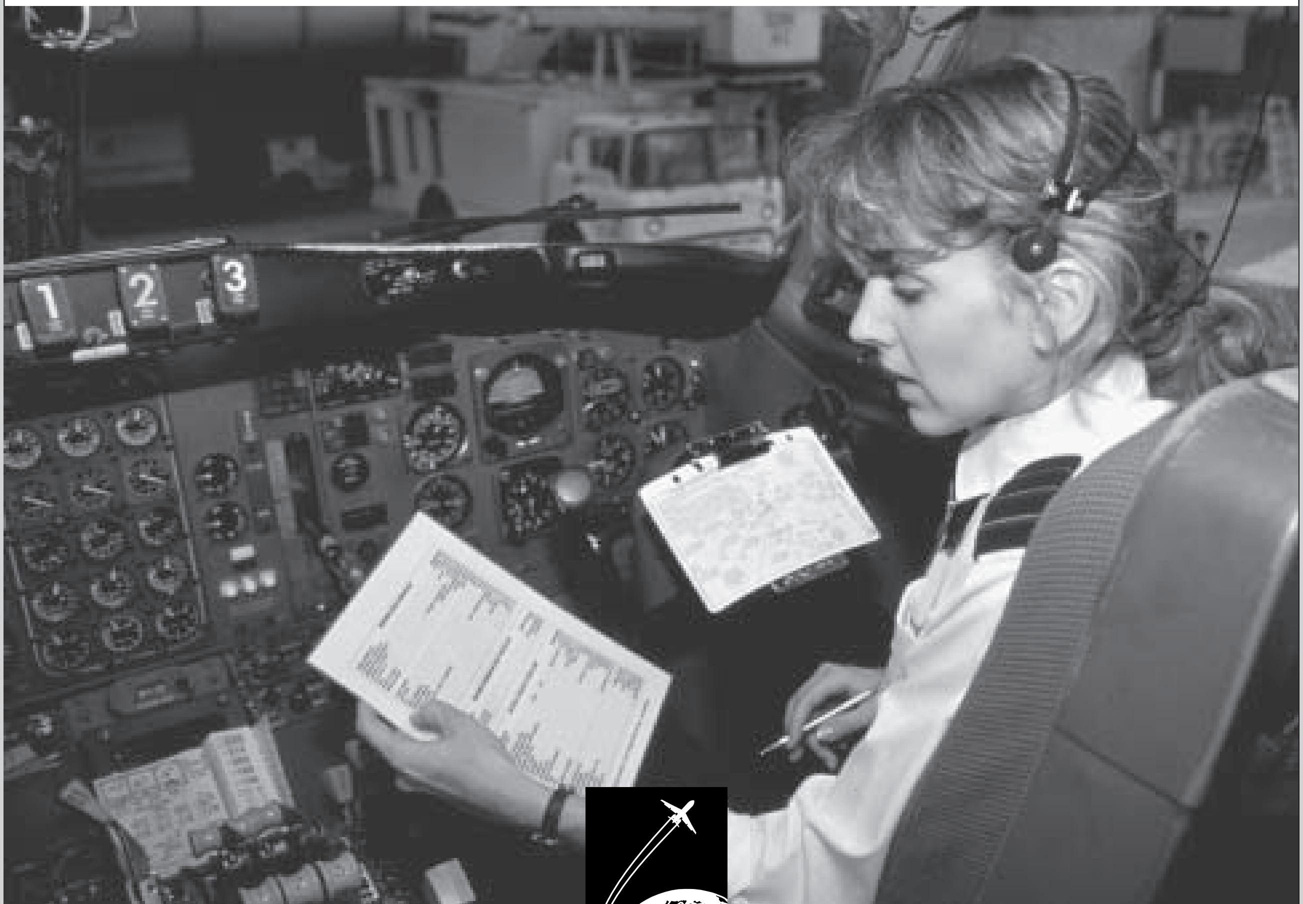
FLIGHT SAFETY DIGEST

The Human Factors Implications for Flight Safety Of Recent Developments In the Airline Industry



FLIGHT SAFETY FOUNDATION

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In This Issue

Flight Safety Foundation is an international membership organization dedicated to the continuous improvement of aviation safety. Nonprofit and independent, the Foundation was launched officially in 1947 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 910 member organizations in more than 142 countries.

The Human Factors Implications for Flight Safety of Recent Developments in the Airline Industry

A Research Study for the Joint Aviation Authorities

Contents

Executive Summary

Introduction

The study was carried out during 2000, on behalf of the Joint Aviation Authorities (JAA), by a team led by Icon Consulting and including Human Reliability Associates, International Air Transport Association (IATA) Aviation and Research[1] and experienced pilots. The aim of the study is to consider the human factors implications of recent commercial developments in the airline industry and to assess their potential impact, if any, on flight-deck safety.

Approach

The overall approach was as follows:

- To investigate whether there is a theoretical possibility of commercial developments having a safety impact on the flight deck — it was concluded that there is a possibility;

- If there is a theoretical possibility, to identify whether the conditions exist for a safety impact to occur — it was concluded that the conditions do exist and that continuing changes in the industry are increasing the likelihood of their occurrence;

- If the conditions exist, to seek evidence on whether incidents are occurring as a consequence — relevant incidents were identified, but it was concluded that there is insufficient evidence to link them directly to this cause; and,

- To identify any mitigating factors that could be used to reduce the threat — it was concluded that there are factors and that they should be enhanced to deal with this threat.

A wide range of people were consulted for the study, including airline management, management pilots, line pilots, safety regulators, an airframe manufacturer, a flight crew agency and pilot-representative organizations. The airlines consulted included national, regional and cargo carriers, charter airlines and new entrants in the low-cost sector. The countries represent a broad cross section of the whole of the JAA region and are not biased toward any one part of Europe.

All contributions to the study are confidential to the study team.

At the beginning of the study, the team reviewed commercial developments in the air transport industry and the published literature on possible human factors impacts. The following paragraphs provide a very short summary of the principal dimensions in which commercial developments potentially have a human factors impact.

Culture

The impacts of national, professional and organizational cultures were investigated.

A link between national culture and potential flight-deck behavior was established. National differences were identified in the dimensions of individualism/collectivism (achieving individual desires as opposed to group harmony), power distance (relationship between subordinates and superiors) and uncertainty avoidance (tolerance to risk and uncertainty). These differences may result in different attitudes to following standard operating procedures, (SOPs) to the use of automation and to relationships and management on the flight deck.

In terms of globalization, therefore, flight deck crews composed of individuals from different cultural backgrounds might experience conflict in the dimensions identified.

The professional culture of the flight crew is strong. However, the satisfaction level achieved is largely determined by the organizations that they work for and the conditions under which they work. In addition, the sense of professional pride can result in an unrealistic denial of vulnerability to factors such as fatigue.

A link between a negative organizational culture and negative attitudes and behavior was established which would not necessarily be mitigated by the high level of professionalism of flight crews.

Flight Deck Error

Researchers have recorded that errors were made on 68 percent of flights they observed, with an average of two errors per flight. Not all crew errors will lead to adverse consequences. This report identifies the types of errors and their causes.

Direct causes of failures are primarily due to a breakdown in crew-related interactions such as decision making, verbal communication, team organization and workload distribution, rather than a lack of technical proficiency. Team skills are therefore vital to a safe flight. The indirect or latent causes of failures can be due to inadequate training, supervision, resources or oversight, and faulty procedures and policies.

Commercial Developments

The report describes past, recent and possible future developments in the air transport industry that have been motivated by deregulation, liberalization and privatization.

[1]International Air Transport Association Aviation Information and Research (IATA-AIR) input was related to describing and analyzing commercial trends in the industry.

Alliances are formed partly to improve market access and partly to reduce cost. Cost-reduction mechanisms include:

- Management contracts, leading to the reduction in the management head count of members;
- Joint ventures in areas such as ground handling and aircraft maintenance, which allow alliance members to enjoy the benefits of bulk purchasing from key suppliers;
- Sharing of facilities such as training, maintenance and aircraft spares; and,
- Higher utilization of aircraft.

Cost efficiency does not automatically mean a loss of safety, particularly as all carriers are subject to the same regulation. However, the emergence of numerous new-entrant airlines, each of which requires specific regulatory effort, may stretch the resources of the regulators. While previous airline mergers generally took place between airlines within the same country, mergers that cross national boundaries are becoming increasingly common. This is likely to give rise to a more complex mix of cultural factors to be dealt with by the new companies. Further mixing is likely to result from an increase in the number of pilots from the former Soviet Bloc seeking improved employment conditions in Western airlines.

The growth of the low-cost carriers has generated new demand for air travel, a new market sector and new commercial pressures. Not all low-cost carriers have survived, and those that have face increased costs, not least because they now have to compete in the marketplace for the considerable number of pilots they require. Overall, they have contributed toward an increase in volatility in the employment of pilots.

The Effect of Commercial Developments

The consequences of recent developments have the potential to affect flight deck performance. Airline mergers and alliances will change the organizational culture in which individuals work, and this in turn may influence individual performance. They are likely, also, to increase the incidence of multinational flight crews. As more flexibility is required of airline staff, effects such as changes in morale and increased fatigue may be seen.

Of all the potential problems arising from multinational flight crews, differences in language are an obvious concern, and an increase in mixed-language operations is likely to have a negative effect on safety. Language is also a social issue affecting both duty and off-duty time. Social interaction may help to reduce fatigue, maintain alertness between the crew and contribute to teamwork during flights. A lack of conversational or colloquial ability in a common language may have an adverse effect on interpersonal relations during off-duty periods, which will reduce the likelihood of the crew building up a shared knowledge base and a shared set of assumptions about how the team should work together.

Other factors that are thought to cause difficulties are different religious beliefs, membership in different trade unions, different safety or crew resource management (CRM) philosophies and concerns over flying skills and technical knowledge.

Commercial Pressure

In some instances, there is strong pressure to increase flying hours up to the legal limits. Many airlines treat the legal limit as a performance target to be achieved if utilization of flight crew is to be maximized and operational costs reduced. In addition, some airlines allow very little, if any, reduction in flying hours for management pilots, some with critical responsibilities such as flight safety.

Unsympathetic rostering increases fatigue, upsets sleep patterns, reduces morale and has a detrimental effect on the personal life of crew. In some cases, this is combined with a reduced ratio of crew per aircraft, leading to a loss of flexibility and pressure to fly despite personal welfare.

Many pilots interviewed in a wide range of airlines observed that there is a tendency for business people with no flying experience to fill senior operational positions. Their concern was that these managers might not understand the implications of their decisions.

Training is an expensive activity, and there is a fear that training budgets might be reduced to achieve cost savings.

Captains are increasingly being required to make economic decisions, which is often counter to their traditional role of safely flying the aircraft. There is sometimes a dilemma between safety and economics: A captain has the responsibility for the safety of a flight but may be blamed by management if he or she is thought to have taken a commercially detrimental decision. If a pilot succumbs to commercial pressure and as a result is involved in an incident, he cannot, in law, defend his position by saying that the company pressured him to take the actions that he did. Some pilots find this dilemma difficult to resolve on a day-to-day basis.

Mitigating Factors

During the research, a number of factors that might mitigate the effects of globalization were identified. These factors have been classified into three categories: CRM training, SOPs and professional culture. Safety regulation is also available as a controlling measure. The report identifies to what extent each category is likely to produce effective mitigation and whether other control measures can be brought to bear.

CRM training is the approach used within aviation to tackle issues of teamwork among flight crew. Whereas benefits have been claimed by the industry from the use of CRM, there is little hard evidence that CRM has a measurable effect on safety. There are particular concerns that behavior in training sessions is not correlated with behavior under real circumstances. In addition, CRM cannot deal with other causes of error such as fatigue, poor interfaces, cockpit automation issues and problems related to SOPs quality and compliance.

The use of a standard, outsourced CRM "product" that has not been adapted for the particular culture in which it is applied may also reduce its effectiveness. There appears to be no process in place in the industry to spread to others either the experience gained in developing appropriate CRM training or best practices.

The scope of CRM is being extended in some airlines. While the previous emphasis was on team-building skills and communication, other aspects are now being introduced, such as monitoring skills and the management of time and workload. Some airlines run CRM training for mixed groups of cabin and flight deck crew, and in one case also maintenance personnel.

However, there is a serious danger that CRM will be seen as the solution to all human factors issues in commercial aviation. This is reflected in the fact that the human factors departments of airlines are often staffed by CRM specialists rather than by human factors professionals.

The emphasis on CRM may in some cases lead to a culture in which all errors are considered to arise (and be contained) in the cockpit environment. However, many factors that may adversely influence flight safety originate, as in all other industries, from management and organizational failures that occur deeper in the system and are outside the control of individual flight crewmembers. High levels of flight crew training, experience or personal capability will not automatically mitigate the adverse effects of such factors.

The CRM industry is responding to changes due to globalization, and no doubt the more recent versions of such training will improve its effectiveness.

SOPs form the basis for the operation of the aircraft, and it is thought by the whole industry that very few incidents would occur if SOPs were adhered to rigidly. However, it is clear that, in common with most safety-critical industries, absolute compliance with the letter of all written procedures is not regarded as feasible. The extent of the noncompliance is influenced by the prevailing safety culture in the company. In addition, pilots who have experience with more than one set of procedures may inadvertently revert to a previously familiar procedure, particularly under conditions of duress. In a multicultural environment, a flight crewmember's knowledge of an SOP may lead him to interpret ambiguous communication in terms of SOPs with which he is familiar.

Several airlines stressed the highly proceduralized nature of the flying task, claiming that procedures existed for every eventuality. However, crews working in highly proceduralized environments may encounter difficulties when faced with a situation that is not covered by a procedure. Furthermore, crews who normally use SOPs when working for an airline that strongly adheres to procedures may experience difficulties should they then operate in an airline which allows a greater degree of individual interpretation of SOPs.

Airline personnel display strong ownership toward their own SOPs. It would appear that new-entrant airlines tend to adopt manufacturers' SOPs with little, if any, modification, whereas established airlines will often have adapted these SOPs quite considerably. Problems may arise if there are differences in the degree of compliance with SOPs by flight crews from different airlines.

Safety regulators do not allow the operation of mixed SOPs within a single aircraft type under an aircraft operating certificate (AOC). Therefore, it would be difficult to mix crewmembers within an alliance unless all partners of the alliance were using the same SOPs.

The professional culture in aviation is strong and distinctive, and this is particularly apparent in the professional culture among pilots.

Flight crew were described as intelligent, although not necessarily formally educated, with a high degree of self-confidence. Strong self-discipline and self-motivation were said to be essential to cope with the working environment. Flight crew tend to be conservative in nature and are generally uncomfortable with change unless it is long-term and gradual.

A strong professional culture has both strengths and weaknesses. On the positive side, pilots take great pride in their profession and have a strong motivation to perform to the best of their ability. On the negative side, there may be an unrealistic denial of vulnerability to factors such as fatigue, stress or personal issues. Given the great responsibility of pilots, this may be a psychological defense mechanism to avoid performance anxiety.

There is a danger that globalization may degrade those aspects of professional culture that do act as a control mechanism. For example, the movement of crew between countries and companies may diminish the perception of a common identity.

Safety regulation in Europe is not yet harmonized. Differences among member states mean that European airlines are not overseen by a coherent legal entity, unlike the situation in the United States. Given that overall regulation is the remaining control mechanism to deal with conditions not controlled by the other three identified mitigating factors, this has to be a matter of concern to the JAA.

Some regulators are taking a less active role in enforcing standards by allowing airlines to take greater responsibility for their own oversight by means of self-audits. However, it is apparently becoming increasingly difficult for airlines to recruit suitably experienced people as nominated post-holders to carry out this important role.

Conclusions

The aviation industry in Europe is developing rapidly, and a number of human factors effects that can arise from these commercial developments have been identified. Some of these effects have the potential to impact negatively on flight safety, and this threat is likely to increase as the pace of commercial developments increases.

There is a belief in the industry that the control measures of CRM, SOPs and professional culture will mitigate these threats. This report suggests that these measures may not be fully effective in preventing or controlling the issues. An evaluation of the extent to which the three measures are thought to be effective is presented in Table 1.

1. Introduction

1.1 Background to the Study

The aim of this study is to consider the human factors implications for flight safety, if any, of recent commercial developments in the airline industry. In particular, the study focuses on recent tendencies for airlines to merge and form global alliances, and the growth in new entrants with different business models.

The functional reliability of aircraft has improved beyond all recognition over the course of the last century. This improvement, however, has drawn attention to the importance of the human element in determining system safety (David, 1997). It has been suggested that around 70 percent of aviation incidents and accidents are attributable to human error on the flight deck (Foushee, 1984).

Hawkins (1993) states that, despite the low level of accidents per passenger carried or hours flown, the current accident rate is still too high for the comfort of the public. The Final Report of the (U.S.) White House Commission on Aviation Safety and Security (1997) states that if the current accident rate is maintained, the expected growth in air transport means that by 2015 there will be one major accident somewhere in the world each day, a situation which would be totally untenable. Therefore, the accident rate must be reduced to ensure that the total number of accidents per annum is no greater, and hopefully lower, than current figures. As a part of this improvement process, human factors issues need to be addressed.

The global nature of aviation means that issues of communication and interaction between cultures are of particular interest, perhaps more so than in any other industry, apart from international shipping (see Chapter 8). The constant drive for cheaper and more flexible travel may lead airlines to look further afield for their flight crews and to increase their use of multicultural crews.

However, it would be a mistake to assume that issues arising from differences in national cultures are the only or even the most important flight safety issues arising from commercial developments in the airline industry. Mergers between airlines also involve a merger of the individual cultures and practices that have existed in the previously independent companies.

To remain competitive, airlines will also seek more efficient and cheaper ways of doing business, which is likely to result in greater flexibility being required of flight crew and may increase their sense of commercial pressure. The rapid expansion in low-cost carriers and the future movement of flight crew between these airlines and more conventional carriers with very different company cultures may also have human factors implications.

1.2 Scope of the Study

The scope of the study is countries in the JAA area. No organizations were consulted from outside this area, although,

Table 1
Tabulation of Human Factors Issues and Mitigating Factors

	Mitigation Effectiveness		
Human Factors Issue	Crew Resource Management	Standard Operating Procedures	Professional Culture
Teamwork/power gradient	Medium	Medium	Medium
Communication	Medium	Medium	Low
Fatigue	Low	Medium	Low
Morale and job satisfaction	None	Low	Low
Experience/competence	Medium	Medium	None
Situational awareness and mental models	Medium	Low	Medium

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research.

during the course of the study, some examples were provided of airlines based beyond the boundaries of the JAA that have experienced and resolved human factors issues that are relevant to this study. Some of these examples are referred to in this report.

The main thrust of the study has been in obtaining the views, concerns and experience of a variety of stakeholders in European aviation. Table 2 shows the sample of different types of organizations that were consulted by means of either a questionnaire or a face-to-face interview, and their geographic spread.

Table 2
Dimensions of Representation In the Study

Organization Type	Number Consulted	Countries Represented
Airline	21	14
Safety Regulator	4	4
Airframe Manufacturer	1	1
Flight Crew Agency	1	1
Pilots' Representative Association	1	Europe

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research.

The airlines consulted include national, regional and cargo carriers, charter airlines and new entrants in the low-cost sector. Airline managers, management pilots and line pilots were interviewed. The countries represent a broad cross section of the whole of the JAA region and are not biased towards any one part of Europe. To preserve confidentiality, neither the organizations nor the countries are named.

It should be noted that in this report, "flight crew" refers to all those members of the crew who work on the flight deck, including captains, first officers and flight engineers. It does not include cabin crew.

1.3 Methodology

To set the scene at the beginning of the study, two pieces of research were carried out:

- A review of significant historical and current developments in the structure of the air transport industry, together with a look at likely future developments; and,

- A review of published literature relating to the professional culture of pilots, the mixing of national and organizational cultures, the management of culture on the flight deck and the causes of flight deck errors.

Using the output from this research, two questionnaires were developed to elicit relevant information from airlines. The first was a postal questionnaire that could be sent to selected airlines to obtain some preliminary information. The second was a list of follow-up questions that could be used by members of the team in a face-to-face, structured interview. The interview questionnaire provided a framework for the meeting but was used flexibly to ensure that all matters relevant to the study could be pursued as they arose. The postal questionnaire appears in Appendix A, and the interview questionnaire in Appendix B.

These two questionnaires were particularly suitable for interviewing management and management pilots in airlines, and a less structured approach was taken with line pilots and safety regulators. In particular, questions that were asked at meetings with regulators were based on issues that had already emerged from the airline interviews.

Much of the content of the main part of this report is derived from an analysis of the information collected at meetings and from questionnaires.

The human factors issues identified are not only being experienced in the aviation industry but also occur in other safety-critical industries where globalization is taking place. The study team has used its prior experience of the marine industry to compare it with aviation to determine if there are lessons that can be learned.

1.4 Layout of Report

Chapter 2 puts the remainder of this report into context by reviewing previous work that has been carried out on cultural factors in aviation. It discusses three types of culture — professional, organizational and national — and explores how flight crew attitudes are influenced by these cultures. It also considers how cultural issues might be managed on the flight deck.

Chapter 3 reviews different types and causes of human error on the flight deck. It provides a framework model of flight deck error based on the acquisition of information, the sharing of this information between flight crew and its use for decision making. A summary table is provided to illustrate the type of error that can occur during each stage of the framework and relates each error type to possible cultural causes.

Chapter 4 highlights some of the significant historic and current structural changes in the air transport industry of particular relevance to this study. It considers the effects of deregulation, its impact on different types of carriers, the rapid growth in global airline alliances and the emergence of low-cost carriers.

Chapters 5 to 7 are based on the results of the interviews.

Chapter 5 describes the primary results of the survey in terms of the effects arising from the commercial developments described in Chapter 4 that have human factors implications which have a bearing on flight deck errors. Three separate effects are identified:

- Multicultural flight crews;
- The merging of company cultures; and,
- Commercial pressure.

For each effect, the human factors issues and their potential consequences for flight safety are identified.

Chapter 6 considers the factors that could mitigate the adverse effects of the potential human factors problem areas that have been identified. These mitigating factors are:

- CRM;
- SOPs; and,
- Professional culture.

A number of issues are raised with respect to each mitigating factor, and their potential consequences are identified. The chapter concludes with a discussion of the role of safety regulation.

Chapter 7 discusses several recurring human factors issues that have been identified in previous chapters as influencing the likelihood of flight deck errors. These issues are:

- Teamwork;
- Communication;
- Fatigue;
- Morale and job satisfaction;
- Experience and competence; and,
- Situational awareness.

Safety auditing and internal oversight are also considered.

These issues are evaluated in terms of the extent to which their negative effects will be reduced by the mitigating factors of CRM, SOPs and professional culture. A summary table assesses their relative effectiveness in terms of their impact on each of the human factors issues.

Chapter 8 summarizes the similarities and differences between aviation and the marine industry, and considers whether there are any areas where aviation might learn from shipping. A more detailed discussion is provided in Appendix C.

Chapter 9 considers different approaches that are taken to human factors in other safety-critical industries and draws together some lessons that could be learned by the aviation industry.

Chapter 10 summarizes the overall findings and conclusions of the previous chapters, and Chapter 11 contains some recommendations.

2. Culture

Merritt and Helmreich (1995) define culture as “the values, beliefs and behaviors that we share with others that help us define a group, especially in relation to other groups.” Individuals can be members of any number of groups, defined by a wide range of values, beliefs and behaviors. For example, a 40-year-old female pilot who works for a regional airline and lives in Madrid, Spain, is a member of several different cultures. These different cultures — defined by age, gender, organization and location — will all affect a person’s conduct at work.

Helmreich and Wilhelm (1997) identify three main cultural groups that should concern researchers in this field: professional, organizational and national cultures.

2.1 Professional Culture

Pilots, like many others in professions with a strong professional culture, such as medicine, place great value on their work. Helmreich and Merritt (1998) report that pilots describe a greater liking for their job than probably any other profession. They go on to stress, however, that this liking for the job does not mean they are completely satisfied with their working conditions. The organizations that they work for and the conditions under which they work largely determine this satisfaction level.

There are undoubted benefits in individuals taking pride in the work that they do and striving to live up to the reputation that a profession has developed. However, this sense of professional pride can result in an unrealistic denial of vulnerability to factors such as fatigue (see Section 6.3.2).

2.2 Organizational Culture

The majority of the research examining the influence of culture on aviation has focused on international cultural differences — in particular, how they may pose a threat to the safety of aircraft staffed by multicultural crews. However, Merritt and Ratwatte (1997) query whether there is such a thing as a monocultural crew. They suggest that airline mergers and the movement of pilots between airlines always result in intra-crew cultural differences. However, these cultural concerns are not national but organizational. Pilots may not be fully aware of the differences in SOPs between their new and previous companies, or, if they are aware, they may revert to the SOPs used in a previous company when distracted or under stress (referred to as strong stereotype takeover) or due to personal preference. This is just one example of an organizational cultural issue.

2.2.1 The Effect of Organizational Culture on Safety

There is an extensive literature that reports a link between the strength of organizational culture and organizational performance. Helmreich and Merritt (1998) review the area and conclude that the level of coherence and stability of views held within an organization define a strong unified culture. They suggest that it does not particularly matter what these views are, only that they are held by the whole organization. As an example, they compare British Airways and Virgin Atlantic, two successful airlines with markedly different organizational cultures.

In terms of this study, however, the important issue is whether organizational factors can affect safety. Helmreich and Merritt (1998) compared two American airlines with this issue in mind. In the first airline, 87 percent of pilots agreed that morale was high, compared with only 3 percent in the second. The second airline's pilots were cynical about the motives of management, and only 12 percent agreed with the statement "management never compromises safety for profit." Perhaps the most important response, however, was to the statement "crews I fly with adhere to standard operating procedures" — 93 percent concurred with this statement in the first airline, compared with only 73 percent in the second. This latter finding indicates an important link between attitudes and behavior, and implies that the high level of professionalism of pilots may not make them immune from the influence of a negative organizational culture — in this case reflected by the degree of compliance with SOPs.

The European aviation industry has undergone considerable organizational change over the last 15 years; liberalization of airlines has followed changes in the regulatory climate, making it easier for new-entrant carriers to commence operations. The increased competition has resulted in continuing downward pressure on revenue yields and consequent business reorganization. A report commissioned by the U.K. Health and Safety Executive into business re-engineering and its effects upon health and safety management (HSE, 1996), found very little firm evidence to support the hypothesis that business re-engineering negatively impacts occupational health and safety. They were, however, able to cite examples where reorganization had contributed to major systems accidents. Equally, however, occupational accident statistics had generally improved during the period examined, despite individual setbacks. They did find that reorganization could be a major source of stress in individuals and consequently could negatively influence job satisfaction. They concluded that reorganization is a stressful process, that its effect upon safety can be both positive and negative (depending on the nature of the reorganization and the sensitivity with which it is conducted). However, it is difficult to be more specific due to the lack of research evidence in this field.

Many people would consider safety culture to be an aspect of organizational culture. Helmreich and Wilhelm (1997), however, argue that the extremely safety-critical nature of aviation means that it warrants individual consideration. They suggest that the tradeoffs that an organization is willing to make between increased productivity and safety concerns is the principal measure by which employees gauge the extent of that organization's commitment to safety.

2.3 National Culture

2.3.1 Hofstede's Cultural Dimensions

One of the most influential individuals in the field of cultural variation is the Dutch engineer and social scientist Geert Hofstede (Merritt, 1997). Hofstede, using questionnaire data from 80,000 IBM employees in 66 countries across seven occupations, established four dimensions of national culture (Hofstede, 1980, 1991):

- Individualism/collectivism;
- Power distance;
- Uncertainty avoidance; and,
- Masculinity/femininity.

Merritt (1997) attempted to replicate Hofstede's survey using commercial pilots. She found that all of Hofstede's dimensions could be found within the pilot sample, with the exception of masculinity/femininity. This dimension is linked with achievement and the value placed upon it. Merritt suggested that this dimension was absent because aviation is already a financially rewarding profession and, therefore, has little concern for masculine traits such as "the opportunity for high earnings."

The other dimensions are discussed below:

Individualism/collectivism

This relates to the extent to which people are supposed to take care of themselves and be emotionally independent from others. A highly individual culture is one that is characterized by egalitarian relationships, social interaction is conceptualized in terms of costs, rewards and outcomes and self-sufficiency are valued. A collective culture values loyalty to and harmony within the group, and conceptualizes resources, responsibilities and outcomes as shared. There is a powerful motivation in trying not to disgrace the extended group, as mistakes and failure are blamed upon the whole group. Merritt found evidence for the existence of this dimension in pilots but found more individualism and less difference between countries than would be expected in the general population. She suggests that individualists self-selecting into aviation may cause this difference. This was the only dimension to show higher, more convergent scores than those reported in Hofstede's study and may illustrate why pilots are perceived to have similar values worldwide.

Power Distance

This is the extent to which a culture accepts that power is distributed unequally among the members of a group and the extent to which the decisions of power holders are challenged. Low power distance implies limited dependence of a subordinate on a superior and a preference for consultation. Subordinates are comfortable in approaching their superiors and challenging them when necessary. In contrast, high power distance implies considerable dependence of subordinates on their superiors, with subordinates unlikely to approach their superiors and superiors unlikely to consult their subordinates. These patterns of dependence pervade all human interaction.

Uncertainty Avoidance

This is the extent to which members of a culture feel uncomfortable with risk and uncertainty. A culture with high uncertainty avoidance will often attempt to avoid uncertainty by establishing more structure within an environment by means of rules and procedures. Cultures that have low uncertainty avoidance are likely to accept and encourage dissenting views and try new experiences. Interestingly, Merritt found that cultures that believe strongly in the importance of rules and procedures are also strong advocates of automation.

Hofstede's classification provides a useful framework for examining culture in aviation. This area is one that has been addressed by several researchers, using Hofstede's dimensions (Anca et al., 1996; Merritt, 1993; Merritt and Helmreich, 1995). As an example, they suggest that a typical Asian flight crew (which will usually be collective and have a high power distance) will place great emphasis on maintaining group harmony. Conversation will be characteristically discreet and elaborate, and seek to avoid conflict; the focus will be on the "social process." In contrast, a typical Western flight crew, (individual and low power distance), will place emphasis upon "social product." Here, therefore, conversation will be succinct, personal and instrumental.

If these dimensions can be used to describe the cultural aspects of an individual's personality, then there may be implications for the selection, training and mixing of flight crews. This is particularly the case if it could be shown that certain scores on these dimensions are predictive of friction between individuals.

However, care must be taken in using the results of these surveys. For example, by using nationality as the unit of analysis, there is a danger of reducing complex social interactions to simple stereotypes.

2.3.2 The Influence of National Culture on Flight Crew Attitudes

Since Hofstede's classifications were derived from studies using IBM employees in the late 1960s and early 1970s, they may not necessarily apply to flight crew. As Merritt (1997) states, with regard to pilots:

> These pilots are typically at the technological and modernized forefront of their countries' work force — many are trained or travel overseas as part of their jobs — and it seems likely that pilots working in such a regulated high-technology environment might transcend national influences in favor of a universal standard of behavior.

Merritt and Ratwatte (1997) even question whether a multicultural flight crew is a hazard. They suggest that it may reduce complacency, forcing pilots to adhere to the best CRM practices, which may not be the case in a monocultural environment. They also postulate that communication needs to be precise and unambiguous to ensure understanding, and that after a while this precision becomes the norm rather than the exception, thus improving system safety.

