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INTRODUCTION

1. Since the beginning of aviation, human error has been recognized as a major factor in accidents and incidents. Indeed, one of aviation's biggest challenges has been — and will continue to be — human error avoidance and control. Traditionally, human error in aviation has been closely related to operational personnel, such as pilots, controllers, mechanics, dispatchers, etc. Contemporary safety views argue for a broadened perspective which focuses on safety deficiencies in the system rather than in individual performance. Evidence provided by analysis from this perspective has allowed the identification of managerial deficiencies at the design and operating stages of the aviation system as important contributing factors to accidents and incidents.

2. During the early years, aviation safety efforts were directed towards improving the technology, with the main focus on operational and engineering methods for combating hazards. With admirable success, they sustained a reduced accident rate. When it became apparent that human error was capable of circumventing even the most advanced safety devices, efforts were then directed to the human element in the system. The late 70s and 80s will undoubtedly be remembered for the prevailing enthusiasm regarding aviation Human Factors. Cockpit (and then Crew) Resource Management (CRM), Line-Oriented Flight Training (LOFT), Human Factors training programmes, attitude-development programmes and similar efforts have multiplied, and a campaign to increase the awareness of the pervasiveness of human error in aviation safety has been initiated. Human error, however, continues to be at the forefront of accident statistics.

3. Statistics can be misleading in understanding the nature of accidents and devising prevention measures. Statistics reflect accidents as a series of cause and effect relationships grouped into discrete categories (flight crew, maintenance, weather, ATC, etc.). Errors are not registered as such but some of their effects are: controlled flight into terrain, aborted take-off overrun, etc. Statistics then provide the answers when it is too late. They fail to reveal accidents as *processes*, with multiple interacting chains, which often go back over considerable periods of time and involve many different components of the over-all system.

4. The investigation of major catastrophes in large-scale, high-technology systems has revealed these accidents to have been caused by a combination of many factors, whose origins could be found in the lack of Human Factors considerations during the design and operating stages of the system rather than in operational personnel error. Examples of such catastrophes include the accidents at the Three Mile Island (Pennsylvania, USA, 28 March 1979) and Chernobyl (Ukraine, USSR, 26 April 1986) nuclear power plants, the Challenger space shuttle (Florida, USA, 28 January 1986), the double B-747 disaster at Tenerife (Canary Islands, Spain, 27 March 1977) and the Bophal (Bophal, India, 3 December 1984) chemical plant. Large-scale, high-technology systems like nuclear power generation and aviation have been called *sociotechnical systems*, in reference to the complex interactions between their human and technological components. *Management factors* and *organizational accidents* are key concepts in sociotechnical systems' safety. The terms *system accident* and *organizational accident* reflect the fact that certain inherent characteristics of sociotechnical systems, such as their complexity and the unexpected interaction of multiple failures, will inevitably produce an accident. In sociotechnical systems, remedial action based on safety findings goes beyond those who had the last opportunity to prevent the accident, i.e. the operational personnel, to include the influence of the designers and managers, as well as the structure or architecture of the system. In this approach, the objective is to find *what*, rather than *who*, is wrong.

5. Consider the probable cause statement in the aircraft accident report following a twin jetliner crash during an attempted take-off in icing conditions:

> "The National Transportation Safety Board determines that the probable causes of this accident were the failure of the airline industry and the Federal Aviation Administration to provide flight crews with procedures, requirements and criteria compatible with departure delays in conditions conducive to airframe icing and the decision by the flight crew to take off without positive assurance that the airplane wings were free of ice accumulation after 35 minutes of exposure to precipitation following deicing. The ice contamination on the wings resulted in an aerodynamic stall and loss of control after liftoff. Contributing to the cause of the accident were the inappropriate procedures used by, and inadequate coordination between, the flightcrew that led to a rotation at a lower than prescribed airspeed." [1]

While acknowledging the role the operational personnel played in triggering the accident, the analysis looks for system deficiencies and recognizes that the root causes of the accident can be traced back to flaws in the aviation system design and operation.

6. This digest, therefore, addresses the influence of management factors in aviation safety, from the perspective of organizational accidents. Its contents, like any changes or new approaches in aviation, are *evolutionary* rather than *revolutionary*. Management factors in accident prevention go back to some of the earliest industrial safety texts, forty or more years ago; they have been the subject of prevention courses for over thirty years (*Advanced Safety Management and System Safety Factors*, C. O. Miller, University of Southern California, 1965). This digest builds on the ICAO *Accident Prevention Manual* (Doc 9422). This manual, first published in 1984, clearly indicates that the responsibility for safety in any organization[2] rests ultimately with management and advocates a broadened approach to accident prevention. This digest picks up where the Prevention Manual left off, but from the perspective of Human Factors and with the obvious benefit of the wealth of knowledge accrued through the intensified research in the intervening years. In due time, this material will be incorporated in a revision to the Prevention Manual.

7. The objective of this digest is to provide the participants in the decision-making process in the aviation industry — including corporate management, regulatory authorities, manufacturers and professional associations — with an awareness of the impact of their actions or inactions on aviation safety. Throughout the digest, numerous examples are included for clarification purposes. The examples are excerpted from accident investigation reports produced by relatively few States and their inclusion should by no means be construed as a negative reflection on the safety record of those States or as an unwarranted criticism of their administrations or aviation systems. On the contrary, it is an implicit recognition of a progressive attitude towards safety, since by virtue of being pioneers in the application of the perspective advanced by this digest, those States are among those at the leading edge of the international community's safety endeavours.