To ascertain exactly where flight crew attitudes converge and diverge with respect to nationality, Helmreich et al. (1996) used a survey tool, the "Flight Management Attitudes Questionnaire" (FMAQ). The questionnaire was designed to examine attitudes and values of pilots. They collected data from more than 13,000 pilots in 25 airlines in 16 countries. They found considerable consistency of attitudes in some areas and great variability in others. The attitudes that were universally endorsed by pilots were:

- Good communication and crew coordination are as important as technical proficiency for the safety of flight;
- The captain's responsibilities include coordination between cockpit and crews;
- The preflight briefing is important for safety and effective crew management;
- The pilot flying the aircraft should verbalize plans … and be sure the information is understood and acknowledged; and,
- Pilots should monitor each other for signs of stress and fatigue.

These findings indicate that all pilots, worldwide, agree about the importance of safety in aviation. However, the results in Table 3 demonstrate that there are areas, like command interactions and attitudes to rules and restrictions, that differ significantly across nations. The authors do not give the distribution of these scores.

Differing Attitudes to Flight Crew Interactions

Command interactions on the flight deck are vital to flight safety. The next example illustrates an extreme case of how serious differences in attitude can affect flight safety:

> On 13 January 1977, a Japan Airlines DC-8 crashed shortly after take off from Anchorage International Airport, Alaska, U.S. The aircraft was flown by a 53-year-old American pilot with 23,000 hours flying experience; his Japanese copilot was a 31-year-old with 1,600 hours experience. The captain was found to be more than three times over the legal alcohol limit for driving a car.

It is difficult to know exactly what happened on this flight. However, it seems likely that the crash was a partial consequence of the copilot's perception of the command relationships on the flight deck. Stereotypically, an American culture would be low power distance and individualistic, whereas Japan has a culture that has high power distance and is collective in nature. In this particular situation, the captain was far senior to the copilot, who would have been conscious of his role within the cockpit. The copilot may well have questioned the captain, but it would have been in a discreet manner, mindful of preserving working relationships when a more assertive challenge was required, given the intoxicated state of the captain.

Differing Attitudes to SOPs

Difference in attitudes to SOPs can have an effect on aviation safety. The following is an extreme example of the potential consequences of these differences:

> An investigation into the 1987 Detroit, Michigan, U.S., MD-80 accident revealed that the taxi checklist had not been completed. The aircraft took off without flaps or slats, and 156 passengers and crew were killed. The airline had a history of a lack of checklist discipline (Hawkins, 1993).

Differing Attitudes to Automation

Sherman and Helmreich (1995), again using the FMAQ, report that pilot attitudes to automation are affected by three main factors:

- National culture;
- Time spent flying automated aircraft; and,
- Seniority of crewmembers.

National culture was the most important of these, responsible for considerably more diversity of response in the acceptability of automation than any other tested factor. In general, cultures that scored highly in terms of power distance tended to be more accepting of automation. The authors speculate that this may be due to an acceptance of automation as a highly competent authority, endorsed by the company.

In addition, pilots that flew automated aircraft exhibited a slightly more positive attitude toward automation than others, and there were some differences between the attitudes of senior pilots and less experienced copilots. Junior officers tended to endorse pilot discretion and scored more highly on automation concern.

The authors speculate that members of both low and high power distance cultures may characterize automation as an "electronic crewmember." Low power distance cultures see authority without question as a bad thing and are consequently suspicious of automation. Conversely, high power distance cultures see automation as being endorsed by their organization and hence something to be trusted.

Table 3
Culturally Variable Pilot Attitudes — Across 16 Countries

	Range of National Responses Agreeing	
Statement	**Lowest National Response (percent)**	**Highest National Response (percent)**
Crewmembers should not question the decisions or actions of the captain except where they threaten the safety of the flight.	15	93
If I perceive a problem with the flight, I will speak up, regardless of who might be affected.	36	98
Written procedures are required for all in-flight situations.	15	84
The organization's rules should not be broken — even when the employee thinks it is in the company's best interests.	22	76

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research, from Helmreich et al. (1996)

2.4 Managing Cultural Issues on the Flight Deck

CRM training is the approach that is used within aviation to tackle issues of teamwork among all those individuals involved in the execution of the flight. CRM has existed in many guises, its main aim being to tackle human error through training individuals in effective teamwork. One criticism of CRM, based on the experience of airlines employing multicultural flight crew, is that it does not travel well between different cultures. A representative of the International Civil Aviation Organization (ICAO) has observed, "CRM is based on social psychology. This school of thought is scarcely known outside North America; yet CRM has been accepted as gospel by the international aviation community without cultural adaptation" (Maurino, 1993, cited in Kaplan, 1995).

Helmreich et al. (1996) suggest one possible reason for this, using their exhaustive studies of international cultural differences. Namely, that no one culture is exactly congruent with the underlying principles of CRM. One can illustrate this by taking one of Hofstede's dimensions, uncertainty avoidance (UA). High UA scores suggest that an individual will be meticulous in his or her adherence to SOPs, a good thing. However, a second individual who comes from a low UA culture will feel less threatened by novel situations and be more able to make effective decisions than the first individual. Both of these attributes are desirable, depending upon the situation, but it is difficult for one individual to possess both.

A further complication occurs when one considers the interaction between Hofstede's dimensions within an individual. For example, a low power distance score (as characterized by a Western crew) would be considered a desirable attribute in CRM, as such relationships facilitate open and frank idea sharing, an important aspect of good crew decision making (Orasanu et al., 1997). However, this is likely to be tempered in a Western crew by high-individualism/low-collectivism scores. Information sharing, and the construction of shared plans, will be easier in a culture with low-individualism/high-collectivism scores.

In terms of globalization, therefore, flight deck crews composed of individuals from different cultural backgrounds might experience conflict in these dimensions. While it is unlikely that any one nation has the optimum cultural values for good CRM, at least monocultural flight crews are made up of individuals pulling in the same direction. As an example, a flight deck consisting of individuals from a high power distance culture will be accepting of the high power distance between captain and copilot, even though CRM principles suggest this is a bad thing. When a low power distance copilot is introduced into this environment, the first time the copilot challenges a decision or even uses the first name of the captain, a conflict situation could arise.

There have been attempts to design CRM training programs that tackle these issues. Orasanu et al. (1997, citing Merritt, 1995), describe a CRM program tailored to a high power distance/collectivist culture. To overcome the possible communication difficulties that may occur in this sort of culture, the crew is represented as a family business. In the role-playing process, the captain is the head of the business and the copilot is his elder son who will one day inherit everything. The premise is that the captain will be more accepting of a questioning copilot if he thinks of him in these terms. In addition, the copilot is requested to think of the pilot as a close friend, in an attempt to stimulate a questioning attitude.

Helmreich et al. (1996) propose a new generation of CRM that has as its clearly defined objective the "management of human error." They suggest that this focus has several benefits. First, it moves away from a blame culture and recognizes that human error is something that is likely to occur. This, in turn, fosters an environment that enables open reporting systems to be put in place and active efforts made to reduce error-producing conditions. This type of model of CRM facilitates the consideration of cultural issues.

This model allows captains from a collectivist culture to accept suggestions from junior copilots, as they are able to appreciate that the suggestion is not a threat to authority but an attempt to preserve the integrity of the organization. Individualists can feel more at ease relying upon the team unit to manage safety, as the organization promotes the view that individual errors are possible and not necessarily blameworthy.

2.5 Conclusions

The discussion of culture suggests that the consequences of recent developments in the airline industry have the potential to affect flight deck performance. Airline mergers and alliances will change the organizational culture in which individuals work, and this in turn may influence individual performance. As more flexibility is required of airline staff, effects such as changes in morale and increased fatigue may be seen. Finally, increased communications errors could arise if globalization and the introduction of the common European flight crew license result in the greater use of multinational flight crews, since this could lead to conflicting expectations regarding the power distance relationship held by different members of the flight crew.

All these potential issues have been tested against the experience and opinion of flight crew, airline management and regulators. The results are described in Chapter 5.

3. Errors Arising From the Performance of Team Tasks

3.1 Introduction

Researchers at the University of Texas Human Factors Research Project have reported that errors were made on 68 percent of a large number of flights that they observed, with an average of two errors per flight. Robert L. Helmreich, who led the project, defines flight crew error as:

> Action or inaction that leads to deviation from organizational expectations or crew intentions.

However, not all crew errors will lead to adverse consequences. Errors are normally recovered by the person who made the error, another flight crewmember or ground support personnel such as an air traffic controller. Helmreich (1998) defines error management as:

> The process of correcting an error before it becomes consequential to safety.

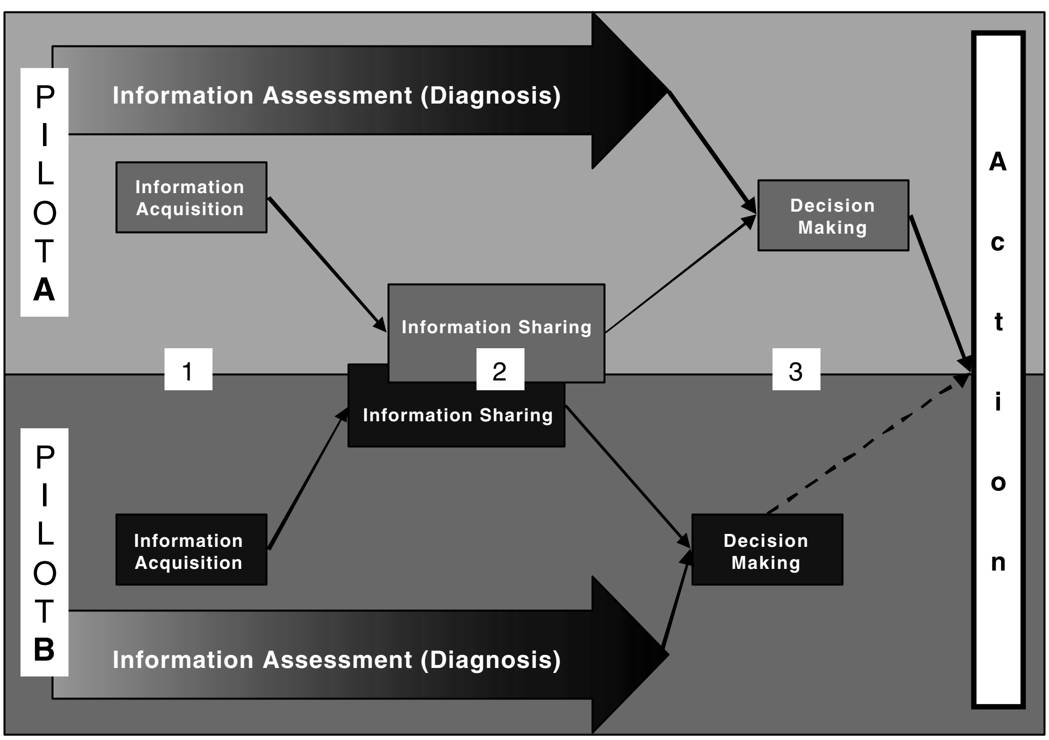
The first section in this chapter provides a framework model of flight deck error based upon the acquisition of information, the sharing of this information by the flight crew and its use for group decision making. In subsequent sections, each of these stages is described in more detail and the factors that affect the likelihood of error at each stage are evaluated. Finally, the results are summarized in terms of the factors that affect each stage.

To gain an insight into the types of flight deck errors that teams can make, we will use a simplified model of the stages in normal performance of team tasks. These stages are loosely based on Rasmussen's (1982) model of the information processes underlying decision making:

- Information acquisition — detection and collection of significant information;
- Information sharing — imparting information to enable a shared understanding of a situation to be established;
- Decision making — interpreting the meaning of the information and developing a plan or strategy for action. This will often require SOPs to be followed, either by the use of checklists or procedures memorized from training; and,
- Action — executing the chosen course of action.

Both pilots on the flight deck will engage in each of these processes to a greater or lesser extent while performing a team task. Their roles will depend on which of them has been designated, at a particular stage of a flight, as "pilot flying" (PF) and as "pilot not flying" (PNF). For example, the PNF may *monitor* certain equipment and pass on any information to the PF, who will make a *decision*, which the PNF may be asked to execute. The interactions of the two pilots at the stages of their independent information-processing systems are illustrated in Figure 1.

Characterization of Flight Deck Interaction



Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

Figure 1

The stages of information acquisition, information sharing and decision making (including information assessment) and the factors that are known to affect error causation will be discussed in the following sections. Some factors that affect errors on the flight deck may not be altered by the changes associated with globalization and mergers. For example, errors that are influenced by the design of the cockpit human-machine interfaces will not be expected to change, as long as the pilots have received appropriate conversion training if the results of the commercial developments involve an aircraft change. The factors that are expected to be susceptible to changes due to globalization will be highlighted in more detail. The action stage in the model has not been considered in this report because most flight deck errors have been shown to be due to crew-related phenomena, not to technical proficiency, and this is unlikely to be affected by globalization.

3.2 Information Acquisition

Complete and accurate information is critical for correct task performance in any environment. The information that flight crews acquire to aid them in performing their tasks comes from a number of sources — for example, flight deck displays, external environment, SOPs, air traffic control (ATC) and cabin crew. The latter two sources of information may also be considered under the information-sharing section of the model, as they involve interaction, but are outside the scope of this study.

3.2.1 Information From Cockpit Displays

Information extraction from flight deck equipment is a skill that is developed through training and experience. This technical proficiency is largely beyond the scope of this study. However, errors arising from the automated component of flight deck equipment will be considered due to the link between attitudes to automation and national culture described in previous sections. A recent study has identified two classes of error that commonly emerge on automated flight decks (Mosier et al., 1998):

- Omission errors — failures to respond to system irregularities; and,

- Commission errors — incorrectly following an automated directive without verifying it against other information or in spite of contraindications from other sources of information.

It is hypothesized that these errors are due to automation bias — the use of automation as a replacement for actively seeking information. A study by Klinect et al. (1999) found that 65 percent of automation errors were associated with failures to cross-verify settings rather than incorrect switch settings or execution modes (21 percent). Laboratory attempts to reduce automation bias through training have not been successful (Mosier et al., 1998). This bias may be connected to the finding that acceptance and perception of automation vary greatly across cultures. It is, however, difficult to anticipate how the interaction between two different attitudes to automation might affect performance at the information-acquisition stage.

The acquisition of information from cockpit technology may be hampered by the number of aircraft types that a pilot may be required to fly. Wise et al. (1993) cite a report stating that corporate pilots typically maintain the capability to fly at least two different aircraft types. They suggest that the potential for performance degradation in these situations is high, due to different software systems used to operate different aircraft. This might become an issue if globalization was to result in a requirement for pilots to be qualified to fly two or more aircraft types. However, no evidence has been found in this study to indicate that this might be an outcome of globalization, and current practice is generally for pilots to operate aircraft that have identical or very similar flight decks — for example, the Boeing 757/767 and many Airbus types.

A crucial factor that can have an impact on gathering information from flight deck equipment is the level of pilot vigilance. The nature of the aviation industry often means nonstandard and altered work schedules and disturbances in circadian rhythms. Fatigue is widely recognized as an important factor leading to decreases in vigilance and regularly featured in incident reports (Rosekind, 1994). Considerable research has been conducted in this area. Pilot fatigue levels may well be influenced by organizational changes. If globalization means that pilots are required to be more flexible, this could result in a greater number of fatigued pilots flying, thereby affecting vigilance levels and quality of equipment monitoring.

3.2.2 Information From SOPs

Checklists and other operating procedures act as a guide to ensure that relevant information is checked and verified. The intent is to provide guidance to pilots and ensure a safe, efficient and predictable (standardized) means of carrying out tasks.

Different airlines normally have different SOPs that reflect the manner in which operational management intends to have various tasks carried out. When the way of performing tasks is quite different between airlines, then the quality of the readjustment training to a new company's way of doing things is obviously important. Firstly, differences in the structure and layout of different company procedures can lead to problems in acquiring information.

Differences in procedures are especially important if there are differences in roles and responsibilities for gathering information. Some responsibilities on the flight deck remain fixed with team member status, but others change with role-assignment changes. The assignment of PF and PNF normally changes on every leg of a journey or on a day-by-day basis.

Team member assignment affects the degree of attention that different flight crewmembers pay to different information sources and the assignment of responsibility to make decisions and monitor them (Bowers et al., 1995). Critical information may not be gathered due to an assumption by one crewmember that it is the responsibility of the other to check and verify. However, this practice has been common for many years, and the roles of both PF and PNF are taught very carefully.

3.3 Information Sharing

3.3.1 Purpose of Sharing Information

The objective of the information-sharing stage is to enable a shared understanding — or mental model — of a situation to be established. The concept of shared mental models has been proposed as a means of explaining coordinated performance in teams (Stout et al., 1997). Through teamwork, crews develop shared understanding of the nature of problems, solution strategies, cue significance and participants' roles and responsibilities. Shared mental models assure that all participants are solving the same problem and create a context in which all can contribute efficiently (Orasanu, 1991).

This stage is central to any team activity. Communication is the primary means by which individuals develop and coordinate activities in order to achieve goals. Therefore, communication can be seen as the mediator of team processes (Helmreich and Foushee, 1989). Over 70 percent of reports made to the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) are related to communication problems (Billings and Cheaney, 1981; Connell, 1995). Language on the flight deck is used to issue commands, state intentions, acknowledge information, ask questions and convey information. Kanki (1996) has divided communication acts that occur on the flight deck into:

- Procedural speech — adherence to regulations, policies and protocol. Routine communication required to fly the aircraft which is highly formulaic and shows little deviation from crew to crew within in an airline; and,

- Task-related speech — first, resource management during routine flight conditions (e.g., managing time and coordinating actions on the flight deck and with ATC); second, metacognitive problem-solving talk during abnormal conditions (e.g., specifying what the problem is and how to go about solving it).

Previous NASA research (Foushee and Manos, 1981) has found that on flight decks where information sharing is good (e.g., high numbers of crew observations about flight status, statements of intent to perform actions, acknowledgements of other's messages and verbal agreements), fewer crew errors occurred. During low workload periods, captains and copilots in effective teams tend to engage in more planning behaviors articulating their plans and strategies. In situations of high workload, copilots increase the amount of information provided in advance, thus reducing the captain's need to request information (Orasanu, 1990).

Crews experiencing high workload were found to share similar communication patterns regardless of whether or not they had flown together before (Kanki et al., 1991). It is suggested that a standardized communication pattern increases the extent to which flight crew can predict each other's actions.

The next sections will examine the following two types of communication failure:

- Failure to share information — the sender does not realize the need for communication or does not actively participate in communication; and,

- Misinterpretation of information — the sender's message is not intelligible for the receiver or the receiver decodes a message accurately but misinterpret the meaning. This causes an illusory understanding and reduces the probability of recovery via a re-send request.

3.3.2 Failure to Share Information

Social Impediments

Unfortunately, this ideal is not always attained, and failures to notice or react can cause "secondary errors," such as the following:

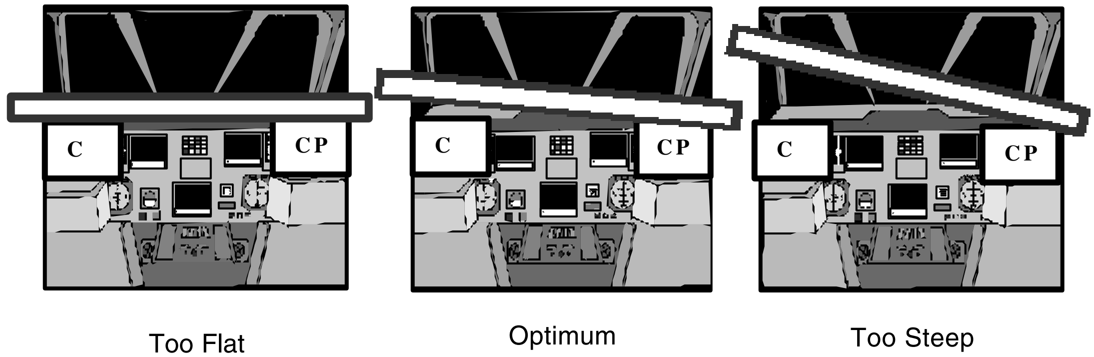
- Monitoring failures — failure to detect the primary error or problem; and,

- Challenging failures — failure to act effectively to mitigate the error (sometimes referred to as assertiveness failures).

Reviews of accidents and incidents indicate that the captain usually commits the primary error and the first officer usually fails to catch or correct it (NTSB, 1994; Jentsch et al., 1997). In Klinect et al.'s (1999) naturalistic study, 53 percent of responses to primary errors were failures to respond. These errors are significant as they often represent the last opportunity to break the chain of events that lead to an accident. Failure to challenge a questionable decision or action taken by another crewmember may occur due to choice or pressure not to say anything.

On the flight deck, the captain has the responsibility for the flight and is effectively the senior member or leader of the team. The relationship or command structure between the captain and copilot is referred to as the "trans-cockpit authority gradient" (Edwards, 1975). Figure 2 (page 17) illustrates the different gradient relationships that may occur between a captain and copilot.

The Trans-cockpit Authority Gradient



C = Captain CP = Copilot

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

Figure 2

Essentially, the angle of the slope describes the power relationship between the two individuals. A too-flat cockpit gradient implies that the captain is adopting a weak leadership role with a consequent lack of authority. A too-steep gradient may result in the copilot feeling unable to question any of the captain's actions or decisions.

Research has found that the degree of challenge to the status or integrity of the challenged person will affect the likelihood of individuals making suggestions (Brown and Levinson, 1987; Jentsch et al., 1997). For example, if the primary error has originated from the captain's actions, or inaction, then calling attention to it involves a higher degree of face threat than if the primary error has occurred due to a problem outside the captain's control (e.g., weather or traffic). The other factor that affects this cross monitoring is the trans-cockpit authority gradient or the power relationship of team members on the flight deck. The effectiveness of the cross monitoring by the crew team member depends on the response that the query generates.

National culture also has an impact on leadership and command structures. It is known that different cultures have different attitudes to power distance that will affect the cockpit authority gradient. For example, a copilot who comes from a high power distance culture may not provide the level of information that a captain from a low power distance culture would expect. In terms of safety, the influence of these expectation mismatches may range from a frosty cockpit atmosphere to poor teamwork and poor information sharing in an emergency. This issue is discussed in more detail in the section on culture in Chapter 2.

Knowledge Impediments

It was mentioned in subsection 3.2.2 that different companies might specify different roles and responsibilities for gathering information. SOPs can be used to dictate what should be said, when and by whom on a flight deck (Orasanu et al., 1997). If globalization means companies merge procedures, training issues will arise. A pilot not familiar with a new company and its SOPs, for example, may not verbalize certain important information that he or she possesses. This will cause problems if the other flight crewmembers assume non-verbalization means that the relevant information is not available or is not an issue.

3.3.3 Misinterpretations

Language Usage

In this section, communication is discussed in terms of language usage. English is the standard language of aviation, and language is an obvious area in which globalization and multiculturalism may affect the flight deck.

The quality of information transfer is critical to a successful cockpit environment (Orasanu et al., 1997). Much research has been conducted on the problems involving flight deck and ATC communication. The information-sharing process that occurs in this interaction is similar in many ways to the sharing of information between the two pilots on the flight deck. In addition, a great deal of the research with ATC involves interactions between participants of different national cultures. It is possible, therefore, to learn a lot about the possible impact of mixed national crews from research in this area.

In a recent study by Orasanu et al. (1997), investigators took a random sample of 100 reports made to ASRS and searched for the terms "culture" and "communication." They also examined 60 reports that dealt with communication problems from the IATA database. Table 4 (page 18) shows the results of this study.

Table 4
Comparison of Language Problems in U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) and International Air Transport Association (IATA) Reports

Language Category	ASRS (U.S.)	IATA (International)
Language/accent	47	5
Partial readback	24	8
Dual language switching	23	2
Unfamiliar terminology	17	4
Speech acts	12	0
False assumptions	9	23
Homophony	7	1
Unclear hand-off	5	3
Repetition across languages	4	2
Uncertain addressee	3	13
Lexical interference	1	0
Lexical confusion	0	4
Unexplained	0	3

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

In the ASRS analysis, three categories of error were affected by national language differences (language accent, dual-language switching and repetition across languages). The IATA database findings, however, had few reports that dealt directly with national language problems, and the most common category of problems involved false assumptions. Orasanu speculated that the unexpected low level of national language difference problems in the IATA database reflects a greater attention to clear communication or a high level of adaptation to linguistic diversity on the part of non-U.S. pilots who operate daily in multicultural airspace.

The use of "unfamiliar terminology" highlights another common communication problem. In aviation, numerous standard words and phrases have been developed, and their consistent use is essential for the limitation of misinterpretation. Both pilots and controllers, however, have been found to use nonstandard phraseology in procedural speech. U.S. pilots show lower levels of adherence to standard communication protocols (Connell, 1996). Moreover, in emergencies, flight crews often revert to everyday speech patterns rather than the highly formulaic communication of clearances and procedures (Orasanu, 1994; Morrow and Rodvold, 1993). These speech patterns differ enormously across cultures and, hence, promote misunderstanding.

In terms of national culture, it is anticipated that globalization may influence flight deck communication. This will be particularly the case where crews are of mixed culture and there are large differences in the languages, accents and verbal styles of the individuals involved. An example is two flight crewmembers communicating in a language that is the mother tongue of neither (as a result of the use of English as the international language of aviation). While this may cause difficulties in interpretation, one might also argue that awareness of this potential problem will cause the crew to take particular care to avoid misinterpretation by using precise, standardized communication (by comparison with a familiar crew that becomes sloppy with their standardized language use and unwary of ambiguous communication).

Higher-level Meaning

Even if the initial message transfer is adequate, successful information sharing is still not guaranteed. The message may not have adequately conveyed the sender's intent. These types of misinterpretation lead to an "illusory understanding" (Orasanu et al., 1997). Here, the sender and receiver both believe that they have communicated successfully, but in fact the message that is received, interpreted and acted upon is not the message intended.

This miscommunication can result from a range of factors. For example, there are only a few basic forms that a message can take: a statement, an instruction or a question. By using a certain construction, a sender expects the receiver to recognize the purpose of the communication and to act accordingly. If a sender asks a question, he expects the receiver to respond with an answer. If the receiver fails to appreciate this intention, he is judged as having misunderstood the message, even though he may have accurately decoded everything else about the utterance. This type of communication problem is probably more likely where the speaker and addressee do not share the same culture or language.

Orasanu's (1997) study of the IATA database showed a high level of false assumptions or illusory understanding. This may simply be an artifact of the two different cultures of controllers and pilots. However, it is possible that this reflects differences in national culture and the interpretation of information.

Any receiver in a communication act will interpret a message using previous experience, learning and expectation. This creates the danger of false hypothesis formation (Hawkins, 1993). The previous experience and learning of pilots from different cultures and organizations will vary along a continuum from very similar to very diverse. The further away two pilots are on this scale, the greater the likelihood that the two will form different expectations and assumptions leading to misinterpretation. This situation might be expected to become more common with the increase of mixed-company and mixed-national flight crews.

3.3.4 Social Communication

The third type of speech act that occurs on the flight deck is non-task-related speech. This social communication develops general flight deck atmosphere and interpersonal relationships between flight crewmembers (Kanki, 1996). The introduction of mixed-cultural crews may result in a lack of non-task-related "banter" on the flight deck. If banter is difficult due to lack of a common language, then this may lead to boredom in flight (Smith-Christensen and Duckert, 1995), although this is unlikely to be safety-critical. If there is a cultural clash between individuals, then non-task-related communication may lead to a possible reduction in morale. Although low morale may not have a direct effect on flight deck errors, it would be wrong to ignore the possible indirect consequences that could occur.

3.4 Decision Making

To discuss decision making in aviation, we shall adopt a model designed by Orasanu and Fischer (1997), which is illustrated in Figure 3.

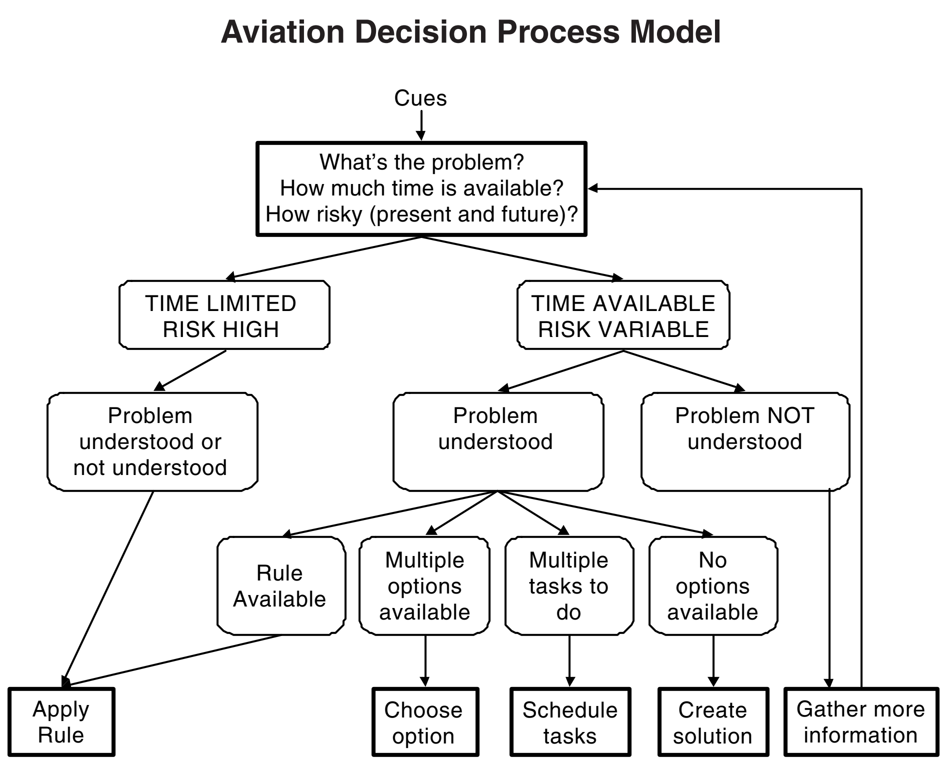
This model is based on a paradigm called "naturalistic decision making." This means that it accounts for the way in which individuals use their own knowledge to make decisions under dynamic conditions. Orasanu (1997) concludes that a naturalistic model of decision making in aviation will be different to such a model in any other domain. This is because any such model requires consideration of the structures, demands and expertise required by a specific domain.

Because information acquisition and information assessment involve interaction between individuals, they will be more influenced by globalization issues than decision making. Moreover, the proceduralized nature of the aviation industry means that if information has been adequately obtained and information sharing has been good (in other words, if situational awareness is high), then it is highly likely that a procedure can be applied, limiting the need for creative decision making.

There is certainly little research linking decision making and cultural factors. It is possible to speculate, however, where cultural change or interaction may indirectly affect decision making. These issues are drawn out in the sections below.

3.54.1 Decisions Under Time Pressure With High Risk

Performance under these conditions will be affected primarily by an individual's training and experience. This hypothesis is supported by Stokes and Kite (1994), who found that more experienced pilots make the right decision under stress more often than inexperienced pilots. The primary issue is that experience enables individuals to locate the vital cues and act on them. Knowing how to respond in an emergency and the capability to act in a timely manner obviously increase the likelihood of a correct response. A finding from stress research is that people under stress tend to make premature hypotheses, based only on the information that is originally available at the onset of the situation or is subsequently easy to obtain. This is a result of the finite information process capacity available in novel situations. The Kegworth accident was an example of this tendency.



Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research, adapted from Orasanu and Fischer (1997)

Figure 3

[The U.K. Air Accidents Investigation Branch, said, in its final report on the accident, that the no. 1 (left) engine on a British Midland Airways B-737 malfunctioned during a scheduled flight from London, England, to Belfast, Ireland. The crew believed that the no. 2 (right) engine had malfunction and shut down the no. 2 engine. The crew diverted the flight to East Midlands Airport in Kegworth, England. During approach, a loss of power from the no. 1 engine occurred, and the crew was unable to restart the no. 2 engine. The aircraft then struck terrain. Of the 126 occupants, 47 were killed and 74 received serious injuries.]

In terms of globalization issues, this implies that any decision to fly two inexperienced pilots together, in an attempt to drive down costs, should be resisted. A good organizational culture will provide pilots with specific training to help them cope with high-stress situations such as these.

3.4.2 Choice of Action Under Variable Risk

Due to its safety-critical nature, aviation is a highly proceduralized operation. In the vast majority of situations, decision making is limited to deciding which SOP should be used. SOPs are integral to the correct performance of complex tasks on the flight deck and are one way in which an organization can exert control over the decision-making process. Ideally, SOPs provide a logical, efficient and safe means of carrying out set tasks, with the further virtue of predictability. Even pilots who have never flown together in the same cockpit should be able to work smoothly as a team because they have learned to perform the same functions in the same way. However, if there is little consistency among the procedures used by different carriers that pilots move between, then this level of predictability will be lost. When airlines merge, care must be taken to ensure that pilots are given proper training to familiarize themselves with any new procedures they are likely to encounter.

National culture may influence the choice of action. For example, mistrust of automation in low power distance countries may manifest itself in a preference for manual flying. Sherman and Helmreich (1995) found that national culture strongly predicted automation usage.

3.4.3 Choice of Action With No Standard Options Available

This situation should be experienced very rarely. Under such conditions, there is a need for creative thinking. The professional culture of pilots is informed by tales of brave pilots improvising and remaining calm under extreme stress. Although the need for this kind of response is less likely in modern aviation due to the reliability of the technology involved, there are still examples that perpetuate the stereotype.

In terms of national culture, high uncertainty- avoidance scores may increase stress in situations where no standard options are available and consequently hinder decision making.

3.5 Latent Failures

There are other indirect factors operating at the regulatory, organizational and cultural levels that have the potential to increase the likelihood of a human error being made. They result from latent causes such as inadequate training, supervision, resources or oversight, and faulty procedures and policies. They are known as latent failures and may be present for many months or years prior to an incident.

Failure to identify the underlying causes of error results in a "fire fighting" response and means that similar or more serious incidents are still likely to recur. If the error-maker is blamed or punished, the reporting of other incidents will be suppressed. As a consequence, fundamental failures in management or regulatory policy remain unaddressed and resources may be squandered on ineffective initiatives.

Given that each latent failure has the potential to influence several active failures (immediate causes), removing latent failures is a cost-effective method of incident prevention. Latent failures will only be discovered if the root cause of a crew error is established by adopting a fact-finding rather than a blame-assigning approach.

3.6 Summary of Factors Influencing Flight Deck Errors

In Table 5 (page 21), Table 6 (page 21), Table 7 (page 21), Table 8 (page 22) and Figure 4 (page 22), the main types of flight deck errors are summarized, together with their primary causes.

4. Commercial Developments in the Airline Industry

4.1 Historical Perspective

Historically, state-owned and state-funded national carriers operated the majority of strategically and commercially important international and domestic air services. Other airlines within Western Europe generally fed key trunk and long-haul routes from hub airports. At the time, this was probably the only possible structure for developing a new and expanding industry. The economic climate was essentially protectionist, and few truly global entities existed in any industry. Since ownership structures were largely government-led, there was no clear commercial imperative.

Scheduled international air traffic was regulated for economic purposes on the basis of bilateral agreements negotiated between respective national governments. The main element of these agreements was the principle of reciprocity, effectively creating cartel dominance on routes by limiting either the number of designated carriers,

Table 5
Errors During Information Acquisition

Information Acquisition Source	Error Types	Factors Influencing Errors
Cockpit displays	Use of cockpit displays for monitoring and situational awareness instead of actively searching for information (“automation bias”) Inadequate monitoring of displays	Cultural attitudes to automation (mistrust of automation in low power distance cultures) Number of aircraft types pilot is required to fly Loss of vigilance due to fatigue, possibly arising from rostering policies
Standard operating procedures (SOPs)	Failure to monitor information sources	Lack of clarity of roles and responsibilities arising from different interpretations of SOPs

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

Table 6
Errors During Information Sharing

Information Sharing Process	Error Types	Factors Influencing Errors
Information sharing between flight crew	Failure to detect primary error (monitoring failures)	Command structure on flight deck (trans-cockpit authority gradient) Cultural differences in power distance Lack of verbalization about problems due to assumptions about shared standard operating procedures
	Failure to challenge incorrect decisions or actions (error recovery or assertiveness failures)	

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

Table 7
Misinterpretation Errors

Aspect of Interpretation	Error Types	Factors Influencing Errors
Interpretation of simple information	Misinterpretation	Language differences Use of unfamiliar terminology Lack of social communication during or between flights leading to failure to build up shared knowledge of experience and attitudes
Interpretation of higher-level meaning	Surface meaning of message understood, but higher-level significance not appreciated	
Shared knowledge of other crewmember attitudes and knowledge	Incorrect expectations arising from different cultures or experience understanding Boredom leading to lack of vigilance	

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

frequency (number of operations) or capacity (number of seats offered). Standard tariffs (fares) on these routes were also agreed by carriers, with clauses concerning reciprocal acceptance of fare structures. Carriers were often required by their governments to operate unprofitable routes for socio-political reasons.

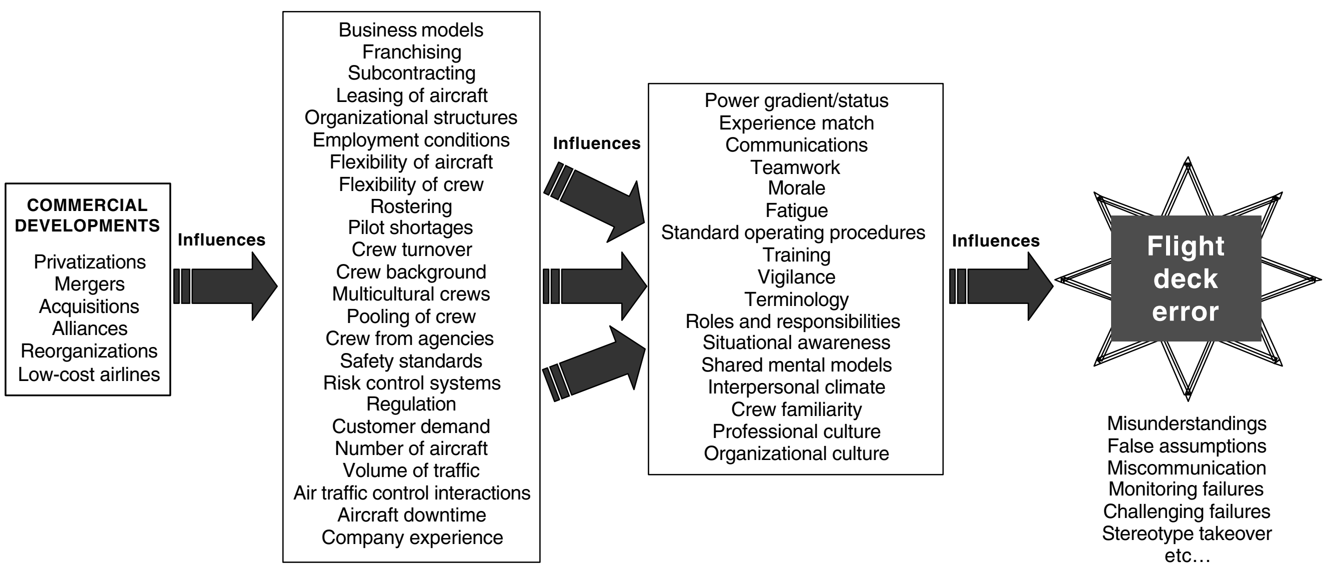
There was limited opportunity for “second-force” airlines to establish themselves in the market, as national carriers had strong market position on the most lucrative routes and could act to reduce competitive threats. Bilateral agreements could also prevent entry by other carriers to key routes through use of carrier-designation clauses.

Table 8
Decision Making Errors

Decision Making Process	Error Types	Factors Influencing Errors
Decision making in high-time-pressure and high-risk situations	Only easily available information used — leading to premature hypotheses	Level of experience Quality of information provided in cockpit
Choice of action in standard (i.e., included in standard operating procedures) contingency situations	Pilots used to differing procedures may not coordinate effectively	Degree of difference between procedures normally used by different crewmembers
Diagnosis and choice of action in non-anticipated situations	Inability to diagnose and formulate corrective strategy under stress	Persons from high uncertainty avoidance cultures may lack experience in operating outside standardized procedures

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

The Effects of Commercial Developments on Flight Deck Errors



Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

Figure 4

During the development phase of the industry, there was a tendency on the part of governments to protect incumbent carriers. Where a country had more than one international airline, routes were allocated on a geographic or shared basis. In addition, there was only limited scope for multiple designation, since both the originating and destination countries had to agree to add a second or third airline.

Eventually, market pressure and competition rules saw economic regulators, particularly in the U.S. and Europe, intervene to open up markets to more competition. Governments increasingly came to accept that airlines should be run as commercial businesses and not as an extension of government activity. This created the conditions for a number of airline privatizations.

Deregulation of air services within the U.S. paved the way (Airline Deregulation Act of 1978), and the liberalization of air services within Europe followed. Nevertheless, forms of bilateral agreements are still in place for operations between Europe and certain countries outside Europe.

4.2 Effects of Deregulation

Deregulation proved to be a decisive watershed in the structural development of the air transport industry, particularly in the United States and Europe.

In outline, the results of U.S. deregulation were:

- An overall reduction in the number of carriers offering international services;
- The creation of a series of "fortress" hubs dominated by five major carriers; and,
- The development of low-cost feeder carriers, often owned by the major carriers, supplying traffic into "mother" hubs.

European liberalization began in earnest from 1987, and the results have been:

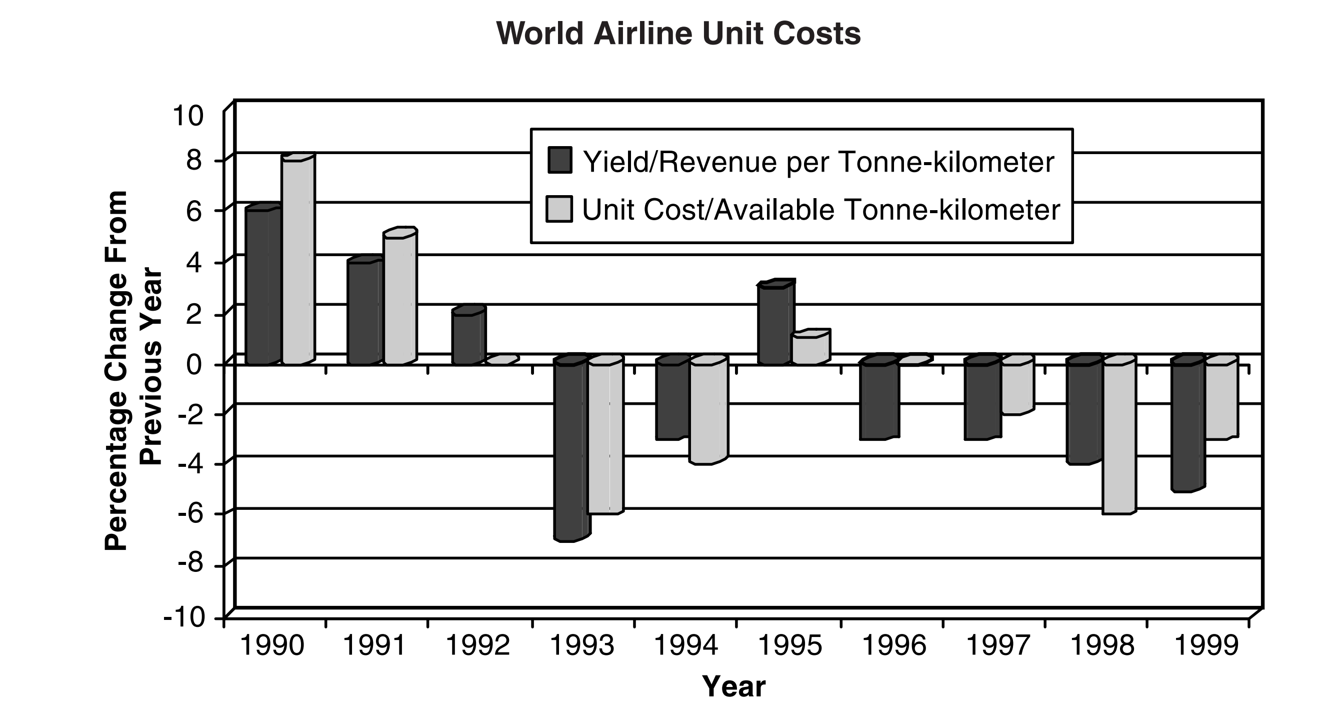
- Significant growth in passenger demand;
- Carriers allowed more flexibility to enter markets, leading to greater competition; and,
- The formation of low-cost carriers.

An international trend that has arisen as a result of deregulation and the privatization of aviation markets is the creation of larger, more cost-efficient airline business structures where economies of scale can operate. An example is the growth in global airline alliances in recent years. Year-on- year unit costs have decreased for all but one of the years between 1993 and 1999 inclusive, and this is illustrated in Figure 5.

Cost efficiency should not come at the expense of safety, however. In the fourteenth report of the U.K. Select Committee on Environment, Transport and Regional Affairs (1999) concerned with aviation safety, easyJet Managing Director Ray Webster is quoted as saying:

> Airline deregulation applies to control measures over commercial activity and not to airworthiness standards, and, therefore, any assumption or implication that safety standards have lowered as a direct consequence of deregulation would be false. It is such false assumptions that give rise to comment that an airline that offers low-cost, value-for-money fares must be cutting back on something, with safety being the most frequently quoted area by the less informed. We should be actively dispelling such views because value-based airlines are regulated in exactly the same way and to the same standards as the larger, established airlines.

However, the director of the Safety Regulation Group (SRG) of the U.K. Civil Aviation Authority (CAA) is quoted in the same report as saying:



Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

Figure 5

The emergence of low-cost carriers is stretching our resources insofar as we have to put specific regulatory effort into these new start-ups.

The remainder of this chapter describes current and possible future developments in the European air transport market resulting from deregulation.

4.3 Privatization

Some previously state-owned carriers have adapted more quickly to the new environment than others. A variety of factors accounts for this disparity, from customer-driven management success to the characteristics of the marketplaces in which they operate. All of the major carriers have faced some degree of negotiation with key staff, including flight crew, as they face the challenge of the need for continuous productivity improvements within the new economic forces at work in a global business.

Nevertheless, the rate of return achieved by airline businesses has not, on average, compared well with typical stock market returns, and there is a need to improve performance further to guarantee the viability of the industry. Despite the inherent challenges, few international carriers within Europe have actually gone out of business. Where necessary, financial rescues have been achieved either through partnership with other airlines or by government or private capital injections.

Competitive pressures continue to build, and it would be surprising if Europe can continue to support the number of major national carriers that it currently does in a fully competitive marketplace.

The consolidation of airlines that has taken place in the U.S. is likely to be replicated in Europe. Whereas most nations within Europe are likely to retain a national carrier in name, some of these carriers may become subordinate entities within perhaps four or five major alliance groupings.

Another strategy developed by major carriers to broaden the service offering has involved franchising smaller (lower-cost) regional carriers within their organization to operate as feeders to hubs.

The breakup of the former Soviet Union, both geographically and economically, has had a major influence on aviation in the former Eastern Bloc. The trends seen include:

- An undoubted latent demand for travel released by the end of travel restrictions;
- The emergence of significant airline growth among former satellite countries;
- The replacement of Russian aircraft by Western aircraft requiring fewer flight crew; and,
- A reduction in demand for military pilots.

Some of these countries appear to be establishing successful airline businesses but are growing from a low base and with a high exposure to market volatility. They generally have sufficient flight crew and staff, but this is outweighed by capital shortage, market size and dollar-denominated costs. It can be speculated that there will be a reservoir of former military and other Eastern Bloc pilots with a keen interest in employment at Western European airline salaries if the opportunity arose.

4.4 Alliances

Strategic alliances have become as common in commercial aviation as in other industries and are formed between competitors and collaborators. Although such agreements have always been a feature of the airline industry, there has been a rapid expansion in the number of alliances in recent years, which almost doubled in the four years from 1994 to 1998.

Most airline alliances are loose, flexible and based on relationship-oriented partnering. They tend to be strategic alliances involving inter-organizational cooperation but lacking the formation of a joint legal entity. Given prohibitions by some states on the foreign ownership of airlines, these companies forge international alliances seeking to capture some of the benefits normally achieved through a merger.

The true global airline alliance requires a combination of carriers from each of the major traffic-generating regions of Europe, Asia and the U.S. Currently there are five major alliance groupings, namely: Star, oneworld, Wings, Qualiflyer and Sky Team. These groupings are still in some degree of flux and differ in the degree of integration that has been achieved.

The degree of volatility of the alliance groupings is indicated by the changes that have taken place since April 2000, involving additional carriers joining alliances and a breakup in part of the Wings grouping.

The rapid development of global alliances between 1996 and 1999 is shown in Table 9 (page 25).

There are a number of key drivers that led to the creation of global airline alliances. These can be grouped under market access and cost-based motives.

Market access motives are:

- Greater global reach from linking into the networks of other carriers;
- Circumvention of restrictions imposed by the bilateral system;
- Creation of corporate sales and marketing teams to coordinate activities across all airline members;

Table 9
Numbers of International Air Travelers, 1996–1999

	1996	1997	1998	1999
Global Total (million)	381.8	414.0	432.2	459.0
Alliances (million)	34.4	85.7	134.9	212.5
Alliances share (percent)	9	21	31	46

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research, from International Air Transport Association World Air Transport Statistics Annual Reports, 1996–1999

- Joint passenger and cargo flights;
- Coordination of flight schedules, leading to the optimization of connecting opportunities at each carrier's home base;
- Code-sharing agreements, which are particularly important for developing new route opportunities; and,
- Links between frequent flier programs, which extend the benefits to passengers by increasing the available network for free flight opportunities.

Cost-based motives are:

- Management contracts, leading to the reduction in the management head count of alliance members;
- Joint ventures in areas such as ground handling and aircraft maintenance, which allow alliance members to enjoy the benefits of bulk purchasing from key suppliers;
- Sharing of facilities such as training, maintenance and aircraft spares; and,
- Higher utilization of aircraft.

There is no inherent economic justification for a national carrier framework, and therefore alliances and marketing cooperation provide a good way to achieve these benefits within the existing political and regulatory framework. The cost benefits are difficult to quantify and will be less than their full potential when the alliance members continue to operate as separate businesses. Efficiency gains are more likely to occur on the demand side, where higher frequencies and more routes attract more passengers to the network of the alliance.

Alliances are not as efficient as full mergers. For example, the joint investment is likely to be lower, as airlines will fear a breakdown of the alliance. Nevertheless, in a deep alliance, the exit costs may be prohibitive.

The Organization for Economic Cooperation and Development (OECD) reports a tendency towards deeper alliances involving cooperation on all aspects of the airline business, from marketing to procurement. It further reports that 70 percent of alliances include provision for code sharing,[2] 50 percent include provision to share frequent flier programs, and 15 percent include agreement to share facilities such as catering, training, maintenance and aircraft purchases.

Pressure is being felt within some alliances for a degree of convergence. In the future, SOPs may become more similar within the member airlines of an alliance and there may be some movement of pilots between alliance partners.

Global alliances look likely to continue as the major force in the commercial development of the industry. Although there will almost certainly be some changes in airlines between the major groupings, the degree of concentration will continue. Economic regulators and politicians in both the United States and in Europe are likely to continue to investigate the perceived "competitiveness" of these groupings. The limits on what such regulators will accept are unclear and may always remain so.

4.5 Mergers and Acquisitions

The merging of two airlines is perhaps the largest organizational change that those airlines may ever face. The potential for such mergers is increasing significantly around the globe as the national basis of air-carrier structure and operations becomes weaker and the search for greater operational efficiency increases. Such mergers have already become commonplace in other global industries such as banking, telecommunications, pharmaceuticals and media. While previous airline mergers generally took place between airlines within the same country, mergers which cross national boundaries are becoming increasingly common. This is likely to give rise to a more complex mix of cultural factors to be dealt with by the new companies.

Generally, the economic drivers for change and the economic consequences of change are thoroughly considered. However, the priority accorded to the effect of the merging of companies on the employees is generally lower. Paying too little attention

[2] Code sharing refers to the practice of one airline selling seats on a flight operated by another airline, a practice assisted by the development of advanced computer reservation systems. Airlines share the two-letter code used to identify carriers in these reservation systems used by travel agents.

to the social effects of a merger can have negative consequences, and these have been illustrated particularly in the United States and Canada with Continental/Eastern, Pan Am/United and CP/Wardair given as examples.

4.6 Low-cost Carriers

The broad business philosophy of the low-cost carriers is that money can be made on any route where a carrier can fly three times a day to a low-cost airport, based on a minimum market size of around 200,000 passengers per annum.

The basis of commercial success for such entry airlines is maintaining a 30–40 percent cost advantage over established airlines. This is primarily done in several ways:

- Use of secondary airports, enabling lower airport landing fees, lower ground-handling charges and fast turnarounds, typically 30 minutes or less;

- Lower passenger costs achieved through no passenger frills and the use of direct selling techniques, particularly on the Internet, to reduce distribution charges from travel agent commissions and computer reservation system costs. These currently average 16 percent of international carrier costs;

- Implementing a new set of processes to optimize operational efficiency and minimize overhead costs; and,

- Higher average passenger load factors.

Cost advantages are passed on to passengers by means of low fares. As well as taking market share from national carriers, low-cost carriers are creating additional demand for air travel.

The corporate structure of these carriers often reflects their niche-player role, and they are frequently able to benefit from the latest technology and working practices. Many low-cost carriers standardize on a single aircraft type and purchase new aircraft in bulk, thereby minimizing maintenance costs. Their financial performance is regarded as being attractive to the stock market, and this is exemplified in the United States by Southwest Airlines, whose market capitalization and financial performance currently exceed any of the major U.S. airlines that are many times its operating size.

The European low-cost carriers seek to emulate the success of their counterparts in the United States, most notably Southwest. This is achieved through high load factors, together with tight cost control. They are the fastest-growing segment of the European airline industry, and new routes are being opened each year. The leading European low-cost carriers are planning to double their aircraft fleets over the next three to four years.

In spite of the successful profit record of Southwest Airlines, the experience of U.S. low-cost carriers has been mixed, and many have failed. In Europe, Debonair has been the highest-profile casualty.

Debonair embarked on a strategy to form a multi-hub system and pan-European network by setting up alliances with regional airlines, aimed at establishing a strong presence in Continental Europe. It attempted to distance itself from the low-cost-carrier culture and introduced a dedicated business-class cabin. In doing this, it departed from the true low-cost philosophy and was caught between the market segments of the low-cost carriers and the established carriers.

The major carriers initially adopted a “wait-and-see” attitude towards the low-cost segment, taking time to assess the impact on their own traffic, particularly with regard to any dilution in the number of premium-class passengers carried. Eventually, competitive reaction came with the creation of Go by British Airways, which is now being sold, and Buzz by KLM. At the present time, other major European carriers are actively considering the introduction of low-cost subsidiary airlines. The dedicated low-cost carriers are therefore facing increased competition, and the charter sector may also react aggressively, particularly on the important leisure markets out of the United Kingdom.

The low-cost carriers are facing rising costs, particularly in the areas of fuel, airport charges and salaries. In addition, they are generally limited at the present time to regional operations, which does not allow them to develop a more balanced portfolio of services. This restriction might widen their exposure to increasing delay costs in Europe due to shortage of airport capacity and airspace. Finally, the levels of initial growth they have achieved are unlikely to be continued as they extend to weaker markets.

5. Effects on Flight Crew of Commercial Developments

Three major effects occur from recent commercial developments in the airline industry that could give rise to human factors issues. They are:

- The mixing on the flight deck of crew from different cultural and national backgrounds;

- The merging of company cultures when one airline takes over or merges with another; and,

- Commercial pressure, which arises from greater competition between the airline companies.

5.1 Multicultural Flight Crews

5.1.1 Introduction

In 80 percent of the airlines returning questionnaires and in all of the national flag carriers interviewed, at least 95 percent of the flight crew employed are local nationals. In many Southern European states, all the flight crew employed are local nationals and, as a consequence, multicultural flight crews are more frequently found in airlines operating out of Northern Europe. The highest proportion of non-nationals was found at a small operator in Northern Europe where 70 percent of the flight crew originate from outside the local state, coming from around 20 different countries within and outside Europe.

Although the number of aircraft movements in Europe with multicultural flight crews is relatively small at present, there are indications that this will increase in the future for the following reasons:

- The segment of the market employing the highest proportion of non-nationals was found to be the low-cost sector where typically 25 percent of the pilots employed are non-nationals. Since low-cost entrant airlines are expanding rapidly, it can be expected that mixed flight crew will become a greater proportion of the whole;

- More than half the people surveyed believe that a pilot shortage will occur in Europe in the short to medium term and that this will encourage a greater movement of trained flight crew between airlines and between member states. This movement will be facilitated by a common European flight crew license and the freedom of movement of labor within the European Union (EU);

- In a climate where the demand for experienced pilots exceeds supply, qualified foreign nationals from outside Europe are also likely to be attracted to working for European airlines, particularly if the salaries are greater than they could earn in their own countries; and,

- It is anticipated that there will be a growth in airline mergers that cross national boundaries (see Section 4.5) with a consequent mixing of crews from both airlines.

The standard industry practice and aim is to be able to roster any captain with any copilot in order to give maximum company and personal rostering flexibility. Normally, the only time this might not be appropriate from a safety viewpoint would be to prevent a new captain and a new copilot on a fleet to fly together. Not surprisingly, therefore, none of the airlines that employ foreign nationals attempt to match flight crew of the same nationality together.

However, the small airline employing a very large number of different foreign nationals rosters very carefully to ensure that flight crew are mixed in what the airline considers to be a safe combination. Acceptable combinations take into account language ability, experience of flying in Europe and length of flying experience. Certain nationalities in this airline are never permitted to fly together.

Another airline with subsidiaries in three different states mixes crew between the subsidiaries to provide short-term flexibility and reports that this mixing has been successful and is likely to increase.

While most airlines say rostering is carried out on a random basis to provide the greatest flexibility, informal rostering systems sometimes operate to avoid known personality clashes.

None of the airline management interviewed could give any examples of problems that had been experienced with mixed national crews in their own airlines, and a few saw the mixture of different nationalities and cultures in the cockpit as a strength. However, some said that crew training is challenging when a wide range of cultural backgrounds is mixed.

A different view was given by a line captain who said that he and his colleagues had experienced problems on the flight deck with crewmembers of certain nationalities. These problems were related to their language ability and general safety philosophy.

While the subject of this study is mixed flight crew, it should be noted that it is quite common for airlines to mix nationalities within the cabin crew and between the flight deck and the cabin.

5.1.2 Language Issues

Of all the potential problems from multinational flight crew, differences in language are an obvious concern.

With a flight crew of two, there are four distinct language combinations. Since English is the standard language of aviation, it will be used to demonstrate these combinations:

- Both native English-speaking;

- One native English-speaking, the other non-native English-speaking;

- Both non-native English-speaking of the same nationality; and,

- Both non-native English-speaking of different nationalities.

Several people said that flight crew tend to think in their own language and are likely to revert to their mother tongues when an abnormal situation or emergency arises. Non-native English speakers commented that they have to adapt their minds to work in English and become familiar with working in a foreign language. While communication between different nationalities may be perfectly acceptable under normal operating circumstances, communication may become impaired in certain situations, which may lead to a loss of situational awareness.

This is particularly true when decisions that have to be made are time-critical.

Not only is effective communication a problem between people of different native languages, two people who share a common language but come from different countries can also misunderstand each other. For example, countries such as the United Kingdom, the United States and Australia often have different interpretations of the same words or phrases. Although this is not an issue in the use of a standardized aviation language, nontechnical words may be misunderstood. Furthermore, there may be difficulties in understanding accents or dialects. An example quoted by Helmreich is that of an Australian pilot's pronunciation of "Mode A" being heard by an ATC officer (ATCO) in the United Kingdom as "Mayday."

It was suggested that language differences between the flight deck and airport services could be important. For example, when a maintenance engineer or dispatcher is of the same nationality as a member of the flight crew, they may converse in their native language. If the other flight crewmember is of different nationality, he or she may not understand the communication, and misunderstandings may result unless a (correct) translation is given.

Countermeasures to misunderstandings are greater cross-checking and more rigid use of SOPs. One person said that SOPs are particularly important when nationalities are mixed, as they provide discipline and encourage safety. However, the rigid use of SOPs may lead to non-native English speakers anticipating what will be said next by knowing the subsequent step in the SOP. An example reported by a line captain was of a non-native English-speaking first officer who mistook a casual remark for an anticipated instruction. The result was that the undercarriage was lowered prematurely. In other words, there may be an increased tendency for crew whose English is relatively inadequate to hear what they expect to hear, rather than what is actually being said.

Not only should language be considered in terms of the flying task, it is also a concern where multinational crews are unable to fully engage in social conversation either inside or outside the cockpit. On long-haul flights, social interaction may help to reduce fatigue, maintain alertness between the crew and contribute to teamwork. A lack of conversational or colloquial ability in a common language may have an adverse effect on interpersonal relations, with flight safety implications.

Furthermore, language and sociability are both barriers to a satisfying social relationship with all the members of the crew during rest periods. Being excluded in this social interaction for reasons of language or personality will have a negative effect on team building. It was reported that someone would be treated as an outsider if they had difficulty in or were resistant to speaking the native language of the airline, particularly in social situations, and that this treatment would carry across to the flight deck.

The correlation between age and the likelihood of a person being able to speak a foreign language was raised by several people. Younger pilots tend to be reasonably fluent in more than one language, whereas older pilots tend not to be. Inadequate language ability may therefore be a significant factor in the employment of crew after they have passed an airline's retirement age, perhaps by an agency.

A safety regulator said he concentrates on people's general ability to speak and understand English, not just on their technical use of the language. His reason for doing this is a concern that flight crew will use nontechnical language in degraded situations and, if their mastery of English is inadequate, that they will revert to their native language.

5.1.3 Resistance to Recruitment of Non-nationals

Given the relatively low rates of pay in Eastern Europe, it is more likely that experienced Eastern European flight crew will join a Western European airline than vice versa. However, in the past there has been resistance from some pilot unions to the employment of Eastern Europeans. Reasons given were that their handling skills and/or technical knowledge were alleged to be inadequate and their English language skills were alleged to be inadequate. In addition, because they may be prepared to join an airline in Western Europe for less than the normal rate of pay, some unions have been concerned that jobs might be taken away from local nationals.