8. This digest comprises the following:

Chapter 1 includes an introduction to contemporary safety thinking, presenting the shift from individuals to organizations.

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1. National Transportation Safety Board, Aircraft Accident Report 93/02 (NTSB/AAR-93/02).
2. Within the context of this digest, organization is defined as *"…a body of persons organized for some specific purpose".*

Chapter 2 elaborates the concepts presented in Chapter 1, provides examples of how system deficiencies whose roots can be found far away from the site contribute to accidents and introduces the concept of safe and unsafe organizations.

Chapter 3 is a "how to" to help decision-makers recognize why they should act upon safety; it provides details on and examples of what decision-makers can do to contribute to safety.

Chapter 4 presents a case study to illustrate in practical terms the concepts discussed in the digest.

9. This digest was produced with the assistance of the ICAO Flight Safety and Human Factors Study Group and was developed from an outline prepared by Study Group Member Jean Paries. The sources of reference and additional reading material are included at the end of each chapter. The other digests in this series are:

- Digest No. 1 — *Fundamental Human Factors Concepts* (Circular 216);
- Digest No. 2 — *Flight Crew Training: Cockpit Resource Management (CRM) and Line-Oriented Flight Training (LOFT)* (Circular 217);
- Digest No. 3 — *Training of Operational Personnel in Human Factors* (Circular 227);
- Digest No. 4 — *Proceedings of the ICAO Human Factors Seminar* (Circular 229);
- Digest No. 5 — *Operational Implications of Automation in Advanced Technology Flight Decks* (Circular 234);
- Digest No. 6 — *Ergonomics* (Circular 238);
- Digest No. 7 — *Investigation of Human Factors in Accidents and Incidents* (Circular 240);
- Digest No. 8 — *Human Factors in Air Traffic Control* (Circular 241); and
- Digest No. 9 — *Proceedings of the Second ICAO Flight Safety and Human Factors Global Symposium* (Circular 243).

Chapter 1
FROM INDIVIDUALS TO ORGANIZATIONS

1.1 "At 01:24 on Saturday, 26 April 1986, two explosions blew off the 1000-tonne concrete cap sealing the Chernobyl-4 reactor, releasing molten core fragments into the immediate vicinity and fission products into the atmosphere. This was the worst accident in the history of commercial nuclear power generation. It has so far cost over 30 lives, contaminated some 400 square miles of land around the Ukrainian plant, and significantly increased the risk of cancer deaths over a wide area of Scandinavia and Western Europe … There are two immediate questions: (1) How and why did a group of well-intentioned, highly motivated and (by other accounts at least) competent operators commit just the right blend of errors and safety violations necessary to blow this apparently safe reactor? (2) Could something like it happen here?" (1)

1.2 The first step in answering these questions is recognizing that operational personnel do not act in isolation, but they plan and execute their actions within a social milieu. They are part of an *organization* and, functioning on a continuous basis and through a division of labour and a hierarchy of authority, seek to achieve an objective or a set of objectives (2). Operational personnel are *organized*, which implies the existence of task distribution, co-ordination, synchronization, shared objectives and acceptance of a common authority. Furthermore, operational personnel do not operate in a vacuum. Their actions and attitudes are a reflection on those who employ and represent them. For example, an attitude of disrespect for the disciplined application of procedures does not develop overnight; it develops after prolonged exposure to an atmosphere of indifference. (3)

1.3 The second step involves the recognition that during the second half of the twentieth century, large-scale, technically based systems and organizations have become firmly established during what is sometimes called the "second industrial revolution" (4). The term *sociotechnical systems*, coined in 1960, refers to organizations which use high technology on a large scale. The aerospace industry, nuclear power generation, marine and railroad transportation and the chemical processing industry are examples of sociotechnical systems. The organizations in these systems bring together two components to achieve their objectives: the technical component (technology) and the human component (people). These two components interact with each another at every human-machine interface. Both components are highly interdependent and operate under *joint causation*; that is, both humans and machines are affected by the *same* causal events in their surrounding environment (5). Organizations in sociotechnical systems pursue *production goals*: transportation of people and goods in aerospace, marine and railroad systems; energy in nuclear power generation, etc. It is characteristic that the consequences of safety breakdowns in organizations within sociotechnical systems are catastrophic in terms of loss of life and property, since they involve high-risk/high-hazard activities. Likewise, in large-scale technological systems, potential hazards are concentrated in single sites under the centralized control of relatively few operational personnel: the control room operators in a nuclear power plant; the flight crew in an aircraft, etc. (6) Within the aviation system, organizations include airlines and other operators, manufacturers, airports, air traffic control, weather services, civil aviation authorities, safety investigation agencies, international organizations (ICAO, JAA, EUROCONTROL, etc.) and professional associations (IATA, IFALPA, IFATCA, ISASI, etc.).

1.4 As a consequence of the close interdependence between people and technology, complex and often-overlooked changes in sociotechnical systems may occur over time. Therefore, when pursuing safety in these systems, it is narrow and restrictive to look for explanations for accidents or safety deficiencies in exclusively technical terms or purely from the perspective of the behavioural sciences, i.e. human error. Analysis of major accidents in technological systems has clearly indicated that the preconditions to disasters can be traced back to identifiable organizational deficiencies. It is typical to find that a number of undesirable events, all of which may contribute to an accident, define an "incubation period" which is often measured in terms of years, until a trigger event, such as an abnormal operating condition, precipitates a disaster. Furthermore, accident prevention activities in sociotechnical systems recognize that major safety problems do not belong exclusively to either the human or the technical components. Rather, they emerge from as yet little understood interactions between people and technology (7). The environment in which these interactions take place further influences their complexity.

1.5 With these basic concepts at hand, let us attempt to marry theory to practice and answer the questions in 1.1. When viewed from the perspective of sociotechnical systems' safety, it is obvious the ingredients for the Chernobyl disaster were present at many levels. There was a *society* committed to the production of energy through large-scale power plants; there was a *system* that was complex (i.e. with many control parameters that could potentially interact), potentially hazardous, tightly coupled (i.e. with relatively few ways of achieving particular goals), opaque (i.e. with many unfamiliar or unintended feedback loops) and operating in borderline conditions; there was a *management structure* that was monolithic, remote and slow to respond; and there were *operators* who possessed only a limited understanding of the interdependences of the system they were controlling and who, in any case, were assigned a task that made violations inevitable (8). These factors are not unique to any particular State or to nuclear power generation. By substituting a few terms, the description becomes a framework applicable to aviation accidents anywhere in the world aviation community.

1.6 On 1 February 1991, a Boeing 737 collided with a SA-227-AC (Fairchild Metroliner) while the 737 was landing on Runway 24 left at Los Angeles International Airport (*a society committed to the production of large-scale, high-technology transportation*). The Metroliner was positioned on the runway, at an intersection, awaiting clearance for take-off. The glare from the apron lighting made the aircraft inconspicuous and difficult to see from the control tower (*system operating in borderline conditions*). Both aircraft were destroyed and 34 persons fatally injured. The probable cause statement reads as follows (text in italics added):

> "The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Los Angeles Air Traffic Facility Management to implement procedures that provided redundancy comparable to the requirements contained in the National Operational Position Standards and the failure of the FAA Air Traffic Service to provide adequate policy direction and oversight to its air traffic control facility managers [*management structure slow to respond*]. These failures created an environment in the Los Angeles Air Traffic Control tower that ultimately led to the failure of the local controller 2 (LC2) to maintain an awareness of the traffic situation, culminating in the inappropriate clearances and subsequent collision … [*operator with a limited understanding of the system she was controlling and set to a task that made violations inevitable; system opaque*]. Contributing to the accident was the failure of the FAA to provide effective quality assurance of the ATC system [*management structure slow to respond; system tightly-coupled, hazardous, complex*]." (9)

1.7 This analysis takes into consideration all the components described in the previous paragraphs. It looks into the human and technical elements, recognizing their interdependence and interaction, thus observing the principle of joint causation. It goes beyond — although it does not ignore — the actions of the operational personnel (the air traffic controller and the pilots). It acknowledges that operational personnel do not operate in isolation and it looks into the organizational deficiencies and management factors involved in the "incubation period" of the accident. In this broadened view, system safety deficiencies are crystal clear, as are the remedial actions necessary to correct them. Most importantly, by determining *why* the accident occurred, it indicates *what* is wrong in the system and should be corrected rather than *who* made a mistake and should be punished. Blame and punishment have, in themselves, limited value as prevention tools.

1.8 On 10 March 1989, a Fokker F-28 Mk-1000 crashed after take-off from Dryden Municipal Airport in Dryden, Ontario, Canada. A total of 24 persons died as a consequence of the crash and the accompanying fire. The Final Report of the Commission of Inquiry recognizes that take-off was attempted with snow and ice contaminating the wings, a fact which eventually led to the accident. However, in keeping with a system analysis, the Report poses a fundamental question: what caused or prompted the pilot-in-command to make the decision to take off; and what system safeguards should have prevented or altered this decision? It further states:

> " … The pilot-in-command made a flawed decision, but that decision was not made in isolation. It was made in the context of an integrated air transportation system that, if it had been functioning properly, should have prevented the decision to take off … there were significant failures, most of them beyond the captain's control, that had an operational impact on the events in Dryden … the regulatory, organizational, physical and crew components must be examined to determine how each may have influenced the captain's decision."

The results of this examination are summarized in the Report as follows:

> " … the captain, as pilot-in-command, must bear responsibility for the decision to land and take off in Dryden on the day in question. However, it is equally clear that the air transportation system failed him by allowing him to be placed in a situation where he did not have all the necessary tools that should have supported him in making the proper decision." (10)

1.9 Again, all elements have been considered. This approach also puts into perspective who is in the best position to undertake remedial actions, i.e. who can provide the greatest contribution to safety. Had they survived, the flight crew could have improved their future performance as the last safety valve in the system through increased training and re-certification, personal improvement, etc. Focusing remedial action around improved performance by this particular crew would enhance safety at the individual level, that is, only as far as this crew is concerned. However, the door would remain open for many other flight crews operating in the same unimproved system to make errors invited by imperfect system design. The major contribution must then originate at the decision-making levels, those who have the ultimate power to introduce radical changes and modify — system-wide — the architecture, design and operation of the system.