Resistance to the employment of Eastern Europeans has also come from some safety regulators. For example, it was reported that one regulator has refused to allow an airline to recruit flight crew again from a certain Eastern European country because of a previous bad experience. Reasons given were that these flight crew had displayed undesirable national characteristics such as dogmatism and authoritarianism, and that the concept of CRM was unfamiliar to them.

The influence of Russian aviation is strong in Eastern Europe where most pilots have a military background and are accustomed to flying single-seat aircraft. They are required to learn procedures by heart, whereas the use of checklists is the standard in Western Europe and most of the remainder of the world. An Eastern European airline reported that some experienced captains found it difficult to make the transition from Russian to Western aircraft types, and it took them a year to complete transition training. Others were unsuccessful and no longer work for the airline.

Cuba has always had a close relationship with the former Soviet Union, and one airline stated that they found it necessary to double the simulator time when training Cuban flight crew in order to obtain the standard that they required.

Eastern European and some Southern European countries also resist the employment of non-nationals. Several examples were given:

- Unions and representative associations may be strongly opposed because of high local unemployment;

- Work permits may be difficult to obtain; and,

- A state may have a regulation that a minimum proportion of all flight crew should be local nationals.

When foreign nationals are employed by an airline, the morale of local nationals may be affected, perhaps unreasonably. An example was given of an airline with a base in a foreign country where the newest aircraft are located. This base employs many different nationalities, and senior flight crew at the home base feel resentment because the new aircraft are being commanded by foreign nationals, some with less experience than themselves. Conflict may arise if crew at the two bases are mixed in the future.

5.1.4 The Role of CRM

Several people stressed the importance of CRM when mixing flight crew of different nationalities and culture. One regulator said that CRM is the glue that ensures flight safety. The management of an airline employing over 20 nationalities said that this mix of nationalities requires them to be more proactive in the implementation of CRM because it is used to help manage the cultural issues. They suggested that with further globalization of the industry, greater emphasis will need to be placed on the development of CRM training, as the mixing of cultures will only work if CRM is effective. They recognize that the necessary development of CRM will be expensive.

It should be noted that while many airlines and regulators believe that CRM is an effective tool, the standard of CRM training and its implementation is perceived by many flight crew to be variable. There is little doubt that some airlines have devoted substantial resources to try to achieve the highest standards, while for others it is more a question of providing what might be described as a barely adequate course to meet the legal requirements, with little positive commitment from senior management.

5.1.5 Summary — Multicultural Flight Crews

Table 10 (page 30) shows the human factors issues involved with using multicultural flight crews and the potential consequences.

5.2 Merging of Company Cultures

5.2.1 Introduction

The discussion of multicultural crews has focused on differences between national cultures, such as language and behavior. However, several management pilots have suggested that the difference in culture between countries may be less than the difference in culture between companies within the same country. For example, there are great differences between the cultures of a national flag carrier and a low-cost airline where simplicity and efficiency are built into every business process and little, if any, importance is placed on seniority.

This view about the relative strength of company culture is supported by work being carried out on the JAR-TEL (Joint Aviation Requirements — Translation, Elaboration and Legislation) project that is being funded by the European Commission (EC).

5.2.2 The Nature of Company Culture

National carriers, whether government owned or privatized, might be expected to have a strong national culture. They are often referred to as flag carriers and, to an extent, represent their countries overseas. They have prestige, and one national carrier said that crew tend to stay for the duration of their career. It may be postulated that part of the company culture will be influenced by this stability.

However, sometimes the cultural roots of an airline may be found in a country that is remote from where the airline is located. For example, the business model of more than one Northern European low-cost airline is based on Southwest Airlines, a very successful and profitable U.S. carrier, and many of its cultural values have been adopted.

Because of the limited opportunities for contact between company managers and flight crew, company practices and culture are normally instilled during initial training and reinforced in all subsequent training. In a few airlines, and particularly those based on the Southwest model, company culture may be promoted by staff briefings and social events that are held on a frequent basis.

Several airlines stressed the importance of crew fitting in with their culture. When these airlines select new pilots, the ability to fit in is considered to be just as important as the possession of appropriate technical skills. In some cases, an airline will try to avoid the use of agency crew to prevent potential cultural clashes. The view of one management pilot was that personal qualities are difficult to change, whereas technical skills can to a large extent be taught.

5.2.3 Mergers and Culture

Mergers often reveal the cultural differences between airlines. One example given was of a national carrier that merged with a regional carrier providing domestic services, both owned by the state. The business case for a merger was strong, as the route networks of the two carriers were complementary, but many human factors difficulties were experienced in attempting to merge the two cultures. Both airlines had identical A320 fleets but “merger CRM” had to be put into place to allow

Table 10
Multicultural Crews: Human Factors Issues

Issue	Potential Consequences
Flying-task communication between flight crew (of different nationalities)	Misunderstandings may occur in verbal communications and may not be recovered if both crew believe that they are understood
The use of multinational and multicultural crews requires careful and specific management	May not always be provided, particularly where resources are tight; reduced internal oversight
Social communication between flight deck crew (of different nationalities), both in-flight and on the ground	Language/cultural differences may lead to difficult interpersonal relationships, loss of team spirit, etc.
Communication between crew of different nationalities in non-routine situations where language becomes less formal/structured	Misunderstandings may occur; crew unable to form coherent team to solve the problem; crew may not be able to communicate situation effectively to air traffic controllers or others.
Communication between crew of different nationalities in time-critical situations	As above
Communication between flight crew sharing a common language but with different dialects/accents/meanings	Misunderstandings may occur, but aviation requires standard language
Increased reliance on standard operating procedures (SOPs)	May lead to anticipation errors where crew hear what they expect rather than what has been communicated
Older crew may be less able/willing to communicate in a common language	Misunderstandings; difficult interpersonal relationships; crew resource management (CRM) issues
Wide disparity in religious, etc., beliefs	Leading to, for example, feelings of having “nothing in common”
Different CRM philosophies, for example, between East and West Europe, or lack of CRM training	May be poor team players or bring different power gradient issues
Experience on very different types of aircraft (for example, Russian fleets)	Low CRM skills
Resentment over non-nationals taking jobs away from local pilots	Leading to difficult interpersonal relations
Concerns over alleged deficiencies in flying skills and technical knowledge of pilots from certain regions/countries	Reduced experience or technical competence, either real or perceived, may directly affect flight safety or affect interpersonal relationships with other crew
Concerns over safety philosophy/performance of pilots from certain regions/countries	Reduced safety philosophy may directly affect flight safety or affect interpersonal relationships with other crew

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

both populations to fly together. After three years, some cultural differences are still causing friction within the merged airline.

A similar but less extreme example was given of a merger between a national carrier and a combined charter/freight carrier where the employment conditions and attitudes of the two groups of flight crew were very different.

Another example was referred to of a major airline in the United States where almost all the positive aspects of its organizational culture were affected by cultural clashes arising from a series of mergers in which it had engaged.

Prospective mergers do not always succeed. An example was given of a failed merger between an airline in Northern Europe and an airline in Southern Europe. Cultural differences were given as a contributory cause. The way of doing business in the two companies was different and was eventually found to be incompatible. Both airlines were strongly influenced by national culture.

Past mergers appear to have been most successful when both airlines have been operating in similar markets and have the same national identity. A manager from one airline said that very few human factors problems were experienced as the result of mergers that his airline had been involved in, primarily due to the fact that the mergers were with other airlines in the same country where the culture was similar. Several other people thought that there would be few problems in merging a Northern European airline with a U.S. airline, as flight crew in both are likely to have similar standards and status. The same people believed that mergers between Eastern European and Western European airlines and between European and Asian airlines would have the greatest potential for producing human factors problems related to culture.

Several management pilots interviewed were of the view that a merger between a large and a small airline would be much easier to handle than a merger between two airlines of a similar size. When two airlines of dissimilar size merge, it is normally the case that the larger partner will impose its culture on the smaller partner. Part of the culture of the smaller airline that will be subsumed will be the working conditions and operating practices under which flight crew are expected to work, including SOPs, flight time limitations and stopover policy. However, all these changes frequently lead to resentment among the staff of the smaller airline who may fondly refer to the way that things used to be done.

Pilot unions may also create problems following a merger, particularly when different unions operate in each of the companies. In some cases, integration between the unions is never achieved. Friction can arise when pilots belonging to different unions are rostered together, and it was suggested that this can lead to distraction on the flight deck. Examples were given of pilots leaving one union to join another that is willing to exert greater pressure on the airline. Some airlines do not recognize a trade union, but generally unions remain a powerful influence.

Many people raised seniority as the most contentious issue for flight crew arising from a merger. A pilot's seniority in an airline determines several important aspects of his/her professional life, including promotion prospects, bids for annual leave and work selection/allocation. The merging of seniority lists is a major cause of resentment and can lead to disrespect when flight crewmembers previously employed by the different merger partners are mixed. This disrespect can lead to distraction and inattention in the cockpit when one of the flight crew displays his or her resentment. It can even cause a pilot from one of the merged airlines to refuse to work on the same flight deck with a pilot from the other airline.

Resentment can lie dormant in an organization for a considerable period of time and may eventually emerge as a latent failure (see Section 3.5). From a human factors viewpoint, resentment could probably be minimized by involving flight crew more in operational decisions arising from a merger and by adopting best practice from both airlines, particularly in the area of staff benefits. A suggestion was made that representatives from both airlines could be used in focus groups in an open forum to identify differences between the companies and to discuss the way forward.

The merger of seniority lists can take a considerable time to complete; one example that was given was a period of almost 10 years before the flight crew seniority lists were fully merged.

A large airline often assumes that it has nothing to learn from the smaller partner and finds it easier to impose its own culture on the new organization. However, one captain from a national carrier said that a merger was a learning opportunity for the larger partner to improve its own processes and procedures. It is interesting that this captain made reference to the adoption of principles of the DuPont Safety Resources, a world leader in industrial safety management. One of these principles is to make people feel involved in and contribute to safety. The uniting of employees towards a single clear goal or direction is a recognized tool in integrating two cultures.

The most dangerous period in a merger was considered to be the transition phase, when misunderstandings could occur in SOPs. It was suggested that the transition phase should be carefully managed with targeted and effective training, and that eventually the two cultures would become integrated and there would no longer be a safety issue. However, this may be a little optimistic. First, it could be argued that cultural integration may never be achieved completely. Second, in a degraded or emergency situation, even a few years later, crew may revert to the procedures that they first learned, which may no longer be the appropriate and expected action.

Flight crew may see mergers and acquisitions as a threat, especially if they have worked for an airline for many years. One person said that people experience a fear of the unknown and added that whereas some aspects to be managed in a merger are visible and concrete (such as SOPs), other aspects are less tangible. For example, there may be even more mistrust of the new management than the old one.

To avoid all these problems, a merged airline may operate its bases as independent subsidiaries for a while. The subsidiaries retain their company culture and operating practices, but the result is that some of the potential benefits of the merger will be lost. One airline that operates in this way said that they will not form a single integrated company in the foreseeable future, as the industrial relations issues concerning seniority, pensions, etc., are too great. They anticipate a gradual integration as the harmonization of laws across Europe increases.

The management of another airline that is planning further bases in Europe said that they are aware that they will experience problems in integrating new employees into the company culture and added that managing these cultural issues will be the major challenge of globalization.

One airline has a policy of encouraging management to move between companies in a merger. Such movement may assist in the integration of the two cultures or the installation of the parent company's culture in an acquired company. However, they realize that the relocation of executives in the merged organization may actually create cultural problems. Therefore, it should be recognized that a clash of cultures may not just occur between flight crew, it may also exert a strong influence on the interactions between management — before, during and after a merger.

5.2.4 Alliances and Culture

Alliances between airlines are very different from mergers and acquisitions, as their aim is to extend their networks to create seamless travel for passengers and to achieve economies of scale in purchasing and the sharing of support facilities. Individual members of the alliance continue to operate as separate entities, and cultural integration is not attempted. An airline can, and sometimes does, move from one global alliance to another and will wish to maintain its own identity and differentiations from other airlines.

It is in the interest of all the members of an alliance to maintain a high level of safety performance. It is noted that in mid-1999, Air France and others in the Sky Team alliance suspended code-sharing arrangements with Korean Airlines on account of its safety record. If safety standards are a condition of entry into an alliance, global alliances may play a role in the self-regulation of safety. There may be pressure, encouragement and assistance from members to lift the safety performance of all member airlines toward that of the best performer in the alliance. A member of one alliance said that it is normal practice for the senior operator in an alliance to carry out safety audits of other members and potential members to ensure that suitable processes are in place to maintain an adequate safety standard. Another alliance member said that multicompany teams very often carry out the audit.

Mixing of crews within an alliance does not take place at present, and, from a regulatory point of view, the harmonization of SOPs of all the airlines in the alliance would be a necessary prerequisite. But entire flight crews do sometimes operate the aircraft of another alliance partner using their own SOPs. Sometimes there may be minor differences between the flight decks of the same aircraft type, and this could lead to transition problems when crew move between aircraft that are essentially similar but not exactly the same. However, some operators carrying out this practice say that they do not experience this problem as the flight decks are standardized for the particular aircraft type.

It is possible that alliances will form their own cultures in the future based on their increasingly integrated working relationships. It is not clear whether such alliance cultures will become more pervasive than company cultures.

5.2.5 Conclusions

The interpersonal skills required in order to manage the social aspects of a merger successfully involve similar principles to those that characterize most CRM courses, namely:

- Active listening;
- Developing a cooperative, problem-solving relationship with others; and,
- Establishing a climate that encourages group decision making.

Despite the difficulties, the merging of two companies provides the opportunity to create a new organizational culture, constructed from the more positive elements of the two cultures involved. However, any process of culture change is a slow one and should be measured in years rather than months. In the early stages of a merger, it is very easy to create problems that may take years to resolve.

5.2.6 Summary — Merging of Company Cultures

Table 11 (page 33) shows the human factors issues involved in the merging of company cultures and the potential consequences.

5.3 Commercial Pressure

5.3.1 Introduction

As the market for air travel becomes more competitive, airlines are forced to reduce costs, and increasing globalization is one of the consequences. Passengers increasingly expect more for less, partly as a result of the emergence of low-cost airlines and their very low fares to certain destinations. A manager in one airline said that there are great economic pressures in the industry and suggested that these pressures may be more significant than any other globalization factor. Another commented that there is pressure to reduce every aspect of cost to that being achieved in the lowest-cost airline and that alliances are driven by cost savings.

However, it should be noted that in the view of one regulator, commercial pressures do exist, but they are no greater than in the past. Furthermore, personnel in several airlines thought that commercial pressures would not affect their airline because they are already efficient but might adversely affect others.

Cost reduction is clearly leading to changes in the industry, although the influences on flight deck safety are not clear.

Many airline managers thought that certain structural changes in the industry that would have a potential impact on safety, such as the mixing of crews from different airlines in an alliance, were unlikely to occur. However, it is difficult to predict how increasing commercial pressure will change the nature of aviation. For example, five years ago, very few global alliances existed, whereas in 1999, 46 percent of global air transport movements took place within an alliance. Change is very rapid within aviation, and the structure of the industry and its operating practices could be very different in five years.

Table 11
Merging of Company Cultures: Human Factors Issues

Issue	Potential Consequences
Not recognizing that differences between airline cultures within a single nation are important when mixing crews	Failure to manage different company cultures
Differences in crew resource management (CRM) philosophies	Confusion; adoption of an inadequate compromise of the merged philosophies
Merging of seniority lists	Threats to promotion prospects, bids for shifts/routes/leave/new aircraft, etc., impact upon discontent and morale, may impair cockpit relations if resentment is harbored toward other crew who fared better in the merger. All of these factors can lead to distraction on the flight deck.
Differences in rostering terms (for example, less sympathetic rostering)	Increased fatigue, reduced morale
Changes in employment conditions, such as annual/parental leave allowances or other benefits such as pension contributions	Reduced morale/job satisfaction
Differences in standard operating procedures (SOPs) — particular concerns in the transition phase, or in emergency situation	Reversion to previous SOPs in error or otherwise; interpersonal conflict as to "the way of doing things"
Differences in speeds of promotion	Reduced experience on the flight deck; impact on merging of seniority lists — resentment toward crew from other company who were promoted sooner
Airlines of different type/size merging, for example, flag carrier and small charter operation (whether within or between countries)	Different company cultures not recognized as being as important as national cultures when airlines merge. Resentment to pilots from the smaller airline which may be seen as less prestigious.
Failure to recognize that the transition phase is a critical time	Increased risk from all issues during this period
Resentment at the loss of a company and its identity in the event of a takeover	Reduced morale; interpersonal conflicts between crews
"Fear of the unknown"; dislike of change, etc.	Reduced morale
Larger organizations becoming less flexible or able to change/adapt	Loss of management control
Reluctance by larger partner to consider the procedures, etc., of the smaller partner	Resentment toward the pilots from the larger partner in the merger
Airlines in alliance may share aircraft	Differences in cockpit layouts
Alliance members may share training functions to reduce cost	Training may no longer be tailored to the airline (e.g., CRM training)

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

The following subsections provide examples of possible links between commercial pressure and flight safety.

5.3.2 Flying Hours and Rostering

Flying hours in some airlines were reported to be very high, bordering on legal limits in several cases. Many airlines treat the legal limit as a performance target to be achieved in order to maximize the utilization of flight crew and reduce operational costs. Within the airlines interviewed, there is wide variation in the average number of hours flown, ranging from 500 to 950 hours per annum. Some, but not all, of this variation can be explained by the length of sectors flown.

In addition, some airlines allow very little, if any, reduction in flying hours for management pilots, some with critical responsibilities such as flight safety.

Some flight crewmembers said they were unhappy with the rostering system in use in their airlines. They frequently operate five-sector days alternating between early starts and late finishes, and work such long hours that they have little leisure time during the work week. Crew in one airline reported difficulties in obtaining compassionate leave because of commercial pressure, indicating a lack of sufficient crew. Although annual leave allowances are quite reasonable in comparison with most other professions, flight crew are often not able to take leave when they wish, with, for some, seniority as a determinant in the allocation process.

Unsympathetic rostering increases fatigue, upsets sleep patterns, reduces morale and has a detrimental effect on the personal life of crew.

One airline believes that flight crew should be educated so that they are aware of the effects of fatigue from both their work and their lifestyle outside work, and should adjust their personal lifestyles accordingly.

Management in several airlines said that lifestyle is becoming a major issue with flight crew who are increasingly willing to trade money for a better lifestyle. It is interesting to note that at least one airline is addressing the lifestyle issue. It has been widely reported in the aviation press that easyJet is currently trying to recruit a large number of experienced pilots partly to support a rapidly growing aircraft fleet but partly to increase the ratio of flight crew per aircraft so that lifestyle can be improved.

5.3.3 Holders of Senior Management Positions

Many pilots interviewed in a wide range of airlines observed that there is a tendency for business people with no flying experience to fill senior operational positions. The concern of these pilots is that the people taking up these critical positions may have less understanding of flight safety. One pilot commented that middle management in the airline he works for tends to be young with no previous experience of working in the airline industry and little understanding of the practices used in other airlines. Pilots may not be able to relate to such commercially oriented personnel, and relationships between flight crew and management may become degraded.

There clearly needs to be a balance between the commercialism of management and the safety performance of the airline. Some senior captains holding management positions have been very successful in selling the concept of safety to their bosses. The expression "if you think that safety is expensive, then try an accident" was quoted by more than one person as a means of effectively communicating the message.

5.3.4 Aircraft Turnaround

The efficient utilization of aircraft is a critical factor in aviation economics. Low-cost airlines achieve this partly by minimizing delay through the use of uncongested airports and partly by minimizing turnaround times between sectors flown. Short turnaround times are achieved by streamlining procedures and not serving meals and other amenities, thus reducing subsequent "mess." All members of the crew are involved in the turnaround process.

However, a potential danger is that pressure to achieve a fast turnaround may result in external and flight deck checks being hurried (or even omitted). This may particularly be the case if an airline is trying to reduce turnaround time without making the necessary changes to its procedures or if an aircraft is running late.

5.3.5 Training Budgets

Because emergencies rarely occur in the air, simulator training is the means by which flight crew are taught how to deal with such events and build their confidence in correctly handling these abnormal situations. Regular refresher training in the simulator is necessary to ensure a continued satisfactory standard and to eliminate any bad flying habits that may have been detected between such training sessions. Although recurrent CRM training might be viewed as the means by which nontechnical skills may be maintained or improved, such training should ideally be incorporated into the annual simulator training program and be supplemented by classroom instruction, as is the case in some airlines.

As commercial pressure increases and organizations reach the point where all unnecessary overhead cost has been removed, perhaps by outsourcing non-core activities, management will begin to look for cost reduction in the core activities of the business. Since training is an expensive activity, training budgets will be scrutinized for cost savings. A consequence might be pressure to reduce the frequency of recurrent training to the minimum specified by JAR-FCL (JAR — Flight Crew Licensing) or to outsource it to a third party. However, since the importance attached to company culture varies between airlines and differing SOPs may be used, there are concerns that third-party instructors who may train a variety of airlines might be in the wrong "company mode" when training.

Airlines in general and new entrants in particular are acutely aware of the public relations damage that a serious incident would inflict on their success. One new entrant emphasized that expenditure on training is generally forthcoming and fully supported by senior management. This airline is making large investments in training, although it was suggested by this individual that this was unusual in the industry.

It was suggested that airlines only provided CRM training originally because it was imposed on them, but now that their CRM trainers have a better understanding of its benefits, they wish to develop and extend the syllabus. However, senior management are frequently only willing to do what the JAA stipulates, since such additional training would be expensive. These trainers would like the JAA to increase its CRM requirements and are actively promoting its development within the airline management community.

5.3.6 Commercial Decision Making

Management at one airline reported that captains are increasingly being required to make economic decisions. A captain at another airline said that his job was to satisfy himself that his aircraft was fully serviceable, irrespective of any economic consequences and knock-on effects that might arise from delaying departure to have a problem fixed.

There is clearly a dilemma between safety and economics: A captain has the responsibility for the safety of a flight but may be blamed by management if he or she is thought to have taken a commercially detrimental decision. If a pilot succumbs to commercial pressure and as a result is involved in an incident, he cannot, in law, defend his position by saying that the company pressured him to take the actions that he did.

5.3.7 Summary — Commercial Pressure

Table 12 shows the human factors issues involved in commercial pressure and the potential consequences.

6. Mitigating Factors

The previous chapter discussed the effects that commercial development in the aviation industry can have on flight crew. While many of these effects have the potential to impact on flight safety, there are mitigating factors at work to compensate. Three distinct mitigating factors were identified during the study.

CRM and SOPs were mentioned by everyone as a means by which human factors problems are anticipated and overcome, and safety during flight is maintained.

Although not explicitly referred to as a mitigating factor, the professionalism of pilots was mentioned frequently in the interviews and is thought by many people to counter some of the potential problems that have been identified.

In addition to the three mitigating factors, safety regulation sets the safety standards for the industry and defines the limits within which airlines must perform. It therefore acts as a control on the industry and attempts to ensure that any negative effects that may arise from globalization are prevented.

This chapter discusses each of these mitigating factors in turn and considers the influence of safety regulation.

6.1 Crew Resource Management (CRM)

Research in the 1970s into the causes of aviation disasters revealed that the majority of accidents and incidents in aviation involve human error rather than equipment failure or adverse weather.

Table 12
Commercial Pressures: Human Factors Issues

Issue	Potential Consequences
High flying hours	Fatigue, low morale, adverse effects on lifestyle
Unsympathetic rostering	Fatigue, low morale, adverse effects on lifestyle
Management pilots achieving high flying hours	As above; reduction in internal oversight and safety auditing
Reduced ratio of crew per aircraft, with resultant loss of flexibility	Reduced flexibility and possibly increased pressure to fly in adverse conditions (e.g., when flight deck crew are ill)
Senior management positions held by nonpilots	Lack of understanding of operational and flight safety issues, poor interpersonal relationships between pilots and management
Reduced turnaround times	Pressure to hurry/omit external or flight deck preflight checks
Reduced training budgets, particularly for areas that are not legislated (e.g., crew resource management)	Reduced exposure to training scenarios and reduced team-working /error management; particular issue when combined with crew of lower experience or multinationals
Use of third-party training organizations	Inconsistency of trainers who work for a variety of airlines leading to incorrect training; or adoption of generic training by trainers for range of airlines
The contracting out of functions such as training and maintenance to third parties	Less direct control over the quality of such functions
Captains increasingly being required to make commercial decisions	Conflict between flight safety issues and commercial issues may influence decisions to operate in cases where the captain is not 100 percent satisfied

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

The most common types of errors made by the flight crew involve failures in leadership, team coordination and decision making.

Subsequently, training courses were developed for flight crew to try to reduce these errors by focusing on their human factors causes. Initially known as cockpit resource management, this training was a radical shift from traditional pilot training, concerned with the technical aspects of flying.

CRM training has been widely adopted by airlines throughout the world, and its scope has been extended in some airlines in recent years to include other aspects such as monitoring skills and the management of time, workload and stress. It is now known as crew resource management. Sometimes, other personnel such as cabin crew and ground engineers are included in the training.

6.1.1 CRM as a Means of Reducing Human Error

CRM was initially applied to improving team performance within flight crews of the same nationality, but it is increasingly being applied to avoid any negative effects in situations where crew from different national and cultural backgrounds are mixed on the flight deck. A regulator said that CRM has to work "because it is the glue that holds a multicultural crew together." He also said that CRM has to be effective in extreme situations such as a 19-year-old ab-initio pilot flying with a 59-year-old captain with 20,000 flying hours.

It is widely believed in the civil aviation industry that CRM is successful within monocultural organizations, but a question that this study has had to address is whether CRM is as effective in improving the performance of multicultural flight crews.

One airline gave us an example of the success of CRM in their training of Filipinos. Initially, the Filipinos had difficulty in reducing the steepness of the power gradient between captain and first officer, but after a year they were able to overcome this problem. They believe that CRM has helped them to define their roles and responsibilities.

Two Cuban pilots said that CRM enabled them to increase their knowledge and awareness of crew behavior and allowed them to improve their performance when flying. It also alerted them to conflict situations that might arise during a flight and helped them understand why these situations might arise and how to handle them.

An airline said that it is difficult to quantify the benefits of CRM because it becomes part of the system, as indeed it is supposed to. This airline also has a concern that although the quality of CRM instruction is continuously improving, crews may not comply with the lessons which they should have learned.

While everyone interviewed said that CRM training was important and had potential benefits, there appeared to be a variation in their depth of understanding about the need to modify the training to make it effective for a group containing a diverse cultural mix. Not surprisingly, airlines employing monocultural crew were less perceptive about this need than airlines employing crew of many different nationalities. One airline employing flight crew from more than 20 different countries quickly discovered that the outsourcing of CRM training was not effective and, after bringing it in-house, has found it necessary to develop the training over a period of several years to make it effective in a multinational environment. It was suggested that no process appears to exist in the industry to spread this learning experience to others.

Despite the widespread use of CRM as the primary strategy for the reduction of human error on the flight deck, there are some dissenting voices regarding its efficacy. This is supported by recent research (Johnson, 1999) which reports that the successful introduction of CRM training into many U.S. airlines has not been mirrored by any quantifiable reduction in the number of incidents and accidents that stem from crew coordination and communication problems. The same author states that "the relatively high frequency of incidents caused by poor flight crew performance also indicates the failure of existing CRM training techniques" (Johnson, 2000). While no evidence has been found in Europe to either confirm or deny the conclusion of this research, it raises fundamental questions about the overall effectiveness of existing CRM training and the efficacy or cost-effectiveness of the approach itself compared with other possible strategies for reducing human error in aviation.

6.1.2 CRM and Human Factors

The human factors departments of airlines tend not to employ human factors professionals with appropriate qualifications. Instead, they generally consist of CRM trainers and line pilots who have developed an interest in the subject of human performance. Although these personnel have the appropriate industry-specific knowledge, the lack of human factors professionals in the airlines is perhaps surprising compared to other safety-critical industries. This is also true of some safety regulators where it is rare to find professional expertise in human factors.

The implications of not having qualified human factors specialists working in the safety function of airlines is that the opportunity to capitalize on the broader base of human factors knowledge, including that used in other safety-critical industries (see Chapter 9), will be missed. Also the current tendency within the operational area to suggest that CRM and human factors are synonymous will continue unchallenged.

6.1.3 CRM in Different Cultures

One safety regulator said that to be effective, CRM must be tailored to an airline's culture. In his opinion, CRM should not be purchased as a package since people from different cultures think differently to arrive at the same solution. He believes that CRM should first be adapted to a country and then to an airline within the country.

A U.K. airline reported that they train CRM trainers from overseas subsidiaries in the United Kingdom. These trainers then return to their home base to train staff in a manner appropriate to their own national culture. They believed this approach to be effective.

An Eastern European airline that has only recently started to provide CRM training said that the principles of CRM have been carried out informally for a number of years. The airline has purchased a package developed by a U.K. company. They recognize that culture is important in the presentation of the material, and the supplier has adapted the package to suit the local culture.

Cultural adaptation of CRM material is therefore taking place in two distinct ways: within an airline and by the supplier. It has not been possible to collect any evidence in this study of the effectiveness of these two approaches.

CRM appears not to be adopted by all cultures; for example, pilots from a certain Eastern European country were described by one airline as being poor team workers and unfamiliar with the concepts of CRM. From the evidence collected during this study, it would appear that some Eastern European countries are addressing this omission.

A Japanese company suggested to one regulator that CRM is a solution to Western problems and that it may not be appropriate in cultures that experience different problems.

An interesting situation exists when non-European pilots wish to maintain their licenses in their countries of origin and in Europe. Two Cuban pilots said that they are required to maintain their Cuban license as well as their European license. To meet this requirement, they have to undertake CRM training in Spanish in Cuba and in English in Europe. There may be flight deck safety implications should the philosophies of these two CRM training courses differ. On the other hand, there may be positive effects if the two CRM courses reinforce each other.

6.1.4 CRM Expectations

CRM creates expectations for the relationship between flight crew, cabin crew and engineering staff, and one airline said that there has been confrontation in the past when these expectations have not been met. An interesting comment made about CRM is that younger crew tend to have great expectations about teamwork after training in CRM which are not always met when working with a much older captain. In one sense, therefore, CRM may actually make matters worse in a relationship when expectations are unfulfilled.

6.1.5 Outsourcing of CRM Training

Outsourcing of CRM training is generally considered to be undesirable. For example, one airline's experience of external CRM trainers was that their material was too generic. The solution for this airline was to bring the training in-house and develop the material to make it more suitable for many different nationalities.

Nevertheless, outsourcing of CRM training is common, particularly for smaller airlines that believe it would be uneconomical to run their own training. When CRM training is outsourced, it may not be company-specific. For example, one airline that was interviewed uses a local company that includes pilots from other airlines operating out of the same hub in their training sessions.

6.1.6 Integrated CRM

In some airlines, there are few barriers between the cabin crew and the flight crew. For example, one airline described the relationship between the two as being very relaxed and said that cabin crew have ready access to the flight deck. However, this is not the case in all airlines or on specific aircraft types. Some airlines conduct CRM training for mixed groups of cabin crew and flight crew. One airline said that they also involve maintenance and engineering personnel in the CRM training. Feedback from participants is that the integrated approach is successful.