1.10 In general terms, there are three levels of action decision-makers can choose in pursuing the safety recommendations from analyses such as those exemplified in the previous paragraphs (11):

- The first level of action is to eliminate the hazard, thereby preventing a future accident. In the case of the runway collision accident, for example, a decision could be made that in airports having parallel runways, one runway should be used for take-offs and the other for landings. In the icing example, it could be decided to absolutely forbid operations when conditions are conducive to airframe icing. These are the safest decisions but they may not be the most efficient.

- The second level of action is to accept the hazard identified and adjust the system to tolerate human error and to reduce the possibility of an occurrence. In this context, the decisions following the Los Angeles accident might include eliminating intersection take-offs or clearances involving taxiing into position on an active runway and holding for take-off clearance. In the Dryden example, the decision might be to eliminate operations into stations without proper de-icing facilities, or when aircraft equipment related to anti-icing protection is unserviceable, in environmental conditions conducive to icing. Although not as safe as first level actions, these options are more realistic and efficient and they work.

- The third level of action involves both accepting that the hazard can be neither eliminated (level one) nor controlled (level two) and teaching operational personnel to live with it. Typical actions include changes in personnel selection, training, supervision, staffing and evaluation, increasing or adding warnings, and any other modifications which could prevent operational personnel from making a similar mistake.

Third level actions should not be taken in preference to first or second level actions, since it is impossible to anticipate all future kinds of human error. Attempting to eliminate all human error is an unattainable goal, since error is a normal part of human behaviour. The total system (including aircraft, crew, airports and ATC) should identify, tolerate and correct human error. *Tolerate* is the key word; as long as humans are involved, the system must be designed to tolerate the entire range of "normal" human behaviour, including human weaknesses. It must be error-tolerant.

1.11 On Monday, 12 December 1988, a commuter train was approaching Clapham Junction station (England) when it crossed a signal which suddenly turned red. The driver, in accordance with standard operational procedures, stopped the train and went to phone the signal box to report that he had crossed a signal at "danger". During his absence, the signal turned from red to yellow as a result of faulty rewiring work performed by a technician two weeks earlier. This allowed another commuter train to enter the same track and crash into the back of the stationary train. Thirty-five people died and nearly 500 were injured, 69 of them seriously. The Report of the Investigation into the Clapham Junction Railway Accident states:

> "The vital importance of [the] concept of absolute safety was acknowledged time and again in the evidence that the Court heard [from the railway company management]. The problem with such expressions of concern for safety was that the remainder of the evidence demonstrated beyond dispute two things:
>
> (i) there was total sincerity on the part of all who spoke of safety in this way but nevertheless
>
> (ii) there was a failure to carry those beliefs through from thought to deed.
>
> The appearance was not the reality. The concern for safety was permitted to co-exist with working practices which … were positively dangerous. This unhappy co-existence was never detected by management and so the bad practices never eradicated. The best of intentions regarding safe working

> practices was permitted to go hand in hand with the worst of inaction in ensuring that such practices were put into effect.
>
> The evidence therefore showed the sincerity of the concern for safety. Sadly, however, it also showed the reality of the failure to carry that concern through into action. It has been said that a concern for safety which is sincerely held and expressly repeated but, nevertheless, is not carried through into action, is as much protection from danger as no concern at all."

Adhering to the notion of accident causation in sociotechnical systems, the Report concludes:

> "[The railway company management] commitment to safety is unequivocal. The accident and its causes have shown that bad workmanship, poor supervision and poor management combined to undermine that commitment". (12)

1.12 The message underlying the foregoing is twofold. Firstly, it should be obvious that manifestations of intent like the well-known truism *"safety is everybody's business"* are not enough; decision-makers have to adopt an active stance in promoting safety action (13). Indeed, it is asserted that management participation in safety deficiencies prevention is an everyday commitment and safety promotion by decision-makers requires as active an involvement as that of the operational personnel. Secondly, it would be misleading and quite unfair to suggest that decision-makers are not interested in or neglect safety promotion. The Clapham report exemplifies that, beyond any reasonable doubt, concern for safety ranks high in decision-makers' thoughts. Why the failure in carrying thought into deed, as evidenced by accident investigations from the organizational perspective? One answer may be *because of lack of awareness.* Those at the decision-making levels may not be aware of how and why their actions or inactions may affect safety; and even if they are aware, they might not know what to do to actively participate in safety promotion endeavours. If you are unaware of a problem, then for all practical purposes that problem does not exist. Should this contention about lack of awareness be true, it follows that decision-makers need the tools and knowledge to discharge their responsibility. This digest is but one attempt in that direction.

1.13 In filing a dissenting statement to the probable cause stated in the accident report following the runway collision between a Boeing 727 and a Beechcraft King Air A100, one of the members of the investigating agency asserted:

> "I also disagree with the notion that agencies cause accidents. Failure of people and failures of equipment cause accidents. Shifting the cause from people to agencies blurs and diffuses the individual accountability that I believe is critically important in the operation and maintenance of the transportation system" (14)

1.14 This assertion reflects a real and valid concern, as well as a somewhat widespread misconception. There are some who fear that when exploring the relationship between Human Factors, management and organization — and how it influences aviation safety and effectiveness —, the notion of individual accountability may be lost. Others contend that this may also be a subtle way of "passing the buck" for safety entirely to management. In fact, the concept of organizational accidents represents a broadened view of system safety, which does not intend either to shift responsibility or blame from operational personnel towards management, or to remove individual responsibility. Firstly, as already stated, blame only has a limited safety or prevention value. Secondly, it is not suggested that operational personnel do not make uncalled-for errors; that they sometimes do is beyond doubt. The contention is that the potential for these errors has long been realized and measures to mitigate them are reasonably well recognized. What has been rather neglected are measures directed at enhancing the system's tolerance to human failures committed — by the simple fact that they are human beings subject to human biases and limitations — by those at the decision-making levels of the aviation system. In the past, limiting prevention endeavours to the flight deck, the ATC workstation, the maintenance shop or any of the other human-system interfaces has proved to be successful in making aviation the safest mode of massive transportation. In the present *and* the future, such an approach may turn out to be of limited safety value and, perhaps, futile.

References

(1) Reason, James. 1987. "The Chernobyl Errors". *Bulletin of the British Psychological Society*, 40, 201-206.

(2) Hendrick, Hal. 1991. "Ergonomics in Organizational Design and Management". *Ergonomics*, Vol. 34, No.6, 743-756.

(3) Bruggink, Gerard. 1990. "Reflections on Air Carrier Safety". *The Log*, 11-15.

(4) Turner, B., N. Pidgeon, D. Blockley and B. Toft. 1989. "Safety Culture: Its Importance in Future Risk Management". The Second World Bank Workshop on Safety Control and Risk Management. Karlstad, Sweden.

(5) Pidgeon, Nick. 1991. "Safety Culture and Risk Management in Organizations". *Journal of Cross-cultural Psychology*, Vol. 22, No. 1, 129-140.

(6) Meshkati, Najmedin. 1991. "Human Factors in Large-scale Technological Systems' Accidents: Three Mile Island, Bhopal and Chernobyl". *Industry Crisis Quarterly* 5, 133-154.

(7) Reason, James. 1991. *How to Promote Error Tolerance in Complex Systems in the Context of Ship and Aircraft.*

(8) Reason, James. 1987. "The Chernobyl Errors". *Bulletin of the British Psychological Society*, 40, 201-206.

(9) National Transportation Safety Board (NTSB), 1991. Aircraft Accident Report AAR-91/08.

(10) Moshansky, The Hon. Virgil P. 1992. Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario. Final Report, Vol. III.

(11) Wood, Richard H. 1991. *Aviation Safety Programs — A Management Handbook.* IAP Incorporated, Casper, Wyoming, USA.

(12) Hidden, Anthony (QC). 1989. Investigation into the Clapham Junction Railway Accident. The Department of Transport. London: HMSO.

(13) Miller, C. O. 1991. Investigating the Management Factors in an Airline Accident. Brazilian Congress of Flight Safety, Rio de Janeiro, Brazil.

(14) National Transportation Safety Board (NTSB), 1991. Aircraft Accident Report AAR-91/03.

Chapter 2
SAFE AND UNSAFE ORGANIZATIONS

INTRODUCTION

2.1 Over time, researchers and academics studying organizations have resorted to a metaphor to assist their endeavours: they have compared organizations to living organisms, notably the human being. Organizations are viewed like complex living structures, with brain, body, personality and objectives. Like human beings, organizations struggle for survival within a constantly changing environment (1). Within organizational literature, it is a basic premise that " … organizations think. Like individuals, they exhibit a consciousness, a memory, an ability to create and solve problems. Their thinking strongly affects the generation and elimination of hazards." (2) In this comparison, the managers and decision-makers become the brain; the hierarchies, departments and other permanent structures (including the workforce) become the body; and corporate culture becomes the personality. Traditional Human Factors endeavours have focused on the brain, body and personality of human beings and their interactions with the surrounding environment. The purpose is to either foster safe behaviour or discourage unsafe behaviour and thus improve safety and efficiency as well as the well-being of those in the aviation system. Human Factors ideas and techniques can also be applied to organizations. This chapter borrows from the organism metaphor and discusses the equivalent components of brain, body, personality and objectives as they apply to organizations. Thus the characteristics of safe and unsafe organizations and organizational behaviour can be considered as yet another contribution to the pursuit of safety, efficiency and individual well-being within the aviation system. The world-wide survey conducted in 1986 by a major aircraft manufacturer (discussed in Chapter 3) attests to the relevance of the concept of safe and unsafe organizations.