However, this practice is not adopted in all airlines, and it is often the management of the airline who are not convinced about the value of integrated CRM. One airline interviewed used to carry out joint cabin and flight deck crew training, but the practice has now been stopped at the request of management. This attitude may indicate a lack of understanding of the purpose of CRM. Interestingly, one regulator said that the "C" in CRM should stand for "company," since in his view the philosophy of CRM should pervade the entire organization.

Finally, as noted earlier, while CRM is believed in the industry to be a very effective tool, the standard of CRM training and implementation is perceived by many flight crew to be to very varying standards, both nationally and internationally. There is little doubt that some airlines have devoted substantial resources to try to achieve the highest standards, while for some others, it is rather more a question of providing what might be described as a barely adequate course to comply with legal or authority requirements, with little positive commitment from senior management.

6.1.7 The Effect of Recent Commercial Developments on CRM

CRM training has undergone several updates since its inception over 30 years ago. The more recent versions of this training have undergone considerable development to take into account changes in the industry, such as the increased use of multicultural crews. The latter versions of CRM also consider human performance limitations such as fatigue and attention, widening the scope further to include more areas of traditional human factors, rather than emphasizing social psychological issues exclusively. It is therefore difficult to make generalizations regarding the efficacy of CRM as a control measure due to the many variations in the scope and content of CRM training programs. There is some evidence that the CRM industry is therefore responding to changes due to globalization.

It should be noted that other approaches exist to tackle a wider range of human factors problems such as cockpit automation issues, fatigue and SOPs compliance, and these approaches should not be neglected because CRM is seen as the solution to all human factors problems.

6.1.8 Summary — CRM

Table 13 shows the human factors issues involved in CRM training and the potential consequences.

6.2 Standard Operating Procedures (SOPs)

6.2.1 Variation in SOPs Between Airlines

Each airline may modify manufacturers' SOPs to a greater or lesser extent and has a strong sense of ownership toward its own SOPs. Several airlines said that SOPs can vary greatly between carriers, although others suggested that most carriers' SOPs are only slight modifications from the manufacturers' versions. One regulator said that SOPs are largely standard and that most airlines use those recommended by the manufacturers.

It would appear that new-entrant airlines generally adopt manufacturers' SOPs with little, if any, modification, whereas established airlines will often have adapted these SOPs quite considerably.

Since safety regulators do not allow the operation of mixed SOPs, crew could not be mixed within an alliance unless all partners of the alliance were using the same SOPs.

In mergers and acquisitions, SOPs need to be harmonized, and one of the airlines involved, usually the larger, will normally impose its SOPs on the other. Equitable harmonization is unusual and was defined by one airline as "where discussions take place and agreement is reached on a compromise where no party is satisfied."

Merging SOPs may well be a lengthy procedure. One airline involved in a merger reported that in spite of both companies having sets of procedures that were very close to those issued by the aircraft manufacturer, merging them was still a major task. A long consultation process was necessary, involving technical managers, training managers and pilots' representatives.

6.2.2 Adherence to SOPs

One safety regulator said that he would be naive if he thought that SOPs were followed all the time, but he believes that in the vast majority of cases they are. His opinion is that very few incidents would occur if SOPs were always adhered to rigidly.

Table 13
Crew Resource Management (CRM): Human Factors Issues

Issue	Potential Consequences
CRM training may not be tailored to reflect the increasing use of multinational crews	CRM initially was devised for use within a sole country/culture and may not have been tailored for use in multinational crews
Reliance on CRM to solve all human factors issues	Neglect of other causes of error on the flight deck (e.g., fatigue, interface and automation issues)
Heavy reliance on CRM training to reduce errors, with little validation that it has the desired results on the flight deck	Crew may pay lip service to CRM, rather than embracing its principles; unjustified confidence by management that CRM will prevent incidents
CRM trainers are pilots, not human factors professionals	Concern that CRM trainers are part of the culture and therefore may be unable to assess CRM objectively, or may be unable to consider novel approaches to error management
CRM increases the expectations of younger crew and non-nationals	May make matters worse if the high expectations of these crew are not met
Outsourcing of CRM training	May not be successful if not tailored to the individual company
Crews maintaining licenses in more than one country are required to attend several CRM courses	The different courses may reinforce each other, but they may have different or conflicting philosophies
Over-regulation of CRM	Standardization and inflexibility may not allow for changes to the philosophy

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

The management of one airline stated that crew are trained to follow SOPs at all times since it is the primary means to reduce risk. Two pilots from the same airline said that they always follow SOPs and that almost everything is included within them, including how to deal with unusual problem situations. In their experience, if anyone deviates from the standard, they are asked by the other member of the flight crew to desist. It follows that adherence to standards and procedures will be influenced by the prevailing safety culture in the company.

However, one airline raised a concern that as flying becomes increasingly routine, crew may not follow SOPs through a desire to be individualistic. A line captain said that procedural violations are a fairly common practice. He gave an example of when he requested that another member of the crew follow the SOP and was told that “this is not a line test.” A pilot from an airline in Southern Europe suggested that Southern Europeans are worse than Northern Europeans at following procedures. The reason he gave is that SOPs violations are tolerated more easily in his country than in some Northern European countries. He added that all rules have a philosophy behind them and pilots may try to follow the spirit of the rule rather than the rule itself.

There may be variations in SOPs adherence at different times during a flight. For example, one pilot said that he would be more likely to follow SOPs if he was suffering from fatigue toward the end of a long flight.

Flight operational quality assurance (FOQA) using quick-access recorders (QARs) to pick up deviations from the flight parameters specified in the SOPs is becoming increasingly common throughout Europe, and all the major operators generally use such systems. These systems allow individual flight-parameter exceedances to be identified. In cases of best practice, in the event of a major exceedance, the pilot is contacted by a “trusted person” to give his or her version of the event. The most beneficial effect of using information from QARs is achieved in those airlines which have adopted a “no blame” policy and where full and open reporting is actively encouraged without the fear of disciplinary action.

The use of QARs assists the safety process by highlighting areas of exceedance which will then be brought to the attention of the pilot force and which may require particular attention during the annual refresher training program.

6.2.3 SOPs and Flight Deck Error

Many interviewees stressed the use of SOPs as an important factor in reducing pilot error, reinforcing the vital necessity of cross-checking. Several airlines suggested that human factors issues should not arise if SOPs are strictly followed and CRM is effective. Another airline said that SOPs are particularly important when nationalities are mixed, as they provide discipline. Singapore Airlines was given as an example of an airline employing many different nationalities where SOPs have been developed to cover all situations and where there is a strong culture of enforcement.

Safety concerns arise where crew from an airline that has been taken over resent having to work to a new set of SOPs which they consider to be inferior. There may be a tendency to use the old SOPs at every opportunity, or the crew may revert to the old, more familiar SOPs in error. Furthermore, crew may be more likely to revert to old procedures inadvertently in a degraded or emergency situation. When major changes are made to procedures, there may well be a transition period of increased risk, which requires careful management.

Human factors issues relate not just to the content of an SOP, but also to the person who is required to perform each task in the procedure. Problems may occur when roles and responsibilities are different from those that the crew are used to. Given that many actions in an SOP require a response from one crewmember to a request or challenge from the other, it is possible that an omission error may occur if the request is not issued.

Agency crew are required to operate the SOPs of the airline to which they are seconded and thus need to be provided with the necessary training. The extensive nature of this training precludes very short-term contracts. Since agency personnel may quite frequently have to adjust to working with different sets of SOPs, they may inadvertently revert to a previously familiar procedure.

SOPs aim to ensure that all pilots within an airline fly to the same procedure on a particular aircraft type. This is desirable if the procedures are robust, but if there is a weakness in an SOP, problems will occur throughout the company.

6.2.4 The Effect of Recent Commercial Developments on SOPs

There may be a trend toward the greater adoption of manufacturers’ SOPs by airlines, and this may be a function of recent developments, as it is the new entrants that are leading this trend. Manufacturers’ SOPs may be adopted due to perceived cost benefits or where the airline lacks the operational experience to modify these procedures.

Although current SOPs may mitigate some of the effects of globalization (such as the mixing of crews with different cultures, backgrounds, experience, etc.), future SOPs will continue to evolve in light of operational experience with such issues. For example, they may become more structured and comprehensive in order to control risks associated with the increased variability of flight crew.

Furthermore, certain globalization concerns actually stem from the SOPs themselves. For example, as discussed in Section 6.2.1, the harmonization of SOPs between different airlines is a formidable barrier to airline mergers.

6.2.5 Summary — SOPs

Table 14 shows the human factors issues involved in SOPs and the potential consequences.

6.3 Professional Culture

For an industry that is relatively young, aviation has developed a strong and distinctive professional identity, and this is particularly apparent in the professional culture found among pilots. National and organizational (company) cultures have been discussed earlier, but professional culture may pervade all other cultural boundaries.

In the interviews, it was stated on a number of occasions that this professionalism counters many of the potential problems that have been identified.

6.3.1 Components of Professional Culture

Flight crew are required to maintain high vigilance during extended periods of low workload and yet have to be able to make an abrupt transition to demanding or occasionally overload conditions. Furthermore, they are normally required to form a coherent team from a group of strangers and immediately begin to perform demanding, safety-critical work. This team formation may not always be successful. Research by the U.S. National Transportation Safety Board (NTSB) has indicated that a disproportionate percentage of accidents involve crew who are flying together for the first time.

Several management and line pilots spoke about the characteristics that are frequently found in flight crew and contribute to a strong professional culture. Flight crew were generally described as intelligent, although not necessarily with tertiary education qualifications, with a high degree of self-confidence. Strong self-discipline and self-motivation were said to be essential to cope with the working environment. Flight crew were also said to dislike change. Because they are conservative, they are more comfortable with change if it is long-term and gradual.

In most European countries, there is an element of self-selection before deciding to become a pilot. Selection for sponsored training, which is not currently the norm, is highly competitive, and many crew pay the considerable training-college fees themselves. A necessary prerequisite in these cases is, therefore, the possession of sufficient finance by them or their families. Few other professions require such significant private investment in order to be considered for employment. Clearly, those that enter training have a great enthusiasm for aviation and a strong desire to become a pilot. People do not drift into this.

Table 14
Standard Operating Procedures (SOPs): Human Factors Issues

Issue	Potential Consequences
Mixing of crews between mergers and alliances. Although not currently permitted in an alliance by regulators, it may become more prevalent in coming years.	Confusion between different SOPs, reversion to more frequently applied SOPs, confusion as to flight deck roles and responsibilities
Differences in culture toward use of SOPs — following written checklists versus working from memory	Conflict of cultures where crew have different attitudes to use of (written) procedures
Differences in culture toward adherence to SOPs	Conflict of cultures where crew have different attitudes to adherence to procedures
Differences in culture toward following SOPs to the letter or following the spirit of the rule	Conflict of cultures where crew have different attitudes
Harmonization of SOPs following a merger Increased use of agency crew	Crew inadvertently applying better-known SOP (particularly during transition period) or willful reversion to the previous SOP; relates to definition of roles in the procedure as well as content
Increased requirement for SOPs for all tasks on the flight deck	Crew experience boredom and express individualistic tendencies (deviating from SOPs for variation); crew become less capable of intervening in a degraded situation "outside" of SOPs; unrealistic faith in the use of SOPs as a measure to prevent human error; crew anticipate subsequent step in the procedure, hearing what they expect rather than what was said; if SOPs are inadequate then the quality in whole fleet or airline could be affected
Crew moving to an airline that places more or less emphasis on SOPs	Crew find difficulty in adjusting to the new environment

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

In some airlines, the selection process for ab-initio and qualified pilots is extremely demanding and includes psychometric, intelligence and aptitude testing, group exercises, written questions, interviews and a substantial medical examination. In others, it only includes an informal interview and a simulator assessment. One airline said that psychometric testing, which is more commonly used in the selection for sponsored training, had been tried for direct-entry pilots but was found to be superfluous since it did not enhance its selection process.

Pilots generally state that they enjoy their jobs a great deal. In a survey by Helmreich, 75 percent of pilots from 19 countries said they were extremely satisfied with their job, compared with only 36 percent of people in other occupations. However, this difference may be partly explained by a psychological theory that postulates that when individuals undergo extensive and expensive training and initiation, they may unrealistically perceive group identity as being highly worthwhile.

Invariably, the professional culture is not monolithic, and there is a variety of subcultures in the industry. These subcultures may exist around several aspects, such as:

- Background (commercial or military);
- Type of airline (flag carrier, regional carrier, etc.);
- Position (management captain, captain, first officer, flight engineer); or,
- Gender (male, female).

6.3.2 Professional Culture and Safety

A strong professional culture has both strengths and weaknesses. On the positive side, pilots take great pride in their profession and have a strong motivation to perform to the best of their ability. However, there are negative aspects of a strong professional culture, such as an unrealistic denial of vulnerability to factors such as fatigue, stress or personal issues. Given the great responsibility of pilots, denial of personal vulnerability may be a psychological defense mechanism to avoid performance anxiety. Researchers at the University of Texas Human Factors Research Project (Helmreich et al.) report that the majority of pilots in all cultures agree that:

- Their decision making is as good in emergencies as in normal situations;
- Their performance is not affected by personal problems; and,
- They do not make more errors under high stress.

This research was supported by evidence from the interviews that were carried out. One management pilot expressed the belief that the high level of professionalism of pilots rules out many potential problems from multinational flight crews. Several pilots said that commercial pressure would not lead a pilot to take risks because they have a very high regard for safety.

Another management pilot divided flight crew into three groups: those that avoid errors (proactive); those that get on to errors quickly (mid-range); and those who are slow to react to errors (reactive). His view is that the proactive group is the safest, but he added that as technology advances and systems become increasingly complex, the vulnerability of humans grows. The consequence is that flight crew tend to become more reactive.

It can be hypothesized that some components of aviation professional culture may sometimes act to decrease flight deck safety, particularly if taken to the extreme. For example:

- A high level of pride in their work may make crew reluctant to admit to error;
- A high degree of personal confidence may lead to a disregard of the opinions of others or to the disregard of checklists and SOPs; and,
- An unrealistic perception of human limitations may reduce teamwork or lead crew to take risk in order to complete the flight.

Two instances were described which support this hypothesis.

The first was of a first officer advising a captain — who had only previously flown domestic routes and was commanding his first long-haul flight — of several operational problems that might arise because their destination was at the limit of the aircraft's range. The captain was not prepared to listen because he thought that he was losing face in front of the rest of the crew and his professionalism was being questioned.

The second was of a captain who made a series of errors, despite warnings from the flight management system, that resulted in an engine being shut down during the cruise phase of a flight. The very experienced first officer was able to recover the situation quickly, but the captain refused to admit that he had done something wrong and blamed the shutdown on an aircraft malfunction.

Given that work is a central aspect of our lives, it is not unreasonable that the values of professional culture become part of the self-concept. Therefore, a sense of invulnerability may become internalized, and this may in part explain why evidence of personal limitation is often played down.

In their book *Culture at Work in Aviation and Medicine* (1998), Helmreich and Merritt pose the following question:

> Do you think that your perceptions of your employer or organization affect your level of commitment and job performance?

Some may argue that regardless of the environment, professionalism should, and does, transcend organizational difficulties. While this is a reassuring answer from a safety perspective, it may not necessarily be true. As has been discussed in section 5.2, issues with the company or management do occur in periods of extreme organizational change, such as mergers and acquisitions.

6.3.3 Professional Culture and CRM

Some researchers have developed a further revision of CRM centered on error management. This generation of CRM recognizes that error is inevitable and attempts to change the professional culture by "fostering a more realistic awareness of personal limits and capabilities" (Helmreich and Merritt, 1998). If pilots universally accept that human error is inevitable, then measures to counter such error will be better received by crew in CRM training. Furthermore, acknowledging the inevitability of error also assists in the reporting of personal mistakes and mishaps, assuming that the airline has adopted a no-blame culture. This generation of CRM stresses that errors will occur despite best efforts to the contrary.

Attitudes are changing over time as CRM training focuses more on human error and the limitations of human performance. There is scientific evidence that agreement with statements such as "even when fatigued, I perform effectively during critical periods" is reduced where the latest generation of CRM is practiced. Clearly, professional culture can be changed, although, as with any culture change, this is a long-term process.

6.3.4 Professional Culture and Change in the Industry

It has been suggested earlier that a strong professional culture can have positive and negative implications for flight safety. The positive effects will act as mitigators, but should professional culture become degraded following any aspect of change in the aviation industry, the positive effects may lessen. If the components of professional culture can be identified, it may be possible to assess the effect that change in the industry will have on each component and therefore on flight safety.

Some examples of the causes and effects of change in professional culture are described below. It should be noted that not all the examples have a negative effect on flight safety.

- Several people that were interviewed said that young people who might previously have trained to be pilots are being attracted to other lucrative professions. This will reduce the number of potential entrants to the profession, which perhaps already does not enjoy the prestige previously associated with a career in civil aviation;

- Mixing flight crew from all over the world may lead to the perception among pilots that they are less of a coherent group. In the past, mergers have tended to combine professionals in similar countries and companies, thereby reinforcing the belief in a common identity. However, as globalization increases, the disparity in training/selection/procedural standards and pay/conditions, for example, may act to diminish the view of such a common identity;

- Increased attention on flight deck safety and human factors, the increased publication of aviation incidents and (particularly) the emphasis on human performance limitations in training may all act to reduce the perception of infallibility/invulnerability in crew; and,

- As technology advances and automation levels increase, the "romance-of-flight" effect may be weakened. In the past, the heroic actions of pilots under conditions of extreme stress have contributed to the professional culture of aviation.

6.3.5 Summary — Professional Culture

Table 15 shows the human factors issues involved in professional culture and the potential consequences.

6.4 Safety Regulation

Safety regulation is different from the other three mitigating factors since it sets standards and limits to which the airlines

Table 15
Professional Culture: Human Factors Issues

Issue	Potential Consequences
Crew may have a high level of pride in their work.	Crew may be reluctant to admit errors or report incidents.
Crew may have a high level of personal confidence.	Crew may disregard the opinions of other crewmembers or ignore checklists and SOPs.
Crew may exhibit an unrealistic perception of human limitations.	Crew may be unwilling to accept error-reduction strategies.
Globalization may erode the positive effects of professional culture.	Professional culture may have less of a mitigation effect on those issues that may adversely affect flight deck safety.

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

must perform. It therefore influences the application and, by extension, the effectiveness of both CRM and SOPs. However, safety regulation in Europe is not yet fully harmonized. Differences in the legal systems of each member state mean that European airlines are not overseen by a coherent legal entity, unlike the situation in the United States.

6.4.1 Objective-based Regulation

Some regulators are taking a less active role in enforcing standards by setting objectives and allowing airlines to take greater responsibility for their own oversight by means of self-audits. One airline suggested that self-audits may work well in a disciplined society like the United Kingdom but will be more difficult to implement successfully in other, less-disciplined countries. Another made a distinction between large established airlines where it was thought that self-auditing would generally be successful and small airlines where it might be more problematic.

One airline said that because of increasing commercial pressure, effective regulation is required to ensure that the required standards are maintained. Another said that regulation is necessary to ensure that airline management invests adequately on safety-related matters. For example, management may only be prepared to purchase and install new equipment on an aircraft if there is a regulatory obligation to do so.

A problem that was raised with the increasing emphasis on self-regulation was that it is becoming increasingly difficult for airlines to recruit suitably experienced people as nominated post-holders to carry out this important role. There is, therefore, a need to provide better training to these people to ensure that they are competent to carry out their duties.

A regulator said that an advantage of airlines working together in an alliance was that they audit each other's operations to ensure that they are of similar and adequate standards. This has the effect of raising the standards of all members of the alliance to the standards of the most rigorous member. Airlines also exert control over their franchise holders by carrying out regular audits.

6.4.2 The Mixing of Flight Crew

In general, regulators are not concerned about airlines operating with multicultural flight crews provided all the standards and regulations in force are satisfied and local licenses or validations are held. One regulator said that his organization had already experienced a number of the effects of globalization as many of the airlines under its jurisdiction employ or contract pilots from all over the world. He would be more concerned about mixing flight crew from different airlines within an alliance, which he said would be more of a challenge. It is interesting to note that several regulators interviewed thought that mixing crew within an alliance was likely to take place in the future, whereas none of the airlines interviewed did.

One regulator made a distinction between "globalization" and "Europeanization." He said that within Europe there are national differences but outside Europe there are continental differences. For example, Africans and those from Far Eastern nations have a very different outlook on life than North Americans. He believes that integration between the JAA and the U.S. Federal Aviation Administration (FAA) will be difficult and said he would be concerned about pilots who did not hold a JAA license flying aircraft registered in Europe.

Cross-validation of foreign licenses is reported to be an increasing problem by one airline which relies on non-JAA-licensed pilots in some areas. These pilots need to validate their licenses to operate in the JAA area, and they are open to problems in transition between the two systems. The airline expects "growing pains" as JARs are interpreted differently in different companies and countries. The same standards apply in all places where the company operates, and the costs involved with compliance are reported to be huge. They said that one of their biggest challenges is to remain JAR-OPS (JAR — Operations) compliant in some of these countries.

One safety regulator provided an interesting example which indicates that regulation can reduce the opportunity to mix flight crew.

The example concerns an operator with airlines in two countries operating under different approvals and licenses. To increase efficiency, the operator wished to create a common pool of aircraft and crew that could be used in a flexible way but did not want to merge the airlines for commercial reasons. This created several legal problems for the regulator in one of the countries. For example:

- Regulations of the country do not permit a captain to command an aircraft registered in that country unless he or she also holds a license issued by that country;
- Each airline had its own chief pilot and set of operating manuals; and,
- Regulations of the country specify that a minimum number of the cabin crew should hold certificates of competency issued by the regulator of that country.

While rules such as these are not in force in all JAA countries, the example is given to illustrate how the safety regulator in a specific country can constrain the flexibility of an airline to mix crew.

6.4.3 JAR-OPS

There are difficulties being experienced by some regulators and airlines in the implementation of JAR-OPS. One airline said that although JAR-OPS is currently being introduced, full implementation is likely to take many years and will have a large impact on the company. Another said that one of their biggest challenges is to remain JAR-OPS compliant in some of the countries that they serve outside the JAA area. They report huge costs in maintaining this compliance. Another airline said they believe that there is a tradeoff between the high cost of training and the benefits arising from this training. A regulator said that it was unable to cope with the amount of work required to implement JAR-OPS, as it requires significant resources.

6.4.4. CRM Training

One captain suggested that CRM training was overregulated. He was concerned that Europe simply took the U.S. CRM approach and approved it, and said that this would be bad practice in a region with only one culture but was even worse in an area such as Europe, composed of many different cultures. He said that the implementation of CRM requires careful management and that a program of research should be set up into how CRM can be effectively implemented in Europe. CRM is highly legislated, but there needs to be scope for the further development of the philosophy. The representatives of another airline believe that the JARs requirements for CRM are too low and that the JAA should be promoting the development of CRM and giving it a higher profile.

Not all countries have their own regulations for CRM training. For example, in Italy, the only requirements for CRM at present are in JAR-OPS. Because the implementation of JAR-OPS is incomplete, CRM training is, in effect, an option for airlines.

In some countries, regulators approve CRM courses, require sight of the airlines' syllabuses and timetables for CRM training, and sit in on CRM courses on a random basis in order to check the quality.

7. Effectiveness of Mitigating Factors On Human Factors Problems Arising From Commercial Developments

A number of tables of human factors issues and their potential consequences have been presented in Chapter 5 and Chapter 6. An analysis of these tables has identified several issues that have the potential to directly or indirectly affect the nature and likelihood of human error on the flight deck. They are:

- Teamwork;
- Communication;
- Fatigue;
- Morale and job satisfaction;
- Experience and competence; and,
- Situational awareness.

In addition, safety auditing and internal oversight have an overarching objective of ensuring that whatever changes take place in the industry, safety standards will be maintained.

This chapter analyzes these issues and considers the extent to which the likelihood of any of them having a negative impact on human error may be reduced by the three factors of CRM, SOPs and professional culture. The impacts identified are partly based on the information gathered during the survey and partly based on the professional judgment of the study team. Direct links are made between structural changes in the industry, human factors issues and flight deck errors. An overview of these links can be found in Figure 4.

These issues are not necessarily independent. For example, fatigue and crew morale may be influenced by the same factors. Furthermore, some of these issues may also be influenced by a variety of factors unrelated to commercial developments in the industry.

7.1 Teamwork

Teamwork has long been recognized by the industry as critical to safe operations, and this has led to the growth of CRM training. One of the key issues in teamwork is the cockpit power gradient (or authority gradient). This refers to the relationship or command structure between the captain and copilot, including the definition of roles (the nature of the task) and responsibilities (who performs what task).

The ability of the flight crew to operate as an effective team may be influenced by a variety of crew characteristics (which may be interrelated), including:

- Nationality;
- Native language;
- Level of experience;
- Technical ability;
- Seniority;
- Background;
- Religion;
- Age;
- Attitudes;
- Morale; and,
- Job satisfaction.

These characteristics may in turn be influenced by several factors resulting from commercial developments in the industry, including:

- The merging of national cultures;

- The merging of company cultures;
- The recruitment of non-nationals;
- The recruitment of less experienced crew;
- The recruitment of agency/contract crews; and,
- The quality of training (both technical and nontechnical).

The impact that each mitigating factor has on teamwork is shown in Table 16.

7.2 Communication

Communication, as discussed here, does not include power-gradient issues, which are included in the above analysis of teamwork. Communication issues may occur in relation to the flying task and to social situations outside the cockpit.

When communication between one flight crewmember and ground crew or ATC takes place in the local language, the other crewmember may be unable to monitor the conversation if his or her knowledge of the language is inadequate. As a result, misunderstandings may occur and situational awareness may be reduced.

Language relating to the flying task is largely standardized, and the use of SOPs will mitigate against errors in standard situations or anticipated contingencies. However, in the case of degraded or emergency situations that are not covered by an SOP or where the situation is changing rapidly, the crew may not have the language ability to communicate effectively within the cockpit and may therefore be unable to work as a coherent team.

Although the formal communication between members of multinational crews may not be impaired in relation to the flying task, they may not have the language ability to be able to socialize properly either inside or outside of the cockpit, which is particularly important on long-haul flights and stopovers. This may further hinder the formation of a coherent team.

A range of factors will influence the success of flight deck communications and include:

- Nationality;
- Native language; and,
- English language ability.

These factors will in turn be influenced by:

- The merging of national cultures; and,
- The recruitment of non-nationals.

The impact that each mitigating factor has on communication is shown in Table 17 (page 46).

Table 16
Effects of Mitigating Factors on Teamwork

Mitigating Factor	Impact on Reducing the Negative Effects of Commercial Developments on Teamwork
Crew resource management (CRM) training	May act to reduce the adverse effects of crew characteristics on flight safety (e.g., by ensuring an appropriate power gradient between crew regardless of background/seniority/age/experience). It may be less effective in addressing issues relating to: • Multinational/multicultural crews, for which it was not originally designed; • Crews that have very different backgrounds (military versus commercial); and, • Crews who have been trained in differing CRM philosophies (e.g., from different national cultures).
Standard operating procedures (SOPs)	Adherence to SOPs may assist in teamwork. However, different cultures have varying attitudes towards the adherence to procedures, which may create conflict and therefore reduce effective teamwork.
Professional culture	A “bond” between aviators (in the sense of being fellow professionals) may act to encourage team spirit regardless of their background, etc. However, it may not assist in team building where conflicts arise on significant issues, such as adherence to SOPs.

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

Table 17
Effects of Mitigating Factors on Communication Problems

Mitigating Factor	Impact on Reducing the Effects of Communication Problems
Crew resource management (CRM) training	CRM may be expected to have positive effects on crew communication in the cockpit, especially in the sharing of information and decision making in emergency situations and their precursors. However, where the crew have no influence on the language spoken (e.g., when air traffic control communicates in the local language to other aircraft), CRM will have no beneficial effect.
Standard operating procedures (SOPs)	Where the flying task is highly proceduralized, communication between different nationalities is driven by the SOPs. However, these will have little value in unexpected situations not covered by SOPs, where communication is less formal.
Professional culture	It is not anticipated that professional culture will reduce communication problems apart from the benefits of shared technical knowledge.

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

7.3 Fatigue

Several of the findings discussed in the earlier sections suggest that recent commercial developments may increase flight crew fatigue, which could have an adverse effect on flight deck safety. Fatigue has direct and well-established influences on human performance. As early as the 1940s, fatigue was shown to produce a higher frequency of errors by pilots in a fully instrumented, static aircraft cockpit. With increasing fatigue, pilots tended to scan instruments less effectively. Pilots increasingly thought that their performance was more efficient when in fact the reverse was true. Timing of actions and the ability to anticipate situations were particularly affected (Bartlett, 1943). More recent research (e.g., Meijman, 1997; Hockey, 1997) has confirmed these effects.

As a result of recent commercial developments, the likelihood of flight crew fatigue may be affected by:

- Increased flying hours;
- Unsympathetic rostering practices;
- The need to perform additional ground-based/management tasks; and,
- Absence of JAA/EU rules on flight time limitations.

These factors in turn may be influenced by:

- Shortage of experienced pilots;
- High utilization rates of crews; and,
- Lack of operations/administration support.

The impact that each mitigating factor has on fatigue is shown in Table 18 (page 47).

7.4 Morale and Job Satisfaction

Of all the human factors issues, the mechanisms by which morale and job satisfaction influence flight deck safety are the most tangible and to a certain extent controversial. However, in other safety-critical industries, morale is considered to be a factor in incident causation. It is stressed that any adverse effect of low morale on flight deck safety is unlikely to be a deliberate decision or action (sabotage), but it may nevertheless influence performance.

There are a number of ways in which low morale could contribute to flight deck errors. The level of morale of an individual or a team influences the amount of "disgressional energy" that they are prepared to put into their tasks. If morale is low, there may be a tendency to perform to the minimum standards rather than to exert extra effort to achieve best practice. The same factors that influence morale may also increase "internal distractions" — for example, concern or preoccupation over significant employment issues (such as the merging of seniority lists during a merger or personal problems) may temporarily divert attention away from the flying task.

Morale may be influenced by:

- Increased flying hours;
- Unsympathetic rostering practices;
- Inability to achieve required or desired days off;
- Discontent with seniority issues (particularly the merging of seniority lists);

Table 18
Effects of Mitigating Factors on Fatigue

Mitigating Factor	Impact on Reducing the Effects of Fatigue
Crew resource management (CRM) training	Recent versions of CRM *may* educate crew as to human performance limits, making crew aware of when and how they may be more likely to suffer from fatigue. They may also outline actions to be taken should pilots experience excessive fatigue (e.g., increased checking or relying more on fellow crew). However, some versions of CRM do not consider such factors.
Standard operating procedures (SOPs)	SOPs may counteract the effects of fatigue by reducing the reliance on judgment and minimizing the need to perform working-memory-intensive tasks such as diagnosis, decision making and strategy formulation. However, as discussed previously, this benefit will only apply to situations that can be anticipated in advance. Also, the effects of fatigue tend to be most manifest in low-stimulation, sustained-attention tasks such as monitoring instrumentation or airspace, or when dealing with unpredicted, stressful situations. These types of tasks are not generally governed by SOPs.
Professional culture	Flight crew may be less aware of their limitations and consider that high levels of professionalism counter any adverse effects of fatigue. However, since the effects of fatigue operate at a physiological level, it is unlikely that they will be effectively controlled even by the levels of dedication and diligence associated with a highly professional attitude.