2.2 Organizations have *objectives* which are usually related to production: building aircraft or other equipment, transporting passengers, transporting goods, etc. Producing profit for stockholders is one of the goals of many organizations. Most organizations within the aviation industry are formed to achieve some practical objective or goal, *and safety is not the primary goal*. Safety fits into the objectives of organizations, but in a supporting role, to achieve the production objectives safely, i.e. without harm to human life or damage to property.[1] Therefore, before discussing safe and unsafe organizations, it is essential to put safety into perspective and decide where it fits within the objectives of aviation organizations. From an organizational perspective, safety should be seen as a method of conserving all forms of resources, including controlling costs. Safety allows organizations to pursue their production objectives with minimum damage to equipment or injury to personnel. It assists management in achieving this objective with the least risk (3). There is an element of risk in aviation that cannot be eliminated, but it can be successfully controlled through risk management programmes directed at correcting safety deficiencies before an accident occurs. These programmes are an essential tool for decision-makers to formulate decisions on risk and to contribute to safety

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1. A few organizations within aviation may not exactly respond to this concept. These organizations include the International Civil Aviation Organization (ICAO), the civil aviation administrations, the Flight Safety Foundation (FSF) and the International Society of Air Safety Investigators (ISASI). Since they have as a major objective the promotion and advancement of safety and effectiveness in civil aviation and they are not actively engaged in production activities, the production of safety becomes a primary goal.

while pursuing the production goals of their organizations (4). Basic risk management concepts are included in the *Accident Prevention Manual* (Doc 9422) and are further discussed in Chapter 3.

CORPORATE CULTURE

2.3 *Corporate culture* is as relevant to organizational performance as personality is to human behaviour. On 4 March 1987, a CASA C-212-C crashed just inside the threshold of Runway 21R at Detroit Metropolitan Airport, Michigan, USA, killing 9 of the 19 persons on board. The probable cause statement indicates that the captain was unable to control the aeroplane while attempting to recover from an asymmetric power condition at low speed following his intentional use of reverse thrust (beta mode) of propeller operation to descend and slow the aeroplane rapidly on final approach for landing. This procedure was strictly forbidden by both the aircraft flight manual and company operating procedures. The investigation also disclosed that this was not the first time this captain — by all other accounts an able and competent airman — had resorted to this procedure. Several questions immediately arise:

- If company procedures were clearly stated, why were they not followed by this captain?
- If use of beta mode in flight was strictly forbidden and this captain [frequently] ignored this instruction, what prevented other pilots who witnessed this captain ignoring that order from bringing the fact to the attention of the company?
- Why was this captain's disregard for company procedures and the aircraft flight manual not exposed before it was discovered following an accident?
- Lastly, if the company knew about the flying habits of this captain, would they — and could they — have taken any action? (5)

2.4 The Final Report of the Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario, in its in-depth discussion of how corporate culture played a significant role in this accident, suggests an answer to these questions:

> " … even in organizations with a strong commitment to standardization … informal subcultures frequently tolerate or encourage practices which are at variance with organizational policies or regulatory standards … Evidence of procedural variance is found in several reported practices these suggest that the [corporate] culture may have allowed crews considerable leeway in making decisions about whether to take-off with surface contamination … a practice which, unfortunately, was not unequivocally proscribed by the then current [civil aviation authority] regulations … " (6).

The inevitable questions then arise: What is culture? Can decision-makers influence corporate culture? If so, what can decision-makers do to influence it?

2.5 Culture refers to beliefs and values which are shared by all or almost all members of a group. Culture shapes behaviour and structures a person's perception of the world. In that sense, culture is a collective mental programming which distinguishes one human group from another. Culture defines the values and predisposes attitudes, exerting a final influence on the behaviour of a particular group. Norms are the most common and acceptable patterns of values, attitudes and behaviour for a group. Norms are enforced by expressing disapproval of wrongdoers; how strongly a culture sanctions those who violate norms is an indication of the importance attached to those norms. For years people have thought that organizations were beyond the influence of culture and were only influenced by the technologies they utilize or the tasks they pursue. Research has demonstrated, however, that culture deeply influences organizational behaviour (7) (8). If an organization attempts to impart values or behaviours which are in contrast with existing organizational/corporate culture or which are perceived to be in contrast with corporate goals, achieving these values or behaviours will either take considerable time and effort or be impossible altogether. A corporate culture may also allow or prevent violations, since they take place in situations where the shared values of individuals and the group favour certain behaviours or attitudes. In the simplest terms, a group will meet whatever norms are established for an organization and will do whatever it *thinks or perceives* management really wants.

2.6 The explanation of the seemingly undisciplined behaviour of the captain involved in the Detroit accident must be sought in the existence of a corporate culture which condoned such practices and in the absence of norms which condemned them. This is best evidenced by the silence surrounding this captain's observed deviations from established procedures. An attitude of disregard of organizational policies or regulatory standards involves more than Human Factors related to the cockpit, since it does not develop overnight. Fast, time-saving, "efficient" approaches — resorting to whatever means necessary to accomplish them — must undoubtedly have been an accepted norm in the operational subculture of the organization. No disapproval can have been explicitly expressed to observed transgressions and thus, over time, such behaviour became a collective mental programming, which fostered this and probably other risk-taking attitudes in pursuing organizational objectives. Ultimately, based upon experience obtained during the term of employment, pilots came to perceive such attitudes and behaviours as the standard management expected from them and they acted accordingly.

SAFE AND UNSAFE CORPORATE CULTURES

2.7 Culture, like personality, involves deep-seated traits and it is extremely resistant to change. As with personality traits, change can be accomplished, but slowly and over prolonged periods of time. By identifying what constitutes a good safety-oriented corporate culture and its characteristics, managers can change and improve existing corporate culture by setting examples which are consistent across the whole value system. A safety culture within an organization can be regarded as a set of beliefs, norms, attitudes, roles and social and technical practices concerned with minimizing exposure of employees, managers, customers and members of the general public to conditions considered dangerous or hazardous (9). It is one which promotes among participants a shared attitude of concern for the consequences of their actions, an attitude which would cover material consequences as well as the possible effects on people (10).

2.8 In general terms, the characteristics which define a safe culture and which decision-makers should observe when modelling corporate safety culture include the following:

- senior management places strong emphasis on safety as part of the strategy of controlling risks;
- decision-makers and operational personnel hold a realistic view of the short- and long-term hazards involved in the organization's activities;
- those in top positions do not use their influence to force their views or to avoid criticism;
- those in top positions foster a climate in which there is a positive attitude towards criticisms, comments and feedback from lower levels of the organization;

- there is an awareness of the importance of communicating relevant safety information at all levels of the organization (both within it and with outside entities);

- there is promotion of appropriate, realistic and workable rules relating to hazards, to safety and to potential sources of damage, with such rules being supported and endorsed throughout the organization; and

- personnel are well trained and well educated and fully understand the consequences of unsafe acts.

2.9 On 19 October 1984, a Piper PA-31 Navajo on a night IFR flight from Edmonton to Peace River crashed into high terrain 20 miles southeast of High Prairie, Alberta, Canada. Six passengers perished; the pilot and three other passengers survived. The investigation determined that the pilot descended in cloud to below the minimum obstacle clearance altitude, a violation which eventually triggered the accident. However, a major objective of the Canadian Aviation Safety Board was "… to discover the circumstances which influenced the pilot to deviate from accepted safe operating practices *Although the final decision in an aircraft cockpit rests with the captain, that decision is often influenced by factors over which he has no direct control … "* (italics added)

2.10 The Board then decided to investigate the company work environment. In so doing, it found out that:

> "In early 1984, a lack of adequate communication between pilots and management was noted by the Air Carrier Branch of Transport Canada. The company chief pilot was subsequently appraised of the problem … "
>
> "Crews … were expected to carry out the operation without further supervision and to adhere as closely as possible to the published schedule … some pilots worked a six-week day and were expected at times to carry pagers during their day off … "
>
> "Some pilots reported that they sensed a subtle but significant pressure to undertake and complete flights … the chief pilot set an example of non-compliance with prescribed weather limitations … "
>
> "Pilots … were encouraged by company management to file VFR, even when the weather might be marginal … VFR flights took less time, fuel and facilitated arrivals … pilots admitted cancelling IFR flight plans while still in IMC … they often descended below prescribed weather minima in an attempt to land …"
>
> " … personnel were apprehensive about doing anything which management would consider as not in the best interests of the company. Confrontation between pilots and management were reported as frequent and often led to the resignation of the employee to avoid imminent dismissal … Company management did not consider the exchanges were of a confrontational nature … "

The Report concludes:

> "The descent procedure used by the pilot was similar to that used during his initial route check into High Prairie six weeks earlier with a senior company pilot. While the pilot knew that this action was contrary to regulations, *he believed it was safe*." (italics added).

This shortcut:

> " … would have allowed the pilot to regain his schedule. By completing the assigned schedule, he expected to avoid further discord with management, thus prolonging his employment with the company." (11)

2.11 These excerpts from the relevant section of the official report can be easily seen to contrast with the characteristics of safe corporate culture listed in 2.8. They also provide guidance regarding areas of remedial action decision-makers can act upon to influence and change corporate culture.

THE STRUCTURE OF ORGANIZATIONS

2.12 The *design of the organization*, i.e. its permanent structures and hierarchies, relates to organizational performance similar to the way body constitution relates to human performance. The role of the organization and its structure is to facilitate departmental interfaces, connecting and joining departments together (12). On 18 November 1987, discarded smoker's material probably set fire to highly inflammable rubbish that had been allowed to accumulate in the running tracks of an escalator at the King's Cross underground station in London, England. Eventually a flash-over occurred and 31 people were killed and many others seriously injured. The Report of the Investigation into the King's Cross underground fire identified that:

> " … running tracks were not regularly cleaned, partly due to organizational changes which blurred maintenance and cleaning responsibilities … Safety specialists scattered over three directorates focused on occupational and operational safety, but passenger safety was neglected … Inadequate fire and emergency training were given to staff … No evacuation plans existed for King's Cross underground station … Trains do not have a public address system and there were no public telephones at King's Cross station." (13)

2.13 In fact, practices in defining and building the structure of organizations had come under the scrutiny of the research community well before this accident. There were compelling reasons for this research. Investigation of well-publicized, major catastrophes in sociotechnical systems clearly suggested that it is quite possible to correctly design individual components of the organizational structure (departments, sections, etc.) so that they can achieve their assigned objectives safely and efficiently, and yet fail to secure over-all organizational safety and effectiveness because of inattention to the way those individual components interact when integrated. If the structure is randomly designed, organizations may collapse when operating under pressure (very much in the same way that incorrectly designed displays or controls will induce human error and provoke safety breakdowns when under operational pressures).

2.14 There are several components decision-makers should consider when defining the structure of organizations:

- *Complexity*. This includes the required number of managerial levels, the required division of labour and job specialization (departments and sections), the degree to which operational personnel and facilities must be geographically dispersed or centralized and the extent to which mechanisms which facilitate communication between levels have been designed into the organization.