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

- Changes in other employment conditions (e.g., relating to leave or other benefits); and,
- Uncertainty regarding the future of the company or the flight crew.

These factors may in turn be influenced by:

- Shortage of experienced pilots;
- High utilization rates of crews;
- Lack of operations/administration support;
- Merging or acquisition of airlines (regardless of cultural issues); and,
- Major organizational change.

The impact that each mitigating factor has on morale and job satisfaction is shown in Table 19 (page 48).

7.5 Experience and Competence

The experience and technical competence of flight crew are critical to the safety of the flight. It has already been suggested that some of the effects of recent commercial developments may act to reduce the average level of experience or technical competence on the flight deck.

As a result of these developments, experience and competence may be influenced by:

- Recruitment of pilots with minimal flying hours;
- Recruitment of pilots from less-developed aviation states;
- Reduced quality of training (both technical and nontechnical);
- Reductions in safety auditing and internal oversight; and,
- Early promotion to command.

These factors may in turn be influenced by:

- Shortage of experienced pilots;
- Difficulty in retaining senior crew;
- Reductions in training budgets;
- Use of third-party training organizations; and,
- Increased load on management pilots during mergers, leading to neglect of training functions.

The impact that each mitigating factor has on experience/competence is shown in Table 20 (page 48).

Table 19
Effects of Mitigating Factors on Morale and Job Satisfaction

Mitigating Factor	Impact on Reducing the Effects of Commercial Developments on Morale and Job Satisfaction
Crew resource management (CRM) training	CRM would not appear to mitigate the effects of low morale.
Standard operating procedures (SOPs)	SOPs will ensure that the minimum level of diligence required for safety-critical tasks will be applied. However, some of the results of low morale that may affect flight deck errors (e.g., diversion of attention by internal preoccupations) will not be compensated for by SOPs.
Professional culture	The professional culture of aviators may to some extent reduce the impact of low morale on the flight deck in that it will ensure that flight crew adhere to the minimum standards of performance.

Table 20
Effects of Mitigating Factors on Experience and Competence

Mitigating Factor	Impact on Reducing the Effects of Commercial Developments on Experience/Competence
Crew resource management (CRM) training	CRM training may ensure that the assignment of tasks to flight crewmembers takes into account their experience and competence levels and uses the cockpit resources to their best advantage. However, if all of the flight crew are inexperienced, then it may be difficult for the captain to exercise leadership.
Standard operating procedures (SOPs)	To a certain extent, a highly proceduralized environment supported by extensive SOPs will compensate for inexperience. However, crew exist on the flight deck for the same reasons that other safety-critical industries employ humans — partly in order to intervene in the event of an abnormal or degraded situation. Safety concerns may arise with inexperienced crews in the situations which require interventions not covered by SOPs.
Professional culture	Professional culture will not directly compensate for inadequate experience or competence.

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

7.6 Situational Awareness

Continual awareness by flight crewmembers of the operating state, location and other characteristics of the aircraft are necessary for a safe flight. This is generally referred to as situational awareness. Situational awareness has an essential predictive element since it implies that a crewmember is aware of how the situation is likely to develop. From a team-performance perspective, it is also important that the crew have a shared mental model of the situation. The term mental model refers to the simplified representation of the state of a situation that is held in a person's mind (or a team's collective mind) and is discussed in Section 3.3. Normally, the mental model is based on the state of a relatively small number of significant variables in the environment — for example, weather conditions, the proximity of other aircraft, the state of the aircraft systems — and this status-monitoring process is updated in line with the changing situation.

The guidance provided by SOPs, which are essentially static and geared toward delineating specific responses to specific situations, is of little assistance in maintaining situational awareness. They may provide some generalized guidance regarding what information it is important to monitor in order to achieve good situational awareness, but this knowledge is more likely to be acquired through training and experience.

There is evidence in the discussions that individual crewmembers may experience a temporary loss of situational awareness under certain conditions pertaining to recent commercial developments. A related issue is that each crewmember could have a different mental model of the situation and that the crew as a whole may not be aware of these differences. As a result, the individual crewmembers may have a different understanding of the situation and the decisions and/or actions to be taken.

Significant effects on flight safety can occur where a lack of situational awareness by a single member of the crew (or a loss of a shared mental model by all members of the crew) is not identified. The following factors may reduce the likelihood of the crew holding a shared mental model of a situation:

- Different levels of operational experience;
- Different training experience;
- Different background (e.g., military or commercial);
- Inadequate local language skills;
- Increased workload; and,
- Fatigue.

These issues may be influenced by several factors resulting from globalization, including:

- The merging of national cultures;
- The merging of company cultures;
- The recruitment of non-nationals;
- The recruitment of less-experienced crew;
- The quality of training (both technical and nontechnical); and,
- Lack of operations support.

The impact that each mitigating factor has on situational awareness is shown in Table 21.

7.7 Safety Auditing and Internal Oversight

There is some concern that the quality or effectiveness of an airline's safety management system (SMS) may degrade as a result of mergers and globalization. Several structural changes to the industry have been identified as possibly increasing the risk of human error on the flight deck, such as the rostering of multicultural crews, the recruitment of agency crews and a reduction in recruitment standards (in terms of experience and technical ability). It is proposed that such structural changes require specific and focused safety management and that this may not necessarily be provided.

A reduction in the effectiveness of an airline's SMS may be influenced by:

- Failure to set up an effective SMS during and following the changes associated with mergers and globalization; and,
- Overemphasis on commercial objectives.

These factors may arise because of:

- The emergence of new business practices;
- The requirement for pilots with management responsibilities to also achieve high flying hours;
- Failure to give suitable priorities and resources to the SMS during periods of change;
- Lack of regulatory requirements for a formal SMS to be developed to ensure commercial developments do not compromise safety;
- Commercial pressures to reduce management and administration support; and,
- Increased competition and reduced margins.

The impact that each mitigating factor has on safety auditing and oversight is shown in Table 22 (page 50).

Since none of the three mitigating factors considered up to now will have a major impact on the higher-level issues of safety auditing and internal oversight, the role of regulatory agencies

Table 21
Effects of Mitigating Factors on Situational Awareness

Mitigating Factor	Impact on Reducing the Effects of Commercial Developments on Situational Awareness and Mental Models
Crew resource management (CRM) training	CRM will assist in the integration of crew with differing backgrounds/ experience and encourage the sharing of information to both enhance situational awareness and develop shared mental models of the situation
Standard operating procedures (SOPs)	Of limited assistance but may provide some generalized guidance regarding information to monitor
Professional culture	Some benefits from a shared culture

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research:

Table 22
Effects of Mitigating Factors on Safety Auditing and Internal Oversight

Mitigating Factor	Impact on Reducing the Effects of Commercial Developments on Safety Auditing and Internal Oversight
Crew resource management (CRM) training	None
Standard operating procedures (SOPs)	May mitigate reductions in auditing or oversight; but these reductions may in fact fail to identify nonadherence to SOPs or inadequate SOPs
Professional culture	Will promote some degree of internal oversight

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research:

will be important in encouraging airlines to support these functions during mergers and other commercial developments.

7.8 Summary of Mitigation Effectiveness

From the above analysis and discussion, it is clear that the control measures that the people interviewed in this study felt would mitigate the effects of commercial developments on flight deck safety may not be completely effective. The extent to which the three measures — CRM, SOPs and professional culture — are assessed to be effective, as concluded from the data and information collected from those European states participating in the study, is presented in Table 23.

By observation of Table 23, it can be seen that CRM and SOPs have a greater mitigating effect than professional culture, and this conclusion is in line with what people in the industry believe.

8. Comparison With the Marine Industry

8.1 Introduction

The shipping industry has seen radical changes in the past 40 years. Most of these changes have been due to economies of scale. Between 1960 and 1980, the average size of tankers and dry-bulk ships grew by a factor of five and is continuing to grow. An even greater revolution has taken place with the introduction of container ships, where turnaround times in port have been reduced from weeks to hours. Competition has driven a large reduction in crew costs, and a ship today, five times the size of a ship 40 years ago, will probably be manned by between one-half and one-third of the crew.

As a result of these changes together with technical innovation, shipping is the only industry recognizably the same as it was in 1960 which has come near to aviation in maintaining unit costs in real terms.

There are two factors that strongly influence the attitude toward safety in merchant shipping:

- In terms of capacity, more than 95 percent of the world deep-sea merchant shipping fleet is engaged in carrying cargo and only 5 percent in carrying passengers. Due to the relatively small numbers of passengers carried, exposure to risk is considerably smaller than in aviation, and the numbers of socially intolerable incidents are fewer; and,

- In general, recovery from serious failures such as total engine failure or electrical blackout is much more likely

Table 23
Tabulation of Human Factors Issues and Mitigating Factors

	Mitigation Effectiveness		
Human Factors Issue	Crew Resource Management	Standard Operating Procedures	Professional Culture
Teamwork/power gradient	Medium	Medium	Medium
Communication	Medium	Medium	Low
Fatigue	Low	Medium	Low
Morale and job satisfaction	None	Low	Low
Experience/competence	Medium	Medium	None
Situational awareness and mental models	Medium	Low	Medium

Source: Icon Consulting, Human Reliability Associates and International Air Transport Association Information and Research

to be successful in shipping than in aviation. This has led to fundamental differences in maintenance regimes between the two industries.

8.2 Differences Between Aircraft Cockpit and Bridge Navigation Operations

There are several fundamental differences between ships and aircraft:

- The navigation of ships involves coordination between two teams, one on the bridge and the other in the engine room. This coordination is a dimension which is missing from aircraft cockpit operations;

- Ships are piloted through inshore waters, where most incidents occur. When negotiating in these areas, ships are required to carry a pilot with specific local knowledge and competence in bringing ships in and out of port and through busy sea lanes. He or she is also able to communicate in the local language with other pilots advising ships in the same area and with the local traffic-control authorities. The pilot's role is purely advisory, but many masters effectively hand over control of the ship to the pilot. A pilot and master who have not previously met will need to quickly establish a working relationship and subconsciously establish a power gradient between them as a component of that relationship. By passing an examination, masters are able to obtain pilotage exemptions for ports that they visit regularly. The dialogue between them and the port authorities will then be much closer to the situation of an aircraft captain liaising with ATC;

- There are often more individuals involved with a wider range of skills in ship maneuvering than in the case of aircraft. Power gradients will therefore be operating at all levels between the master or pilot and the most junior officer present; and,

- There is an extraordinary diversity of ships, which has no parallel in aviation, and each ship type has its own special set of navigational and ship-handling problems. For example, high-speed craft are highly susceptible to extreme environmental conditions, and their operating licenses prescribe the maximum wind and sea states in which they may operate.

8.3 Multicultural Crews

Shipping was the original global industry and has a long tradition of employing multicultural crews, the use of which is far more widespread than in aviation. The driver for this high level of multiculturalism has been purely economic, and, as a result, the market for ships' crews is totally global and is possibly the most global labor market in the world. Most ships owned by the industrialized world are crewed either completely by Third World or former Soviet Union citizens of one or more nationalities, or by senior officers of the owning company's nation and junior officers and crew from elsewhere.

The global nature of the crewing market has led to concerns with regard to the quality of qualifications and certificates of competency issued by flag states, some of which are less scrupulous than others. This has led to the adoption of the two International Maritime Organization (IMO) conventions of 1987 and 1995 relating to the selection, training and certification of watch-keeping officers. The conventions have brought about significant improvements, but the use of underpaid ships' officers with dubious qualifications, sometimes "purchased," is still far too prevalent and has no parallel in commercial aviation.

A catalyst for multicultural crews has been the prevalence of English as the language of the sea. The IMO conventions require proficiency in English as a prerequisite for senior deck officer qualifications for ships in international trades. However, problems do occur with language communication between crewmembers of different nationality and in ship-to-shore communications. These problems are gradually being overcome by the use of formal SOPs and standard vocabularies in ship-to-shore and ship-to-ship very-high-frequency (VHF) radio communications. These procedures are a relatively recent innovation in merchant shipping and have received a significant boost from an International Safety Management code, which has forced their introduction.

8.4 CRM and Professional Culture

CRM, as practiced in aviation, is still at the experimental stage in shipping. Interestingly, it is used mainly in specialist passenger-carrying operations such as high-speed catamaran ferries, which have imported many aspects of their culture from aviation.

The marine industry has a strong professional culture, possibly equal to that of aviation. The seagoing qualifications of master and chief engineer have a particularly high value, and entry to many grades of management in ship operations is all but impossible without such qualifications. Although shipping companies, as airlines, are increasingly run by accountants, ship-operations executives invariably have seagoing qualifications. There is often a reluctance of those who hold these qualifications to accept the opinions of those who have never been to sea on matters of ship operations.

8.5 Safety Regulation

The regulation of the shipping industry is complex and very different from aviation, although there are parallels, particularly in the enactment and enforcement of international conventions.

There are three elements to the regulatory framework of merchant shipping:

- Classification societies;
- Flag states; and,
- Coastal and port states.

The classification societies are self-regulatory bodies which oversee and certify the design, construction and maintenance of ships. They have been much criticized for failing to meet their obligations in the face of commercial pressures and for the diversity of their rules. This led to the formation in the mid-1980s of the International Association of Classification Societies, which has brought about significant improvements in the consistency of ship classification.

The flag state is the country in which a ship is registered and whose maritime laws therefore control its operation. Here, there is a direct parallel with aviation. The vast majority of maritime safety law is dominated by the IMO. Although criticized for being slow and sometimes overconciliatory, the IMO has brought about a fundamental shift in attitudes to safety in the shipping industry, partly through the progressive introduction of auditable safety-management systems.

There are significant differences in the speed with which various flag states adopt IMO conventions and the manner in which they interpret them, which has led to a great deal of criticism of certain flag states.

One of the most significant drivers toward globalization in the marine industry has been the flag of convenience. Certain countries have enacted laws which enable nonresident ship-owning companies to register their ships there and gain benefits of low registration fees and a liberal regulatory regime. The flag-of-convenience system has been much criticized for its safety record, but it has been one of the significant drivers in shaping the industry and keeping international transport costs down.

Port state control is seen as redressing the deficiencies of flag state control, to the extent that ships of certain flags receive particular attention from port state surveyors. Port state control has been particularly significant in providing a system of "spot audits" for the newly introduced International Safety Management code.

8.6 Conclusion

Although aviation may have learned from the marine sector in its early days, in recent years the learning has been in the opposite direction. Nevertheless, there are some areas of resource management in which aviation might learn from shipping, particularly in the area of multicultural crews.

9. Approaches to Human Factors in Other Safety-critical Industries

In the previous sections, we have suggested that the application of human factors principles in the civil aviation industry has mainly focused on the qualities of individuals and teams. This is typified by the strong emphasis on training and CRM. This is partly because the culture of civil aviation has been strongly influenced, particularly in the past, by the large influx of military-trained pilots, who brought with them the ethos that individual discipline, commitment and adherence to procedures were the primary means of achieving objectives. Although former military pilots no longer dominate the industry, many of these beliefs remain in place.

These beliefs are well-founded in systems that are largely under the control of individuals or operating teams. However, there are some useful lessons to learn from other safety-critical industries where different approaches have been applied. In general, the introduction of human factors in safety-critical systems has arisen from the occurrence of major disasters where human error has been implicated as the primary cause. In fact, the first area where research on human performance was applied to reduce losses was in military aviation during World War II. In the early stages of the war, losses from pilot error exceeded those from enemy action by a large margin. This led to considerable improvements in the design of cockpits and other systems such as navigation aids and radios. The design of the cockpit environment and other aspects of military systems is still one of the largest areas of employment for human factors specialists.

Another military system provided the starting point for a more systematic consideration of human performance. In the early days of the Cold War in the late 1950s and 1960s, it was found that the main cause of malfunctions in ballistic missiles was either assembly or software errors. This led to the development of human-reliability-analysis techniques, which attempted to assign error probabilities to human activities in assembly, maintenance and software development. This was essentially a mechanistic approach that treated people as system components such as pumps or valves, without any consideration of why errors arise.

The limitations of this approach were realized when a number of major disasters occurred in the nuclear power industry (e.g., Three Mile Island, Chernobyl), where human failures involving higher-level cognitive functions (e.g., diagnosis, problem solving, decision making, action formulation) were the predominant types of errors. This, together with major accidents in the chemical industry (e.g., Piper Alpha, Flixborough), led to the development of new techniques to analyze these types of errors. The cognitive approach to human error emphasized the fact that people are active participants in the tasks that they perform and are strongly influenced by their prior expectations in how they interpret a situation and the perceived benefits and costs of alternative actions. They are also critically dependent on the information that they receive, either from displays or the physical environment, or from instructions such as SOPs, or remote communications. These factors are often not under the direct control of individuals, and hence the strategy of trying to maximize commitment and motivation will not have a substantial impact on this aspect of human performance.

In recent years, there has been increasing influence in the effects on human performance of the organizational factors that create the preconditions for individual errors, the so-called latent failures. These concepts have been developed most extensively by workers such as Professor James Reason of Manchester University. The approach seeks to identify aspects of organizational policies that can degrade the factors influencing human error directly. For example, the absence of clear policies for training, procedures development or shift work will eventually create the direct conditions for accidents. This approach has been developed into comprehensive methods for tracking the causal paths between organizational conditions and errors at the "sharp end." Recent examples of this approach are in the area of aviation maintenance (Embrey, 2001) and the analysis of signals passed at danger in the rail sector (Wright et al., 2000). This approach, which explicitly models the ways in which specific errors can arise as a result of organizational changes, could potentially be applied to the topics considered in this project.

The occurrence of recent rail disasters such as the Ladbroke Grove and Southall accidents have led to an increased focus on the human factors of rail accidents. Systems are now being developed for confidential incident-reporting systems in the rail sector, similar to the Confidential Human Factors Incident Reporting Program (CHIRP) used in the U.K. aviation sector. There is also an increased emphasis on analyzing the underlying human causes of rail accidents in a more systematic manner.

The other current area of interest for the application of human factors approaches to error reduction is in the field of medical error (or patient safety). There is an increasing realization that medical procedures are subject to the same types of errors that can arise in the other types of safety-critical systems discussed earlier. Interestingly, the long delay in the application of human factors approaches to human error in medicine can be ascribed to many of the same causes as in the civil aviation sector. The existence of a strong professional culture (particularly a strong hierarchy led by consultants) has tended to divert attention to the individual characteristics of surgeons, nurses and doctors, rather than to the systems and policy causes (e.g., inadequate procedures, understaffing leading to resource and time pressures) that underlie many of the medical errors that have recently been the focus of the media. The analogy between the flight deck and the hospital operating theater is readily apparent. Interestingly, the initial response of the U.K. National Health Service (NHS) has also been to recommend the setting up of a confidential near-miss reporting system analogous to the voluntary reporting systems sometimes found in aviation (e.g., the U.K. CHIRP system). Aviation also has mandatory reporting systems for incidents and accidents.

In general, the application of human factors in safety-critical industries has involved two main approaches driven by very different philosophies. The systems approach, described earlier in this chapter, uses knowledge of the mechanisms of human error to optimize various aspects of the system in which the person or the team operates. For example, a typical systems approach might first analyze the critical tasks that the person or team is required to perform (e.g., land a Boeing 747 under extreme weather conditions, deal with an on-board fire, maintain a critical control system). The next stage would examine factors such as the training, procedures, human-machine interfaces and communication systems in order to evaluate the extent to which they deviate from best practice. This profile can then be used to specify where the most cost-effective improvements should be made in order to minimize the probability of failures in the safety-critical tasks. In addition to this proactive approach, a complementary reactive method would analyze the direct and underlying causes (including organizational) of failures that have already occurred.

The alternative behavioral approach only considers the externally observable aspects of behavior and is therefore very different than the systems approach. The behavioral approach attempts to reinforce good behaviors (e.g., by giving feedback to pilots where they have minimized exceedances on approaches). In addition, the aim is to minimize negative behaviors or unsafe acts (e.g., reckless landing practices) by providing feedback without necessarily invoking threats or blame. The effects of behavioral methods can be partly ascribed to changing the balance between the perceived costs and benefits of noncompliant behaviors. In general, the behavioral approach is most successful in simple tasks where the person or team has a high degree of control over the way in which the task is carried out. They are less successful in situations where the technology determines the way in which a task has to be performed. Behavioral approaches rely on the constant monitoring of behavior and, hence, tend to be quite resource-intensive. Another disadvantage of these approaches is that the positive effects may decay over time unless continually reinforced.

In summary, the need for the application of human factors principles to safety-critical industries is becoming increasingly realized even though the quality of technical safety systems continues to improve. Many engineers believe that eventually all critical systems will be automated and the problem of human error will then be eliminated. However, in reality, the human will always be needed to cope with the situations that the designer and engineer — who, after all, are only human — have not been able to anticipate.

10. Conclusions

The preceding chapters have provided an analysis, part structural and part anecdotal, of data collected in discussions with management and flight crew in a number of European airlines and with safety regulators, together with insights from relevant human factors research. Three outcomes of commercial developments in the industry that have an effect on flight crew were identified in Chapter 5.

Multicultural Flight Crews

In 80 percent of the airlines returning questionnaires, at least 95 percent of the flight crew employed are local nationals, and in many Southern European states all the flight crew employed are local nationals. The number of aircraft movements in Europe with multicultural flight crews is, therefore, fairly small at present. Multicultural flight crews are more frequently found in airlines operating out of Northern Europe, particularly in low-cost airlines where typically 25 percent of the pilots employed are non-nationals. Since low-cost entrant airlines are expanding rapidly, it can be expected that the frequency of flight crew from different cultures working together on the flight deck will increase in the future.

Other evidence supporting a growth in the number of mixed flight crews is that more than half of the people surveyed believe that a pilot shortage will occur in Europe in the short to medium term and that this will encourage a greater movement of trained flight crew between airlines and between states. A common European flight crew license will facilitate this movement. Foreign nationals from outside Europe are also likely to be attracted to working for European airlines, particularly if the growth in air transport is less, or even declining, in their own countries.

Merging of Company Cultures

Almost two-thirds of the people surveyed have worked for an airline that has merged with or taken over another airline in the last 10 years. Research into commercial developments in the airline industry has indicated that the potential for two airlines to merge is increasing as the search for greater operational efficiency grows. In addition, mergers which cross national boundaries are becoming increasingly common.

There is little evidence to suggest that individual airline cultures are affected when they become part of a strategic alliance or that flight crew from different airlines in the same alliance are likely to mix on the flight deck in the short to medium term.

Commercial Pressure

As competition within the industry grows, there is increasing pressure to reduce costs. Many of the people interviewed spoke of the increasing commercial pressure that they are expected to work under.

In conclusion, industry trends are likely to increase the likelihood of each of these three outcomes, and these in turn will have an effect on flight crew errors.

Mitigating factors referred to by many of the participants in the study that are expected to reduce the adverse results of commercial developments are as follows:

- CRM training;
- SOPs; and,
- Professional culture.

In addition, safety regulation sets the safety standards for the industry and defines the minimum limits above which airlines must perform. In doing this, it attempts to ensure that the first two mitigating factors are applied properly and that any potentially negative effects on human factors that may arise from globalization are prevented.

The three mitigating factors and safety regulation were analyzed and discussed in detail in Chapter 6, and six human factors issues that have the potential to directly or indirectly affect the nature and likelihood of human error on the flight deck were identified in Chapter 7. Several areas of concern were outlined for each mitigating factor, and these will be discussed in the next sections.

10.1 CRM

CRM is widely used in the aviation industry and was considered by the airline representatives interviewed to be an effective tool for managing the human factors effects of globalization. Nevertheless, the analysis has revealed some concerns that need to be addressed by the industry to ensure that CRM warrants the confidence placed in it.

- Any form of training provided must be effective in an operational environment as well as in the training room. Many incidents have been caused or exacerbated by team-performance problems, even when the crews involved have been trained in CRM practices and have performed well in simulated emergencies. There are particular concerns that behavior in training sessions is not correlated with behavior under extreme (real) circumstances. Individual airlines should, therefore, evaluate the effectiveness of CRM outside the training environment and modify it where necessary.

- The research cited by Johnson (2000) regarding the lack of evidence for the effectiveness of CRM (see Section 6.1.1) means that caution should be adopted in using CRM as the only approach to the reduction of flight deck errors.

- The emphasis on CRM may in some cases lead to a culture in which all errors are considered to arise (and be contained) in the cockpit environment. However, many factors that may adversely influence flight safety originate, as in all other industries, from management and organizational failures that occur deeper in the system and are outside the control of individual crewmembers (see Section 3.5 for a discussion of latent failures). High levels of flight crew training, experience or personal capability will not automatically mitigate the adverse effects of such factors.

- There is a growing awareness that CRM training should be applied to other working groups such as cabin crew, ground engineers and air traffic controllers. Many airlines combine people from more than one working area in CRM training sessions to foster teamwork among those who depend on each other for flight safety. Sessions such as these help others to understand the difficulties that other working groups have to face and the judgments that they have to make.

- The airlines interviewed tended to equate CRM with human factors, but few qualified human factors professionals are employed by airlines in the development of CRM programs. Although later versions of CRM do consider aspects such as error management, some airlines are using versions of CRM that neglect fundamental human factors issues that could influence cockpit errors. The lack of qualified human factors professionals in airlines also raises some concerns that other human factors-based interventions may not be applied.

- Most airlines agree that CRM training material that has been developed for one culture should be modified and developed further to be effective with people from other cultures and with mixed cultural groups. No process is in place in the airline industry to promulgate experience and spread best practices in adapting CRM to different cultures.

10.2 SOPs

SOPs were put forward as a measure that will control the human factors risks on the flight deck to a significant extent. However, there may also be concerns with the effectiveness of SOPs.

- As with CRM training, the presence of SOPs does not guarantee that they will be used all the time or will be followed to the letter by all flight crews. For example, it may be the case that crew will prefer to rely on memory in routine, highly practiced situations in which there is little risk. Alternatively, crew may follow a slightly different procedure with which they are more familiar. There are also individual and cultural differences in the degree of adherence to aviation SOPs, as there are in other safety-critical industries.

- Experience in other industries is that management will tend to overestimate the extent to which procedures are followed. In many cases, a wide disparity has been found between the views of management and the actual working practices in these industries. Procedures are not adhered to for a variety of reasons, including problems with their quality, accuracy, relevance and usability. It is recognized that SOPs in commercial aviation may be more rigorously developed and more thoroughly validated than in other industries. However, there are always concerns where SOPs are being relied upon as a means of achieving safety compared with built-in error removal.

- Although intentional violations of SOPs are relatively rare in aviation, unintentional errors when following procedures can occur — for example, if crew are distracted during the procedure. Distractions arise from a variety of sources, ranging from those internal to the individual, to those arising from other crewmembers, ATC or instrumentation. Crew behavior may differ significantly from that exhibited in training situations, partly as a result of increased stress in extreme conditions.

- Several airlines stressed the highly proceduralized nature of the flying task, claiming that procedures existed for every eventuality. However, crew working in highly proceduralized environments may encounter difficulties when faced with a situation that is not covered by a procedure. This is being addressed by another ongoing EC-funded research project whose results have yet to be published. Furthermore, crew who work for an airline that strongly adheres to procedures may experience difficulties should they then operate in an airline that allows a greater degree of individual interpretation.

- When working for a different airline or with a flight crewmember from a different background, a person's knowledge of an SOP may lead him/her to interpret ambiguous communications in terms of the SOPs with which they are familiar. The flight crewmembers could also interpret the same procedure in a different way.

- The free movement of crew within the industry, between countries and between airlines may create situations in which crew are required to operate to SOPs that differ from those on which they are more experienced (e.g., in terms of content or allocation of responsibilities). In these cases, individual flight crewmembers may also inadvertently revert to a previous procedure.

10.3 Professional Culture

Professional culture, although mentioned extensively in the literature (e.g., Helmreich, 1998), was not explicitly proposed by airline representatives as a risk-reduction measure in the same vein as CRM and SOPs. Several interviewees did refer to the high professionalism of pilots or other factors considered to be components of professionalism. It is obviously true that a professional culture which encourages responsibility, diligence and the safety of passengers as a primary concern will have positive benefits in reducing the incidence of human error. However, as with CRM, there is a danger that it may reduce the consideration of other measures to reduce flight deck errors. It is significant that in medicine, another area in which there has been a strong professional culture, there is an increasing recognition that errors will still arise regardless of the professionalism or diligence of the individual or team. This has led to a realization that the causes of errors need to be addressed at the level of the system as well as the individual.

Several of the human factors issues described in previous sections relate to human performance limitations (such as fatigue) or personal performance constraints (such as competence or technical skill). Although a strong professional culture may reduce the effects of low morale, its efficacy in compensating for human performance limitations will be considerably less.

10.4 Overall

In many safety-critical industries, the traditional approach to reducing human error was to focus on blaming the individual if an accident occurred. However, there is now a much greater appreciation of the effects of the total system within which the team or the individual operates. The total approach considers the technical equipment with which the team has to interact and also the organizational policies and changes which impact on areas such as team effectiveness, training, fatigue levels and SOPs compliance.

This study has shown that there is a widespread belief in the aviation industry that the effects of commercial developments such as mergers and globalization can cascade down through an organization to affect flight deck operations. While some incidents and accidents could have been caused by the effects of commercial developments currently in progress in the industry, no evidence has been found to state definitively that this was the cause. Nevertheless, it is clear that the potential for such a threat exists and that this threat is likely to increase as the pace of commercial developments increases.

There was a belief by the airline-industry participants in the study that the strategies of CRM, SOPs and professional culture will mitigate these threats. The study team has concluded that of these three mitigating factors, professional culture is the weakest, as demonstrated in Table 23. Furthermore, the evidence cited in this report suggests that the other two strategies are unlikely to be fully effective in dealing with the threats identified. This leads to a number of recommendations aimed at improving the effectiveness of the mitigating factors and developing more focused methods for minimizing the potential risks.

11. Recommendations

Although there is little definitive evidence of specific threats arising from globalization and mergers, it is clear that the information gathered in this study indicates that there are a number of potential problems that will not be addressed fully by existing approaches to mitigation. A number of recommendations are made which will help to control the potential risks and increase the effectiveness of the mitigation strategies.

- In order to provide more concrete information connecting the effects of commercial developments on specific classes of flight-deck failures, an explicit model connecting these areas needs to be developed. This would enable the negative effects of these developments to be identified and ranked in order of importance. This model would identify the factors known from incident reports to affect flight deck errors directly (e.g., fatigue, communication failures, assumptions about procedures) and connect these factors with underlying latent-error-inducing factors arising from mergers and globalization — for example, dissatisfactions with changed new shift systems incompatible with the existing domestic arrangements of flight crew, assumptions made during communications which may not be valid with flight crew from different airlines.[3] The proposed research would include the analysis of incidents that had occurred in merged and nonmerged airlines to identify the mechanisms of failure and any links with these developments. Based on the model, guidelines for handling the flight deck human factors issues associated with airline mergers, alliance formation and commercial pressure could be developed. The purpose of these guidelines would be to minimize the possible negative effects discussed in this report. For airlines that had already undergone these commercial developments, an audit process should be developed to enable such airlines to examine their systems to identify where any latent threats exist. The process should become part of an airline's safety-management system and would assist an airline in generating preventive strategies if problems were identified.

- An awareness campaign should be carried out within the aviation industry of the flight deck human factors issues that could arise from current commercial developments if appropriate strategies were not implemented. As a part of the campaign, airlines should be encouraged to identify, within their safety incident reporting systems, any incidents that may be ascribed to factors identified within this report.

- Airlines should determine whether the CRM training that they provide covers all the elements that have been identified in this report. Where gaps exist, the training material should be adapted in an appropriate manner.

- CRM has been adopted by the industry as the primary means of dealing with human factors issues. This study has found that globalization is likely to increase the frequency of occurrence of these issues. A study should, therefore, be carried out to assess the effectiveness of

[3] An illustration of these factors is provided by the Air New Zealand Mount Erebus accident. Failures of procedures and communication led to changes in the coordinates of the final waypoints not being communicated to dispatch and the flight crew. In addition, there was lack of clarity with regard to minimum altitudes during the preflight route briefing. One of the possible effects of a merger, particularly during the early stages of the process, could be disruptions in the communications systems and hence a danger that critical information might not be communicated. Similarly, one of the contributors to the crash of Air Ontario Flight 1363 was ambiguity regarding which flight manual applied, following the creation of Air Ontario from a merger between Austin Airways Limited and Air Ontario Limited.

CRM in the operational environment within different organizational and national cultures.

- CRM training is perceived to be expensive by some airline managements who may be resistant to extending the training for flight crew and other working groups and may wish to reduce the training in the future. A study should therefore be undertaken to determine the cost-effectiveness of the current method of delivering CRM training. The study should also consider alternative approaches to instilling the concepts of CRM into an organization and continually reinforcing these concepts.

- Safety regulators should review their own regulatory procedures and their oversight of airlines to ensure that they will deal with the human factors risks described in this report. As part of this review, regulators should consider how airlines satisfy themselves that CRM trainers have the relevant skills and whether appropriate human factors skills are available within the CRM process.

- The research described in Subsection 3.2.1 of this report has suggested that the acceptance and perception of automation varies greatly across cultures. While outside the scope of this study, the link between cultural attitudes and the interaction with automation might be worth investigating.

- This study has been limited to the effect on flight crew of recent commercial developments. Consideration should also be given to the impact that these developments may have in other functions that contribute to flight safety, such as maintenance, cabin crew, ATC, etc.♦

[FSF editorial note: To ensure wider distribution in the interest of aviation safety, this report has been adapted from *The Human Factors Implications for Flight Safety of Recent Developments in the Airline Industry*. The report was prepared for the Joint Aviation Authorities by Icon Consulting, Human Reliability Associates and International Air Transport Association (IATA) Information and Research. Some editorial changes were made by FSF staff for clarity and for style. Project team members were: Martin Anderson, Human Reliability Associates; David Embrey, Human Reliability Associates; Chris Hodgkinson, independent consultant; Peter Hunt, independent consultant; Bernard Kinchin, Icon Consulting; Peter Morris, IATA Information and Research; and Mike Rose, Icon Consulting. The European Commission and the CHIRP Charitable Trust contributed to the research and preparation of the report.]

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Appendix A
Postal Questionnaire

The purpose of this questionnaire is to gather some preliminary information for the study that we are undertaking for the Joint Aviation Authorities (JAA). The background to this study is briefly described in the accompanying letter.

During the study, we are trying to identify potential flight safety problems that might result from recent trends in the aviation industry. We would encourage you to be open in your response, which will be treated in complete confidence.

If you are willing, we may wish to follow up the questionnaire with a more detailed face-to-face or telephone interview.

Thank you in advance for completing the questionnaire; you are contributing to a very valuable program of research.

– The ICON team

About you		
A1	Name	
A2	Name of your airline	
A3	Position	
A4	Brief summary of your role	
A5	Years of service with this airline	
A6	Years of service in total	
A7	Contact information: Phone E-mail	

About your Airline		Yes	No	Don't know
B1	Is your airline a member of an alliance?			
	• If yes, name of alliance and date of joining			
	• If no, does your airline envisage joining one in the next 5 years?			
B2	Has your airline been involved in a merger during the last 10 years?			
	• If yes, when and with which airline(s)?			
B3	Has your airline taken over another airline during the last 10 years?			
	• If yes, when and which airlines were taken over?			
	• Were you in an airline that was taken over by your present airline?			
B4	Describe any other top-level organizational changes that have taken place in your airline in the last 10 years that might have an impact on flight crew.			
B5	Does your airline have subsidiaries in two or more countries where there is the opportunity for flight crew members from one subsidiary to fly together with those from another?			

About Globalization		Yes	No	Don't know
C1	Have human factors issues arisen as a result of any airline alliances, mergers or takeovers that you have experienced? • Briefly outline the reasons for your answer			
C2	Are there circumstances where human factors issues might arise as a result of airline alliances, mergers or takeovers? • Briefly outline the reasons for your answer			

	Working Arrangements in Your Airline	Yes	No	Don't know
D1	Do flight crew from your airline fly with flight crew from other airlines?			
	• If yes, is this practice becoming more common?			
D2	Do you roster flight crew of different nationalities to fly together?			
	• If yes, is this practice becoming more common?			
D3	What percentage of flight crew are nationals of the country of your airline?			
D4	Are flight crew ever obtained from agencies?			
	• If yes, is this becoming an increasing trend?			
	• If no, would there be any benefits in this practice?			
D5	Have there been significant changes in the salaries and benefits offered to flight crew in the last 10 years?			
	• If yes, what changes have there been?			
D6	Are any flight crew employed under short-term contracts?			
	• If yes, is this becoming an increasing trend?			
	• If no, would there be any benefits in this practice?			
D7	Have there been any other significant changes in the working conditions of flight crew in the last 10 years?			
	• If yes, what changes have there been?			

	Recruitment and Training in Your Airline	Yes	No	Don't know
E1	Have you experienced a change in the turnover of flight crew in the last 5 years?			
	• If yes, has turnover increased?			
E2	Do you expect to experience a shortage of flight crew in the future?			
E3	From where are your flight crew recruited?			
E4	Has your main source of flight crew changed in the last 5 years?			
E5	Has your airline ever sponsored *ab initio* training of flight crew in the last 10 years?			
	• If yes, do you still provide sponsorship			
E6	Is crew resource management (CRM) used in your airline?			
E7	Prior to joining your current airline,			
	• were you in the military?			
	• did you ever work on short-term contract?			

Flight Deck Errors		More likely	Neutral	Less likely
F1	What effect do you think the following will have on the likelihood of flight deck errors being made?			
	(i) A captain being significantly older and having much more flying experience than, say, the copilot.			
	(ii) The merging of organizational cultures as might occur when one airline takes over another and the two flight crew communities are merged			
	(iii) Flight crew from different national cultures operating together			
	(iv) Flight crew from a single national culture operating together			
F2	What, in your opinion, are the three most common primary causes of flight deck errors?			
	1 2 3			
F3	What, in your opinion, will be the greatest threat to flight safety in the coming years, and why?			

Appendix B
Interview Questionnaire

The structure of the interview and the questions that are used will depend on the airline's responses to the postal questionnaire. Not all the following questions will be appropriate for all airlines. Judgment will be required to decide which questions are relevant and will be the most revealing to meet the objectives of the study. Look for examples to illustrate the opinions that are given.

Airline:	
Place:	
Date and time:	

Present at interview	Position	Years of service Airline	Years of service Total

About Your Airline			
B6	How is the Flight Operations Department organized in your airline?		
B7	How does management communicate with flight crew?		
B8	What attributes are sought in pilots and how are they selected?		
B9	How is the company culture instilled in flight crew?		
B10	If you have personal experience of the merging of two airlines or the takeover of one airline by another, were the flight crew seniority lists merged fairly?	Yes	No

About Globalization		Yes	No
C3	Might flight crew from different airlines be mixed within an alliance and what human factors problems would arise if they were?		
C4	What benefits might arise from mixing crew within an alliance		
C5	What human factors issues might arise following a merger of two airlines?		
C6	What aspects of these issues would require careful management to ensure that they did not have a negative effect on flight safety?		

About Globalization (continued)		Yes	No
C7	How might any of the human factors issues related to globalization be resolved?		
C8	What internal systems and processes are in place to carry out risk assessment when two sets of SOPs are merged or large scale changes are made to SOPs?		
C9	And how is safety performance monitored following such changes?		

Working Arrangements in Your Airline		Yes	No
D2a	What problems or issues might arise as a result of flight crew of different nationalities flying together, and how could they be managed?		
D4a	What problems or issues might arise as a result of sourcing crew from agencies, and how could they be managed?		
D7a	In your opinion, what effects might there be on flight crew of changes in working conditions?		
D8	Might any of these effects lead to flight deck safety performance issues?		
	And what is the reason for your answer?		

Recruitment and Training in Your Airline		Yes	No
E1a	Why do you think staff turnover has changed in recent years?		
E2a	Why do you expect to experience a shortage of flight crew in the future?		
E4a	From where were your flight crew recruited in the past?		
E6a	How is crew resource management (CRM) implemented in your airline?		

Flight Deck Errors		Yes	No
F1a	What were the reasons behind the responses?		
F4	Has there been a change in the perceived incidence of flight deck errors in your airline in recent years? What has been the nature of this change?		
F5	Do performance measurement systems exist, either in your airline or your State, that will identify causes of potential flight safety problems? • If yes, what are these systems and are they effective?		

Other Comments

Appendix C
Comparison With the Marine Industry

C.1 Introduction

This appendix seeks to draw parallels between the results of this study and the merchant shipping industry. The overall objective is to indicate whether there are any areas of cockpit flight operations in respect of which the aviation industry might learn from shipping. It should be said at the outset that although aviation may have learned from the marine sector in the early days, in recent years it has been largely the other way around. Merchant shipping has adopted practices from the aviation sector, mainly through the interface between the two in the area of high-speed passenger craft (hovercraft initially in the 1960s, then hydrofoils and lately high-speed catamarans). However, there are some interesting parallels and differences between the two transport modes which assist in providing some further insights into the results of this study. There are also some areas of resource management in which aviation might learn from shipping, particularly in the area of multicultural crews.

C.2 Globalization

Shipping was the original global industry. Despite the advances made by air freight and transcontinental multimodal shipping, including a substantial road transport element, in recent years the vast majority of international trade in goods is still carried by sea. By contrast, air freight still accounts for only 0.1 percent by volume. The global nature of seaborne trade and the ability to move goods around the world cheaply also promotes globalization in other areas, for example of IT equipment.

Shipping also has a long tradition of employing multicultural crews. This tradition dates back to the early days of European imperialism, when sea power supported colonization and at the same time offered employment opportunities for cheap labor in the newly acquired territories. The employment of crews from the Indian subcontinent, China and the West Indies was well established by the early days of steam.

Shipping is still a fragmented industry. Comparatively few ships are operated or even managed by their owners, and many are operated by charterers. Part, if not all, of the management of most ships is contracted out by their owners to specialist ship-management companies. The size of shipping companies varies from single-ship companies owned by one or two individuals to the large fleets of the multinational oil companies of 50 or 100 ships, forming part of a vast vertically integrated industrial conglomerate.

C.3 Economics of Change in Merchant Shipping

The shipping industry has seen radical changes in the past 40 years. It is even arguable that after the introduction of the first jet-engine airliners, sea transport has seen greater technological change than air transport. Most of these changes have been due to economies of scale. In 1960, the average size of tankers was about 20,000 tonnes deadweight. By 1980, this had risen to 100,000 tonnes with a maximum of over 500,000 tonnes. Dry bulk ships also experienced a similar increase in size. An even greater revolution took place in the handling of small parcels of cargo with the introduction of containers, which reduced turnaround times in port from weeks to hours and introduced enormous economies of scale, with containerships of 10,000 20-foot-container capacity now in the planning stage.

Shipping is the only industry recognizably the same as it was in 1960[1] which has come near to aviation in maintaining unit costs in real terms. During the period 1960–1990, the price of a transatlantic air ticket rose by 10 percent and oil freight by about 80 percent, but the price of a new car increased by 800 percent. In both aviation and shipping, unit costs were kept down by a combination of technical innovation and economies of scale.

Competition in shipping has driven a large reduction in crew costs, arguably much greater than in aviation. A ship of five times the size of its 1960s forebear will now probably be manned by between one-half and one-third of the crew as it was then. The nationality of the crew will have changed from predominantly that of the owning company to crew from countries such as the Philippines, India and Korea or former Soviet countries such as Russia, Ukraine and Poland.

C.4 Characteristics of the Merchant Shipping Industry

There are two factors which strongly influence the attitude toward safety in merchant shipping.

The first factor is that, in terms of capacity, more than 95 percent of the world deep-sea merchant shipping fleet is engaged in carrying cargo and only the remaining 5 percent in carrying passengers or passengers and vehicles. This is approximately the reverse of the pattern in civil aviation. Due to the relatively small numbers of passengers carried by ships, exposure to risk is smaller than in aviation and the numbers of socially intolerable incidents are fewer.

During the 1990s, more than 100 bulk carriers were totally lost at sea, mainly with loss of all hands. However, because most of the crews were Third World nationals and the total loss of life was only about 30 per ship, the heavy total loss of life due to these events has been eclipsed by high-profile disasters of passenger ferries such as the *Herald of Free Enterprise* and the *Estonia*. These two

[1] This excludes microelectronics and computing, in which change has been so fundamental that comparisons with 1980, let alone 1960, are meaningless.

casualties have significantly skewed an otherwise excellent safety record, in terms of fatalities per passenger mile or journey.

The second factor is that, in general, recovery from quite serious failures is much more likely to be successful in shipping than in aviation. In shipping, a complete recovery is usually achieved from total engine failure or electrical blackout, whereas in aviation the reverse is true. This has led to fundamental differences in reliability and maintenance regimes between aviation and shipping, where failures are tolerated to a degree which many view as unacceptable.

C.5 Regulation of the Shipping Industry

The regulation of the shipping industry is complex and very different from aviation, although there are parallels, particularly in the enactment and enforcement of international conventions.

There are three elements to the regulatory framework of merchant shipping:

- The classification societies;
- Flag states; and,
- Coastal and port states.

Classification Societies

The classification societies are a form of self-regulatory body which oversee and certify the design, construction and maintenance of ships. The first was Lloyd's Register of Shipping, which came into existence to provide certification of the suitability of ships as an insured risk. This element of insurability still dominates the ethos of the societies today. The classification societies tend have their origins in traditional maritime countries, the most significant being Lloyd's Register (United Kingdom), NKK (Japan), American Bureau of Shipping (United States), Det Norske Veritas (Norway), Genrmanischer Lloyd (Germany), Bureau Veritas (Spain) and the Hellenic Register (Greece).

The classification societies have been much criticized for failing to meet their obligations to the maritime community at large in the face of commercial pressures, particularly competition between them. They have also been criticized for the diversity of their rules, which led to the formation in the mid-1980s of the International Association of Classification Societies (IACS), which has brought about significant improvements in the consistency of ship classification.

Flag State Control

The flag state is the country in which a ship is registered and whose maritime laws therefore control its operation. Here, there is a direct parallel with aviation. The vast majority of maritime safety law is dominated by the International Maritime Organization (IMO), which was set up as a United Nations agency in 1949 and has its headquarters in London, England. Although criticized for being slow and sometimes overconciliatory, perhaps inevitable with over 160 member states, the IMO has brought about a fundamental shift in attitudes to safety in the shipping industry. Of particular significance are the international conventions mentioned previously and the International Safety Management (ISM) code, which has over the past four years led to the progressive introduction of auditable safety management systems aboard ships and in shore-based ship operations.

There are significant differences in the speed with which various flag states adopt IMO conventions and the manner in which they interpret them, which has led to a great deal of criticism of certain flag states.

One of the most significant drivers toward globalization in the marine industry has been the flag-of-convenience or "open-registry" system. Certain countries have enacted laws which enable nonresident ship-owning companies to register their ships there and gain benefits of low registration fees and a liberal regulatory regime. This practice became particularly prevalent immediately following World War II, which released a large number of secondhand merchant ships onto the market. The largest flag-of-convenience fleets remain Panama and Liberia, with Singapore, Somalia and several Caribbean island states also being significant. The flag-of-convenience system has been much criticized for its safety record, but it has been one of the significant drivers in shaping the industry and keeping international transport costs down.

Coastal and Port State Control

During the past 20 years, the countries to which ships trade have assumed increased significance in enforcing both local maritime safety laws and IMO conventions. This role is carried out either through a central agency such as the U.S. Coast Guard or the U.K. Maritime and Coastguard Agency, or through port authorities. The U.S. Coast Guard initially led the way in this area, but the European Commission (EC) now exerts a comparable degree of regulation following the Paris Memorandum on Port State Control.

Port state control is seen as redressing the deficiencies of flag state control, to the extent that ships of certain flags receive particular attention from port state surveyors. Port state control has been particularly significant in providing a system of "spot audits" for the newly introduced ISM code.

C.6 Differences Between Aircraft Cockpit and Bridge Navigation Operations

The study for the Joint Aviation Authorities (JAA) has focused on flight deck issues, which for most purposes these days is restricted to the captain and first officer. In drawing a comparison with shipping, it is appropriate to include all shipboard personnel of officer status, which will generally comprise a master, three watch-keeping officers, a chief engineer and two or three watch-keeping engineer officers. Some ships may also carry an electrician and a cargo engineer of officer status.

One of the most fundamental differences between ships and aircraft is that the navigation of ships in effect involves coordination between two teams, one on the bridge and the other in the engine room. Some ships have automated engine-control systems which can be and usually are operated solely from the bridge, with no one in the engine room outside day work hours. Others have manual telegraph systems which require a response from an engineer in the machinery-control room. Even where control of the engines is fully automated, many emergency situations require intervention from the engine-room team. For example, an emergency full-astern maneuver may require engineer intervention to avoid damage to the main engine. Emergency measures following an incident (e.g., engine failure, electrical blackout, collision or grounding) will often require engineer intervention. This coordination between bridge and machinery-control-room teams is a dimension which is missing from aircraft cockpit operations.

A second fundamental difference centers around ship pilotage through inshore waters. Most aircraft incidents occur at or near takeoff and landing. Similarly with ships, most incidents occur in or near ports and harbors or busy sea lanes such as the Straits of Dover and the Bosporus. Ships approaching or leaving most significant ports and harbors or negotiating restricted channels are required to carry a pilot, a master mariner with specific local knowledge and competence in bringing ships in and out of port. The pilot performs several crucial tasks, namely:

- Advising the master on local navigational hazards, including recent changes;
- Liaison with pilots aboard other vessels in the area; and,
- Liaison with local port authorities and traffic-monitoring facilities.

The fundamental difference between pilotage and air traffic control (ATC) is that the pilot comes to the ship (by small boat, boarding by means of a ladder, often itself a hazardous task). In this manner, someone is always present on the bridge who has knowledge of local hazards and has a common language with other pilots advising ships in the area and the local traffic-control authorities.

The role of a ship's pilot does not subsume the role of the master. The pilot's role is purely advisory. However, many masters effectively hand over control of the ship to the pilot. Some pilots are more assertive than others, and some masters more prepared to hand over control. A pilot and master who have not previously met will need to quickly establish a working relationship and subconsciously establish a power gradient between them as a component of that relationship. Often, there are only a few minutes to establish this working relationship before the first navigational decisions have to be taken and implemented.

A detailed consideration of marine pilotage is to an extent irrelevant to aircraft cockpit operations, because the concept of marine pilotage cannot be used for aircraft. However, it does provide some further insights into some of the human factors issues raised by this project.

> In 1993, a collision took place in the Suez Canal between two general cargo ships, the *Iranabad*, owned by the Iranian national shipping line, and a Sudanese vessel, the *Merawi*. Both ships were carrying Suez Canal pilots. The *Iranabad*, designated as the second ship in a southbound convoy from the Great Bitter Lake, collided with the *Merawi*, designated as the first ship, which was lying across the channel, maneuvering to enter it. Shortly before the collision, a conversation took place over very-high-frequency (VHF) radio between the two pilots in Arabic, a language not understood by the master of *Iranabad* (whose first language was Farsi). The pilot of *Iranabad* assured the master in their common language, English, that it was safe to proceed down the channel and that the *Merawi* would clear the channel before *Iranabad* arrived at her position.

Many ships' masters obtain pilotage exemptions for ports which they visit regularly. In order to obtain an exemption, a master has to be examined in local navigational knowledge while taking his ship in and out of port, in the same way as a pilot would be examined. The dialogue between a ship whose master has pilotage exemption and the port authorities is much closer to the situation of an aircraft captain liaising with ATC.

A third fundamental difference between ship and aircraft operations is that there will often be a wider range of skills and more individuals involved in ship maneuvering than in the case of aircraft. Marine casualties do occur during times when there is only one person on the bridge (the officer of the watch) and none in the engine room (there are even documented cases of casualties occurring with no one on the bridge). However, during "standby" periods, entering and leaving port and in confined waters, there will invariably be the master, at least one deck officer and a helmsman on the bridge (and also in many cases a pilot) and a team of two or three engineers in the machinery-control room. There may also be one or two people on the forecastle as lookouts and available for standby duties,[2] often including a deck officer. During standby periods, there will be a wide variation in skill levels between the master or pilot and the most junior officer present or the helmsman. There will also be a corresponding power gradient. The problems of power gradient which exist between an aircraft captain and first officer have their parallels in ship navigation. However, below the rank of chief officer or chief engineer, power gradient does not create comparable problems to those identified by this study for aircraft, because a junior officer simply would not question the decision of the captain.

A final fundamental difference between commercial aircraft and ship navigation is the extraordinary diversity of ships, which

[2] For example, emergency lowering of an anchor.

has no parallel in aviation. Ships come in all shapes and sizes, from small trawlers to supertankers. Each ship type has its own special set of navigational and ship-handling problems; in the case of large tankers and bulk carriers, it is sheer size and the lead time required to alter course and speed. Containerships have particular problems with regard to visibility when carrying containers on deck (which is most of the time). Fishing vessels have particular problems of maneuverability when fishing. All ship types have differing levels of vulnerability to wind and waves and have to be operated accordingly. High-speed craft, assuming increasing significance in ferry operations, have completely different handling characteristics from displacement vessels and have adapted some of their operating procedures from aircraft operations. These craft are highly susceptible to extreme environmental conditions, and their operating licenses prescribe the maximum wind and sea states in which they may operate.

C.7 Multicultural Crews in Shipping

Multicultural crewing of ships has been a seafaring tradition and has become common in the past 30 years, being far more widespread than in aviation. Very few ships which are owned or operated by companies in the industrialized world have "native" crews. Exceptions include ferries on short sea routes. Most ships owned by the industrialized world are crewed either completely by Third World or former Soviet Bloc citizens of one or more nationalities or by senior officers of the owning company's nation and junior officers and crew from elsewhere. The driver for this advanced level of multiculturalism has been purely economic and as a result, the market for ships' crews is totally global, possibly the most global labor market in the world.

The global nature of the ships' crewing market has led to two problems, exploitation and concerns with regard to the quality of qualifications and certificates of competency, which are issued by flag states, some of which are less scrupulous than others. Exploitation has been addressed by two global organizations, the International Labor Organization and the International Transport Workers Federation. However, economic exploitation is still widespread. The quality of certificates is potentially more serious and has led to the adoption of the two IMO STCW[3] conventions of 1987 and 1995, which have brought about significant improvements. However, the use of underpaid ships' officers with dubious qualifications, sometimes "purchased," is still far too prevalent and has no parallel in commercial aviation.

A catalyst for multicultural crews has been the prevalence of English as the language of the sea. The STCW conventions require proficiency in English as a prerequisite for senior deck officer qualifications for ships in international trades. However, problems with language communication between crewmembers of different nationality and in ship-to-shore communications do occur. These are being progressively overcome by the use of standard operating procedures (SOPs) and standard vocabularies in ship-to-shore and ship-to-ship VHF radio communications.

[3] Convention(s) on the Selection, Training and Certification of Watchkeeping officers.

C.8 SOPs

Formal (i.e., written) SOPs in navigating bridge operations are a relative innovation in merchant shipping. Progress in this area has received a significant boost with the introduction of the ISM code, which has forced the introduction of SOPs. It is thought that the introduction of SOPs has overcome many of the linguistic and cultural problems traditionally associated with multicultural crewing, but the implementation of ISM is so new that it is too early to draw any conclusions.

C.9 Crew Resource Management

Crew resource management (CRM) as it is practiced in aviation is still at the experimental stage in shipping. Where it has been introduced, it is in specialist passenger-carrying operations such as high-speed catamaran ferries, which have imported many aspects of their culture from aviation. This is one area where shipping has yet to learn from aviation, and there is little to offer in the opposite direction.

C.10 Professional Culture

The marine industry has a strong professional culture, possibly equal to that of aviation. The seagoing qualifications of master and chief engineer have a particularly high value, and entry to many grades of management in ship operations is all but impossible without such qualifications. Although shipping companies, as airlines, are increasingly run by accountants, ship-operations executives invariably have seagoing qualifications. There is often a reluctance of those who hold superior seagoing qualifications to accept the opinions of those who have never been to sea on matters of ship operations. However, this pride in qualifications and culture is not backed by the same salary levels as in aviation, which may suggest that financial reward does not play a significant part in the establishment of this type of professional culture.

There is not the same movement between the military and civilian worlds in shipping as there is in aviation. One reason for this may be that the Royal Navy has always viewed itself as the senior service. Former naval officers are more likely to find civilian jobs in shore-based industry than at sea in the merchant navy. Life in military and merchant navies is totally dissimilar, and there is only partial overlap in the skills required between merchant ship and naval ship captains.

C.11 Reference

Stopford, M. *Maritime Economics*. Routledge, 1997. ISBN 0-415-14310-7.♦

Worldwide Apron Accident/Incident Rates For 2001 Show Increase

Data from 353 airports showed that damage to equipment and facilities was more frequent than damage to aircraft on the apron, and that apron accident rates and incident rates were highest in the European Region and at larger airports.

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The number of apron (ramp) accidents and incidents reported in a multinational, multiregional survey increased 55 percent in 2001 compared with 2000, and the rate of incidents and accidents per 1,000 aircraft movements rose from 0.214 in 2000 to 0.372 in 2001.

The survey data also showed variations in the apron incident and accident rate among world regions, with the lowest overall rate in the Pacific Region and the highest overall rate in the European Region.

Data for 2001 were collected from 353 airports, and represented 8,591 apron accidents[1] and incidents[2] — which compared with 5,526 apron accidents and incidents reported in 2000. [Year-to-year comparisons of total numbers of accidents and incidents were affected by differences in the number of airports reporting annually, and rates might have been affected by possible changes in reporting accuracy and changes to some definitions in 2001 (see Notes).]

Stationary aircraft were damaged[3] by contact with apron equipment (16.81 percent of accidents and incidents) more often than moving aircraft were damaged (4.45 percent of accidents and incidents). Among categories of damage to stationary aircraft by apron equipment, the largest number of accidents and incidents involved aircraft-loading equipment, followed by passenger-handling equipment and aircraft-servicing equipment (Figure 1, page 79). Among categories of damage to moving aircraft, the largest number of accidents and incidents were caused by aircraft maneuvering, followed by jet blast (Figure 2, page 79).

The largest percentages of apron accidents and incidents did not involve aircraft. Equipment-to-equipment damage[4] accounted for 43.31 percent of the total, and equipment-to-facility[5] damage represented 34.75 percent of the total. Damage to property[6] or equipment by jet blast was reported in 0.69 percent of the total.

Apron accidents accounted for 2,630 injuries[7] to aviation personnel, of which 10 were fatal[8] and 290 were severe. There were 458 injuries to passengers, including six fatalities and 28 severe injuries. The injury rate was 0.134 per 1,000 aircraft movements, equivalent to one injury per 7,460 aircraft movements.

The highest overall rate of apron accidents and incidents was 0.752 per 1,000 aircraft movements in the European Region (Table 1, page 79), and the lowest overall rate was in the Pacific Region (0.056 per 1,000 aircraft movements). The report said that there was significant variation in overall rates between larger airports (those with more than 70,000 annual movements) and smaller airports (those with fewer than 70,000 annual movements). The rate for larger airports was 0.426 per 1,000 movements, compared with 0.179 for smaller airports (Table 2, page 80). The rate differential existed both for damage to equipment and facilities and damage to aircraft.

Full-year apron accident and incident data were collected and analyzed for 1999 and 2000. The overall rate rose

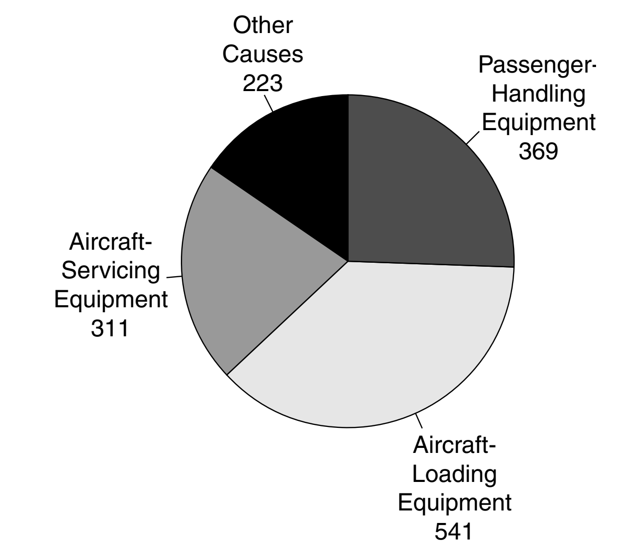

Figure 1

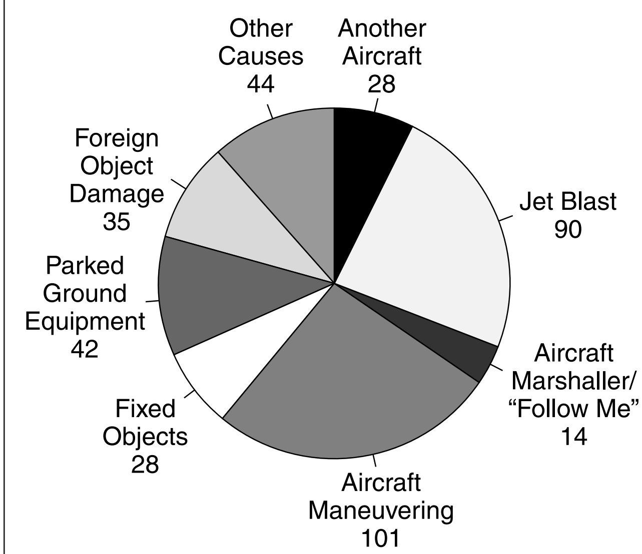

Figure 2

Table 1
Apron Incidents and Accidents at 353 Airports, by Region, 2001

Region	Number of Airports	Number of Aircraft Movements	Incidents/ Accidents to Aircraft	Incidents/ Accidents to Equipment/ Facilities	Number of Incidents/ Accidents	Rate to Aircraft	Rate to Equipment/ Facilities	Rate Overall
Africa	47	652,261	64	78	142	0.098	0.120	0.218
Asia	22	786,903	51	148	199	0.065	0.188	0.253
Europe	155	9,860,669	1,383	6,036	7,419	0.140	0.612	0.752
Latin America/ Caribbean	32	506,427	38	34	72	0.075	0.067	0.142
North America	57	8,857,004	199	424	623	0.022	0.048	0.070
Pacific	40	2,435,702	91	45	136	0.037	0.018	0.056
Total	**353**	**23,098,966**	**1,826**	**6,765**	**8,591**	**0.079**	**0.293**	**0.372**

Note: Rate = number of incidents/accidents per 1,000 aircraft movements.

Source: Airports Council International

from 0.208 per 1,000 aircraft movements in 1999 to 0.214 in 2000 and 0.372 in 2001. During that period, the rate of apron accidents and incidents involving aircraft did not change significantly, but the rate for accidents and incidents involving equipment and facilities rose from 0.129 in 1999 to 0.141 in 2000 and 0.293 in 2001. The overall rate of injuries to aviation personnel and passengers also increased, from 0.060 per 1,000 aircraft movements in 1999 to 0.095 in 2000 and 0.134 in 2001.

The 2001 survey included reports of spills of fuel and other materials, such as lubricating oil, hydraulic oil, liquid from lavatories and deicing fluid, on the apron. At the 353 airports that submitted data, 7,206 spills were reported, of which 3,907 (54.22 percent) were fuel spills. The overall rate for fuel spills and other spills was 0.312 per 1,000 aircraft movements.♦

[FSF editorial note: This article is adapted from *ACI Survey on Apron Incidents/Accidents 2001*, published December

Table 2
Apron Incidents and Accidents at 353 Airports, by Region and Airport Size, 2001

Region	Number of Airports	Number of Aircraft Movements	Incidents/ Accidents to Aircraft	Incidents/ Accidents to Equipment/ Facilities	Number of Incidents/ Accidents	Rate to Aircraft	Rate to Equipment/ Facilities	Rate Overall
Airports Reporting More Than 70,000 Annual Aircraft Movements								
Africa	1	83,293	7	11	18	0.084	0.132	0.216
Asia	4	403,265	35	82	117	0.087	0.203	0.290
Europe	40	7,522,149	1,217	5,703	6,920	0.162	0.758	0.920
Latin America/ Caribbean	0	—	0	0	0	0.000	0.000	0.000
North America	32	8,301,901	182	395	577	0.022	0.048	0.070
Pacific	10	1,713,081	35	15	50	0.020	0.009	0.029
Total	**87**	**18,023,689**	**1,476**	**6,206**	**7,682**	**0.082**	**0.344**	**0.426**
Airports Reporting Fewer Than 70,000 Annual Aircraft Movements								
Africa	46	568,968	57	67	124	0.100	0.118	0.218
Asia	18	383,638	16	66	82	0.042	0.172	0.214
Europe	115	2,338,520	166	333	499	0.071	0.142	0.213
Latin America/ Caribbean	32	506,427	38	34	72	0.075	0.067	0.142
North America	25	555,103	17	29	46	0.031	0.052	0.083
Pacific	30	722,621	56	30	86	0.077	0.042	0.119
Total	**266**	**5,075,277**	**350**	**559**	**909**	**0.069**	**0.110**	**0.179**

Note: Rate = number of incidents/accidents per 1,000 aircraft movements.

Source: Airports Council International

2002 by Airports Council International, Geneva, Switzerland. Internet site: <www.airports.org> The results of the survey were compiled and analyzed by Capt. Agostino Ferrari, advisor to the ACI Operational Safety Subcommittee, and David Gamper, director technical/safety at ACI.]

Notes

1. An accident was defined as "an occurrence associated with the operation or handling of an aircraft in which a person is fatally or seriously injured, or the aircraft sustains damage."

2. An incident was defined as "an occurrence, other than an accident, associated with the operation or handling of an aircraft, which affects or could affect the safety of operation."

3. Aircraft damage was defined as "any *damage or* adverse condition [that] affects the structural strength, performance or flight characteristics of an aircraft or causes delay in flight operations due to repairs." (Italics represent change in 2001.)

4. Equipment damage was defined as "any damage or adverse condition [that] limits or prevents the use of *mobile* aircraft-handling equipment *or requires repairs*." (Italics represent change in 2001.)

5. Facility damage was defined as "any damage or adverse condition [that] limits or prevents the use of a *fixed* aircraft-handling facility or requires repairs." (Italics represent change in 2001.)

6. Property damage was defined as "any damage or adverse condition [that] limits or prevents the use of a structure or building or requires repair."

7. An injury was defined as "any condition [that] requires medical assistance, including first aid."

8. A fatal injury was defined as "any injury [that] results in death within 30 days of the accident."

Publications Received at FSF Jerry Lederer Aviation Safety Library

Report Outlines Procedures for First Responders at Aircraft-accident Sites

Police, firefighters and medical personnel are usually the first to arrive at an accident scene. Australian civil and military safety authorities have issued jointly a report outlining procedures to ensure the safety of these emergency-services personnel, aid survivors and preserve information for accident investigators.

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Reports

Civil and Military Aircraft Accident Procedures for Police Officers and Emergency Services Personnel. Department of Transport and Regional Services, Australian Transport Safety Bureau (ATSB); Directorate of Flying Safety–Australian Defence Force (DFS–ADF). November 2002. 38 pp. Figures, illustrations. Available from ATSB.*

ATSB and DFS–ADF jointly prepared this booklet to assist emergency-services personnel (police, fire and ambulance) who are usually the first to arrive at the scene of an aircraft accident. The booklet provides basic information about civil aircraft accident sites and military aircraft accident sites, a checklist of essential safety actions to be taken by emergency-services personnel, and contact information for notifying appropriate authorities. Although some information is Australia-specific, much of it applies at any accident scene (e.g., "Every piece of the aircraft, its location and exact position, is important in determining the sequence of events and the contributing factors that led to the accident. Secure the accident site by placing a cordon around all scattered wreckage, as well as other evidence such as marks made by the aircraft and ground scars"). The booklet is a first edition and supersedes other ATSB and DFS–ADF publications on the same topic.

NBAA Works: Spirit & Achievement of the National Business Aviation Association. National Business Aviation Association (NBAA). 2002. 136 pp. Photographs. Available from NBAA.**

The report's preface says that it "encapsulate(s) many of the high points, challenges, achievements, innovations and outreach efforts, as well as some of the persistent problems that have helped shape NBAA's growing strength and reputation from the middle years of the 20th century (1947) to the beginning of the 21st." The six chapters reflect the six clauses of the association's articles of incorporation: operating efficiency and safety; closer relations with members; exchange on operational matters; enlightening the authorities; securing proper advantages from regulatory and other agencies; and promoting business aviation's importance to the national economy. Also included are photos and information about current and past members of the board of directors and awards recipients.

Books

Crash and Learn: The S. Harry Robertson Story. Gilbert, Kathleen. Phoenix, Arizona, U.S.: Heritage Publishers, 2002. 142 pp. Photos.

S. Harry Robertson, in his diverse career in aerospace safety, has made a specialty of accident survivability. Most of his professional life has been devoted to studying injuries resulting from aircraft accidents and related preventive measures.

The attempt to design crashworthy fuel systems has been among Robertson's foremost concerns. Looking for a way to test his ideas, in 1961 he joined a division of Flight Safety Foundation called Aviation Crash Injury Research (AvCIR), which was subjecting aircraft to impact forces to gauge the feasibility of survival-enhancing systems. At AvCIR, Robertson worked with two pioneers in the developing field of accident survivability, Howard Hasbrook and Hugh DeHaven, who were — in this book's words — "more concerned with what in the accident caused the injury … than what caused the accident itself."

AvCIR, later renamed Aviation Safety and Engineering Research (AvSER), was working under a U.S. Army contract to develop fuels with a thicker consistency that would be less likely to flow, vaporize and ignite following an accident-induced fuel-system failure. Results of those efforts ultimately proved unsatisfactory, but Robertson led the AvSER team in designing and testing his own concept of a system that would isolate the fuel from ignition sources. A puncture-resistant yet flexible fuel tank contained inside a rigid structure was the guiding principle. After much testing, Robertson's concept for a crashworthy fuel system was adopted for use in U.S. military helicopters. The system, installed beginning in 1970, is credited with significantly reducing the rate of postaccident fires among helicopters in Vietnam. Furthermore, says this book, "The [U.S. Federal Aviation Administration] began enforcing stricter requirements on airliner crash survivability based on AvSER reports." (AvSER was sold by Flight Safety Foundation in 1968.)

The book includes photographs of accident-survival testing and recollections of noteworthy individuals and organizations in the field of aviation safety. It also contains an account of Robertson Aviation, the company founded by Harry Robertson that today provides crashworthy auxiliary fuel systems that have evolved from Robertson's work at AvSER.

Incident Command: Tales from the Hot Seat. Flin, Rhona; Arbuthnot, Kevin, eds. Aldershot, England: Ashgate Publishing, 2002. 297 pp. Figures, tables, references.

The book is presented in three parts. The first part, written by experienced emergency services commanders, discusses the nature of command, building and training teams, and role modeling. The second part presents personal case studies that are written by commanders from several different disciplines — police, fire, military, airline and prison. Although their work environments are different, their work has a common focus: the human aspects of the role of the operational incident commander. The final section covers decision making, principles for training and assessment, and training for decision making by team-based simulation.

Air Carrier Operations. Holt, Mark J.; Poynor, Phillip J. Ames, Iowa, U.S.: Iowa State Press, 2002. 309 pp. Figures, tables, appendixes, glossary, bibliography.

This is an introductory textbook for undergraduate aviation students about U.S. Federal Aviation Regulations (FARs) and the FARs' influence on air carrier operations. The book also is designed to be a review textbook for airline-pilot candidates and an introductory textbook for military pilots transitioning to commercial operations.

Complete text of all FARs is not included. Instead, sufficient references are provided to guide students to the appropriate full-text documents in other locations, such as the Internet. The authors' expectation is that readers will develop an appreciation of the variety of regulatory issues governing air carrier operations and will be able to find, read and apply appropriate regulations.

The book focuses primarily on FARs Part 121 air carriers and includes relevant portions of Parts 119, 135, 91 and 61. There is additional emphasis on instrument flight rules (IFR) flight operations, so readers are expected to have an instrument rating for background.

Regulatory Materials

Commercial Air Tour Operations Conducted Over National Parks and Tribal Lands. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 136–1. Oct. 25, 2002. 12 pp. Available from GPO.***

This AC provides information, instructions and procedures to obtain operating authority for commercial air-tour operations over U.S. national parks and Native American tribal lands. The AC includes precise descriptions of aircraft and operations affected, as well as geographic perimeters and other limitations. The five phases (from application to approval or rejection) of the operating-authority-approval process are explained, and instructions for submitting application packets are detailed.♦

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1200 Eighteenth St. NW, Suite 400
Washington, DC 20036-2527 U.S.
Internet: <http://www.nbaa.org>

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Washington, DC 20402 U.S.
Internet: <http://www.access.gpo.gov>

Airplane Strikes Vehicle Parked Near Gate

The flight crew believed that the area was clear of obstructions when they taxied the airplane to the gate at an airport in England after a night flight from Germany. After the incident, the airport operator planned to publish warnings to drivers of airside vehicles not to leave unattended equipment at the gates.

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The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

Air Carrier

Vehicle's Headlight Was Not Functioning

Boeing 737-300. Minor damage. No injuries.

After a night flight from Germany to England, the flight crew was taxiing the airplane to the gate (stand) when air traffic control told them about a gate change. The change required that they taxi the airplane into the next gate on their right along the taxiway.

Both crewmembers said that they believed that they had checked to confirm that the area was free of obstacles. The captain taxied the airplane along the taxi-guidance line, used the azimuth guidance nose-in stands (AGNIS) system (which uses colored lights to provide centerline guidance) to align the airplane with the gate centerline and then used the mirror guidance system to stop the airplane in the correct position. After the airplane was parked, a ground crewmember said that the airplane's left wing had struck the upper portion of a "highloader" vehicle. The vehicle had been parked near the gate because the driver believed that the gate would not be in use; the driver planned to park there to await the arrival of an airplane in an adjacent gate so that he could put that airplane's chocks in place and could unload the aircraft.

When the driver saw the B-737 approaching, he ran to the front of the gate and tried to use hand signals to warn the crew. The report said that, after the B-737 had been turned toward the gate, "it is likely that the [captain] concentrated on lining up with the stand AGNIS and mirror parking systems, which requires the focus of attention to be in two different places simultaneously. While lining up and stopping the aircraft in the correct place, it is unlikely that, in the dark, he or the first officer would have noticed signals from ground personnel moving in from [the] left-hand side."

Because of an absence of parking for airside vehicles near the gates, drivers of those vehicles sometimes parked at adjacent gates, if they were vacant and were expected to remain vacant. In this incident, the ground crew was unaware of the late gate change. The vehicle had been parked with headlights and sidelights turned on, parallel to the gate, which was 9.6 meters (31.5 feet) away. Inspection revealed that the headlight closest to the approaching B-737 was not functioning.

After the incident, the airport operator said that it would publish safety instructions to remind drivers that unattended equipment must not be parked at aircraft gates and would require that ramp personnel be reminded to "assume that an aircraft may enter an unoccupied stand at any time."

The policy of using remote selection of the gate-entry guidance system also was being reviewed. U.K. Civil Aviation Authority guidance says that the handling employees at the gate should ensure that the gate is clear before the system is activated.

B-737, Cessna 404 Collide At 11,500 Feet

Boeing 737. Minor damage. No injuries.
Cessna 404. Substantial damage. No injuries.

Day visual meteorological conditions prevailed when the two aircraft collided at 11,500 feet over Namibia. The B-737 was being flown from Namibia to Angola; the Cessna was being flown on a domestic flight in Namibia.

The Cessna was in level flight at 11,500 feet, and the B-737 was being flown to 31,000 feet when the accident occurred.

An investigation revealed that the Cessna was equipped with a transponder that had been activated, and the B-737 was equipped with a traffic-alert and collision avoidance system (TCAS). The report did not say whether the B-737 TCAS provided a warning about the location of the other aircraft.

After the collision, the pilot of the Cessna, which received substantial damage to the rudder, vertical stabilizer and the outboard portion of the right horizontal stabilizer, returned to the departure airport. The crew of the B-737, which received damage to the outboard right wing slat and the right wing tip, flew the airplane to the destination airport.

Smoke, Odor Traced to Engine Bleed-air System

Airbus A330-200. Minor damage. No injuries.

The airplane was being flown at Flight Level 390 (approximately 39,000 feet) over Zanzibar during an overnight flight from United Arab Emirates to South Africa when the flight crew smelled fumes and observed smoke coming from the air conditioning vents left of the captain's seat. The flight crew landed the airplane at an airport in Tanzania.

An examination of the engines by maintenance personnel revealed that a "slight acrylic smell" was originating from the no. 2 engine bleed-air system and that the odor disappeared "when the no. 2 engine bleeds were blanked," the report said.

Air Taxi Commuter

Inadequate Preflight Fuel Check Cited in Engine Failure

Beech Duchess 76. No damage. No injuries.

After takeoff from an airport in Australia on an instrument flight rules flight plan, during flight to cruise altitude, power from the right engine decreased.

The incident report said, "The pilot concluded that, from the engine tachometer reading of 1,500 revolutions per minute and the manifold pressure indications, the right engine had partially failed. He carried out engine-failure-confirmation checks but — as the propeller-pitch lever was very stiff — was unable to place it in the feather position. … Therefore, he decided to reset the right-engine controls to a cruise setting because partial power was preferable to no power."

The pilot decided to return to the departure airport, where he conducted a visual approach and landing.

A subsequent inspection of the airplane revealed that the right fuel tank, which had been supplying fuel to the right engine, contained no fuel. The report said that the right fuel-quantity-gauge transmitter unit was "corroded and seized in a position that resulted in the gauge always indicating half full." Feathering the propeller was possible, although the propeller-pitch control was described as "stiff."

The pilot had inspected the airplane before takeoff and had checked the company fuel log and the readings on the two fuel-quantity gauges. He also visually checked the contents of the tanks and estimated that they contained a total of about 200 liters (53 gallons) of fuel. The report said that he did not confirm his estimate because "a fuel-tank dipstick was not provided for that aircraft." He had calculated in his flight plan that the flight would require 128 liters (34 gallons) of fuel, including reserves.

The pilot recently had returned to the company, where he had worked for four years before leaving to work for two years as a pilot with a regional airline. When the regional airline suspended operations, he returned to the company; the day before the incident, he had worked for 12 hours, accumulating 8.1 flight hours while he completed a copilot endorsement on a business jet. He had six hours to eight hours of rest overnight and had awakened early on the day of the incident.

"The pilot reported that he was tired on the day of the occurrence and that he had felt similarly for some time," the report said. "He had been on duty for 16 consecutive days, or a total of 159.4 hours duty time, primarily in a capacity unrelated to his employment as a pilot."

The pilot had accumulated about 3,600 flight hours, including about 3,000 flight hours in turboprop airplanes and jet airplanes and about 600 flight hours in reciprocating-engine airplanes. In the three months before the incident, the pilot had flown about 70 hours, including three hours in the incident airplane.

The report said that significant factors in the incident were that "the pilot did not establish the actual fuel quantity on board the aircraft prior to departure, the aircraft fuel tanks contained insufficient fuel for the planned flight [and] the right fuel-quantity-gauge transmitter unit was inoperative."

Pilot Actions, Fuel-system Anomalies Cited in Off-airport Landing

Partenavia P.68B Victor. No damage. No injuries.

Instrument meteorological conditions (IMC) prevailed for the scheduled flight in New Zealand. The pilot had fueled the airplane the previous night and had flown the airplane about 0.7 flight hours to another airport. She did not add fuel the next morning because she had calculated that the tanks held enough fuel for the morning's return flight and for an additional flight.

She completed the return flight, and four passengers boarded for the next flight. The pilot said that during climb, the left wing was "heavy," and an "uncomfortable" amount of aileron control was required to maintain wings level. The normal operating procedure was to operate the left engine on the left fuel tank and the right engine on the right fuel tank. Nevertheless, the pilot said later that she had considered cross feeding (selecting the right engine to the left fuel tank) but had not done so because of the busy workload and because she believed that company policy did not allow cross feeding. She also believed that there was adequate fuel in the right tank to complete the flight.

After she leveled the airplane at a cruising altitude of 5,000 feet, she observed that the fuel-quantity gauges showed an imbalance, with a low right-fuel-tank reading. The pilot said later that she "did not trust the readings because she believed aircraft fuel gauges were generally unreliable."

During the cruise portion of the flight, the pilot observed that the fuel-quantity gauges indicated that fuel in the right tank was "quite low" and that the left tank was more than half full. About the same time, there was a loss of power from the right engine. The pilot declared pan, pan, an urgent condition. Later, after the airplane could not maintain altitude, she declared mayday, a distress condition. The fuel-selector knobs were "very stiff to operate," but the pilot nevertheless selected the left engine to the right fuel tank. When the left engine began to vibrate, she realized her mistake and reselected the left engine to the left fuel tank to restore power. She did not feather the right propeller

Because the airplane was in IMC and because the pilot was concerned that the left engine also might lose power, she conducted a precautionary landing on a road.

The report said that the incident occurred because of "a chain of avoidable events linked together. The events ranged from the aircraft fuel system itself, to the management of the fuel system and to the handling of the emergency. Any break in a link could have prevented the incident."

The report said that the right engine's power loss resulted from fuel starvation that followed an inadvertent fuel transfer from the right fuel tank to the left fuel tank while the airplane was on the ground. The airplane was "known to be prone to inadvertent tank-to-tank fuel transfer when parked for a period of time," but the pilot was unaware of the problem.

The operator "potentially could have corrected the problem" with additional maintenance, the report said.

The report said that the pilot could have taken several actions to lessen the problem: She could have returned to the departure airport after having difficulty maintaining wings level, could have attempted cross feeding of fuel to the right engine and could have feathered the right propeller after the power loss occurred.

Airplane Overruns Runway During Landing in Snow

Embraer ERJ-145LR. Substantial damage. No injuries.

Instrument meteorological conditions prevailed for the midday approach and landing at an airport in the United States. The flight crew conducted an instrument landing system (ILS) approach to Runway 6L and experienced no problems during the approach. After touchdown, the crew was unable to stop the airplane on the runway. The airplane continued beyond the departure end of the runway on an extended runway centerline, struck the ILS localizer antenna and stopped about 600 feet (183 meters) beyond the departure end of the runway.

Data from the airplane's flight data recorder showed that the position of the air/ground squat switch on the main landing gear changed from air to ground when the airspeed was 150 knots and the airplane was 0.38 nautical mile (0.70 kilometer) beyond the ILS distance-measuring equipment (DME) antenna, which was located 510 feet (156 meters) beyond the departure end of the runway. At the same time, the spoilers deployed; three seconds later, the thrust reversers deployed. When the airplane was 0.13 nautical mile (0.24 kilometer) from the ILS DME antenna, the airspeed was about 100 knots.

The runway is 6,800 feet (2,074 meters) long; the landing threshold is displaced 530 feet (162 meters).

One hour before the landing, a notice to airmen (NOTAM) was issued to tell pilots that the runway was covered with a thin layer of wet snow. The NOTAM said that liquid deicer and sand had been applied to the center 100 feet (31 meters); braking action was reported as good. There was no record of additional runway treatment until after the accident; 11 minutes after the accident, braking action was reported as poor.

Weather six minutes before the accident included winds from 330 degrees at 19 knots with gusts to 29 knots. Three minutes after the accident, the winds were from 330 degrees at 17 knots with gusts to 26 knots.

Corporate
Business

Turbulence Results in Injury to Flight Attendant

Gulfstream Aerospace Gulfstream IV. No damage. One serious injury.

Instrument meteorological conditions prevailed for the descent from Flight Level (FL) 350 (approximately 35,000 feet) to FL 170 in preparation for landing at an airport in China. The captain said that during the descent, he flew the airplane around a line of thunderstorms. The flight crew told the flight attendant that turbulence was possible and illuminated the "fasten seat belts" sign. The report did not say whether the flight attendant was seated and had fastened her seat belt.

At FL 300, about 15 statute miles (24 kilometers) from a weak radar echo, the airplane entered stratus clouds and moderate chop, followed by severe turbulence that continued for 30 seconds to 90 seconds. After the turbulence ended, a passenger told the flight crew that the flight attendant had been injured. She received medical treatment for a fracture of her left ankle.

Deer Strikes Airplane During Takeoff

Cessna Citation 500. Substantial damage. No injuries.

Night visual meteorological conditions prevailed for the flight from an airport in the United States. As the pilot rotated the airplane for takeoff, a deer ran across the runway and struck the nose landing gear. The pilot continued the takeoff and flew the airplane to a larger airport nearby, where he conducted two low passes while ground rescue personnel determined that the nose landing gear was not extended fully.

The pilot flew the airplane to consume fuel and then conducted an approach at the larger airport. About 100 feet above ground level, he shut down the engines, the fuel shut-off and the generators. He landed the airplane, which came to a stop "on the fork of the nose [landing] gear and [landing-]gear doors," the report said.

A preliminary investigation revealed that the departure airport had no perimeter fence and that an airport/facilities directory included a warning of deer at the airport.

Other
General
Aviation

Airplane Strikes Terrain During Approach to Landing

Cessna 340. Substantial damage. One serious injury, three minor injuries.

The airplane was being flown at 16,000 feet on an evening flight in Australia. The pilot decided that, because of a strong tail wind, he would extend the flight to an airport beyond his planned destination. For fuel-planning purposes, he asked air traffic control (ATC) for a clearance that would allow him to fly in the opposite direction on a one-way air route but was told instead to fly to a nearby navigation aid. The pilot agreed but planned to make a later request for a more direct route to the destination.

About 15 minutes later, the pilot told ATC that the airplane had minimum fuel.

"The controller asked the pilot if he was declaring an emergency, to which he replied 'affirmative,'" the report said. "The pilot later commented that he did this in the hope of expediting his arrival."

The pilot said that, when the airplane was about 12 nautical miles (22 kilometers) from the destination, the fuel-flow gauges "were indicating a total flow of 140 pounds per hour, and the fuel-quantity gauges for the selected main tanks, although wandering somewhat, were displaying a healthy amount."

About nine nautical miles (17 kilometers) from the airport, the pilot observed that one fuel-flow gauge indicated zero and that "one [engine] or both engines began to surge and run roughly." He told the controller what had happened, and the controller told the pilot that his airplane was 2.0 nautical miles (3.7 kilometers) from an airstrip. The pilot tried to conduct a 360-degree turn to reposition the airplane for an approach, but the airplane struck terrain before reaching the airstrip. Witnesses said that the engines were operating before the impact.

The pilot said that the fuel tanks had been full before his departure. The report said that investigators' calculations revealed that the airplane should have arrived with 95 minutes to 100 minutes of fuel remaining, "if fuel management and flight planning were as reported" by the pilot.

The report said, "It is likely that the pilot assumed the zero reading indicated impending fuel exhaustion and concentrated on conducting a landing in unfamiliar terrain. During the landing approach, the pilot lost control of the aircraft, and it descended rapidly to the ground."

Broken Propeller Blade Blamed for Engine Failure

Beech D95A Travel Air. Substantial damage. No injuries.

The airplane was being flown on a mid-afternoon approach to an airport in Sweden when a loud bang was heard, the right engine began to vibrate and power from the right engine decreased.

The pilot shut down the engine, feathered the propeller and disengaged the autopilot. He received radar vectors to an en route airport, where he landed the airplane.

An investigation revealed that a blade on the right propeller had fractured about 10 centimeters (3.9 inches) from the blade root flange and had separated from the propeller hub. The fracture resulted from a fatigue crack within the blade that initiated in a defective area of the blade root.

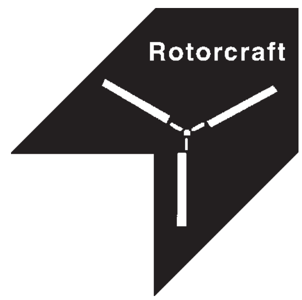
Airplane Strikes Bushes During Familiarization Flight

Piper PA-25-235 Pawnee. Destroyed. No injuries.

The pilot was conducting his first flight in the single-seat airplane to prepare for training for glider-towing operations at an airport in England. Before the flight, he had received a briefing from the chief flight instructor.

After 15 minutes in flight, the pilot attempted to land the airplane on the 600-meter (1,969-foot) wet grass runway. The airplane touched down "well along the runway," and application of the brakes did not slow the airplane, the report said. The pilot began a go-around, but the airplane struck bushes and came to a stop inverted.

The pilot said that the causes of the accident were "a combination of lack of experience on type, calm surface wind conditions and the wet grass." The report said that the pilot also had conducted the go-around with the carburetor heat selected to "HOT" and the flaps extended. Calculations were that the landing distance required was almost 500 meters (1,641 feet).



Fuel Starvation Cited in Double Engine Failure

Agusta A109E. Substantial damage. Two minor injuries.

The air ambulance helicopter was being flown from a hospital to the operator's base in Wales when, at 400 feet, both engines failed. The pilot declared mayday, a distress condition, and landed the helicopter in a field.

Maintenance records showed that two days before the accident, the electric boost pump for the left-forward fuel tank had failed. Maintenance personnel planned to replace the pump three days after the pump failure (one day after the accident) and requested that minimum fuel be in the tank when they performed the work.

The minimum equipment list (MEL) said that flight was permitted with one electric fuel boost pump inoperative, as long as the cross-feed system was operative and the limitations published in the *Rotorcraft Flight Manual (RFM)* were observed. The MEL did not specify what the *RFM* limitations were.

The day before the accident, the pilot of the accident helicopter reviewed the "Failure of Fuel Pump" emergency checklist, which included instructions to manually select the cross-feed switch to "CLOSED" to prevent the cross-feed valve from opening automatically to maintain fuel pressure to both engines. The checklist also included a warning that in the event of a fuel-pump failure, unusable fuel in the forward tank would increase to 20 kilograms (44 pounds) from 4.0 kilograms (8.8 pounds).

The next afternoon, the pilot determined that the helicopter was carrying sufficient fuel — even with the increase in unusable fuel — to transport a patient from a nearby landing site to a hospital and then to fly the helicopter back to the base.

After departure from the hospital, the helicopter entered heavy snow showers, and the "FUEL PUMP 2" warning light on the electronic display unit illuminated. Both engines failed.

The report said that the MEL was "deficient" in providing guidance on flight with an inoperative fuel pump.

The emergency checklist available to the pilot was reproduced from the *RFM*. The last item on page 43 of the emergency checklist discussed a condition not relevant to this particular pump failure; the information on page 44 also was irrelevant, except for a cautionary statement that "the fuel in the forward lower tank with the failed pump (maximum of 105 kilograms [231 pounds]) cannot be used when flying with the cross-feed valve open."

The report said that the pilot "could not recall why he had not closed the cross-feed valve, but not having seen the [cautionary statement] on page 44, he believed that he still had sufficient fuel in the forward left tank to continue the short distance to his operating base."

Helicopter Strikes Terrain During Surveying Flight

Bell 206B JetRanger II. Destroyed. Four fatalities, one serious injury.

The helicopter was being flown on a surveying operation in Australia. After about 90 minutes of surveying, including work performed in the air and on the ground, a passenger asked the pilot to land the helicopter so that the surveyors could perform additional work on the ground. While the pilot searched for a suitable location for landing, one passenger (the only survivor) said that he heard a "beep" in his headphones and observed the pilot checking his instruments. The pilot resumed his search for a landing site.

The survivor said that several seconds later, the beeping became continuous, the helicopter "appeared to fall out of the sky," and the pilot said, "Hang on, boys. This is going down."

The survivor later identified the beeping as the engine-out audio warning tone. The report said that the investigation did not determine whether the single beep was a "momentary warning of an impending engine power failure."

The report said, "The engine compressor and power sections exhibited signs of rotation, but not power, at impact."

The reason for the engine failure could not be determined because of fire damage.

Fractured Oil-line Fitting Cited in Engine Failure

Hughes 369D. Substantial damage. No injuries.

Visual meteorological conditions prevailed for the late afternoon scenic passenger flight in New Zealand. The pilot flew the helicopter from the company's base to a mountain landing site, where he kept the rotors turning while passengers boarded. The pilot conducted a passenger briefing, then conducted the takeoff and flew the helicopter along a mountain-crater rim and across a lake and a valley. At the end of the valley, as he began a cruise climb and turned toward the company base, he observed that the engine chip warning light had illuminated.

The pilot decided to land the helicopter at a nearby airstrip but then observed that indications on the engine-oil-pressure gauge and the engine-oil-temperature gauge were very low and heard the "low revolutions per minute" audio warning. He began an autorotation.

He then heard a "poof" sound from the engine and observed the red "engine out" light. He conducted an autorotative flare and landing on a small area of level land. After landing, the helicopter rolled onto its right side.

An investigation revealed that the engine failed because of oil starvation that resulted from the fracture of a fitting in the oil line to the torque gauge. The investigation did not determine the cause of the fracture of the fitting.

Loss of Tail-rotor Control Prompts Emergency Landing

Rotorway Executive 90. Substantial damage. Two minor injuries.

Visual meteorological conditions prevailed for the instructional flight from an airport in the United States. The student was practicing flight in the airport traffic pattern and autorotative landings.

The student had flown the helicopter onto a base leg for an approach to landing and had leveled the helicopter when a bang was heard. The flight instructor took the flight controls and turned the helicopter toward an open area for an emergency landing. During autorotation, the flight instructor raised the collective to check for controllability; the helicopter yawed left. The flight instructor continued the autorotation, and as he pulled the collective, the helicopter yawed left again, "landed firmly" and rolled onto its right side, the report said.

An examination of the helicopter revealed that the secondary drive shaft had sheared at midspan. The investigation was continuing.♦

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