- *Standardization*, which is related to the complexity of the job and the level of professionalism of employees. In general terms, the simpler the job (e.g. assembly-line manufacturing), the greater the benefits of standardization; the more complex the job (e.g. management tasks requiring high levels of professionalism), the lower the level of standardization desirable. Aviation operational activities are, nevertheless, highly proceduralized, even when the highest levels of professionalism are involved. Complex tasks, such as flight deck management, require *both* high levels of professionalism and standardization.

- *Centralization* of the formal decision-making process. This depends on the stability and predictability of the surrounding environment: unpredictable environments require low centralization to rapidly cope with unexpected changes and vice versa.

- *Adaptability to the environment*[2]. This is the key to success and ultimately to the survival of organizations. Environmental uncertainty is the most powerful of all the system factors affecting organizational design. In highly uncertain environments, organizations should be flexible and capable of rapid response to change. In highly stable environments, it is desirable to design stability and control for maximum effectiveness. (14)

2.15 All these organizational components bear an impact on human performance, which in turn affects the way organizations achieve their objectives, including safety. The relevance of the organizational structure to the safety deficiencies observed in the King's Cross underground fire is apparent. Organizations with unnecessarily complex structures (too many managerial levels or excessive departmentalization) foster dilution of responsibilities and lack of accountability. They also tend to make interdepartmental communications more difficult. Sluggish interdepartmental communications, especially regarding safety relevant information, reduce safety margins and invite safety breakdowns, as the following accident report further illustrates.

2.16 On 17 February 1991, a DC-9 series 10 cargo aeroplane crashed while taking off from Cleveland-Hopkins International Airport, Ohio, USA. Both pilots were fatally injured and the aircraft was destroyed. The crew had failed to detect and remove ice contamination from the wings. During the investigation, the NTSB determined that several organizations within the aviation system had been aware for years of the propensity of this particular series of aircraft for loss of control caused by a minute amount of wing contamination. The manufacturer had issued numerous articles on the subject, and three previous accidents on similar types had been attributed to the same cause. However, the report indicates that, because of the absence of a communications structure:

> " … there was no system to ensure that the critical information reaches all line pilots of these airplanes … the most critical cue that was not provided to the crew on the night of the accident was information that was apparently readily available and known throughout much of the aviation community, that being the sensitivity and vulnerability of the DC-9 series 10 aircraft to minute amounts of ice contamination on the upper surfaces of the plane's wings."

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2. There are at least five aspects to consider in defining the environment: socioeconomic, educational, political, legal and cultural.

The report concludes:

> "The National Transportation Safety Board determines that the probable cause of this accident was the failure of the flight crew to detect and remove ice contamination on the airplane's wings, which was largely a result of a lack of appropriate response by the Federal Aviation Administration, Douglas Aircraft Company and Ryan International Airlines to the known critical effect that a minute amount of contamination has on the stall characteristics of the DC-9 series 10 airplane … " (15)

REGULATORY COMPLIANCE

2.17 When internal responsibilities regarding safety are not clearly defined, organizations tend to rely excessively on external sources to discharge them, i.e. regulatory authorities. Regulations serve a purpose in that certain safety procedures or equipment would never be adopted without them. However, regulations usually represent *minimum* levels of safety compliance; furthermore, if regulations are formally applied but the sense of them is lost, the original reason for introducing them is quickly forgotten. It follows that legislation is, at best, a limited way of affecting human behaviour. Regulations cannot cover all risks involved in aviation since each accident is unique; hence the importance of risk management programmes such as those discussed in Chapter 3. Organizations leaning heavily on regulations to pursue safety usually do not include a risk management structure. The danger of excessive reliance on regulations in lieu of properly organized risk management structures is best illustrated by the opening statement in the findings of most accident reports: *". . . the airplane was certificated, equipped and maintained in accordance with existing regulations and approved procedures … the crew were certificated, qualified and experienced for their duties … "* Yet the accident occurred.

2.18 On Monday, 14 November 1988, an Embraer 110 Bandeirante aircraft on a scheduled passenger flight crashed in the vicinity of the Ilmajoki Airport in Finland. The Finnish Board of Inquiry came to the conclusion that the immediate cause of the accident was the [flight crew] decision to continue the NDB approach below the minimum descent altitude, without the required visual contact. The Board also found as a contributing factor the performance pressures that originated from the airline's poor safety culture. In pursuing the organizational issues which might have contributed to the accident, the investigation revealed:

> " … serious deficiencies in the operation of the airline as well as in the activities of the airport operator and the authorities. Also the legislation was found to be out of date and insufficient, especially as far as commercial flight operations are concerned."

The report is an outstanding example of systemic approaches to accident investigation and as such, it is extremely rich in prevention lessons. The discussion about regulatory compliance is particularly applicable to this section. The report first discusses the very important contribution of regulatory compliance to safety in the following terms:

> " … Flight safety is also affected by the effectiveness of the supervision carried out by the authorities and by what measures are undertaken in response to what is uncovered in the supervision. If the authorities cannot or will not intervene when safety regulations have been violated or if these violations are not even noticed due to ineffective supervision, the violations will probably begin to be regarded as a minor matter … "

Having established the importance of regulatory compliance, the report then goes on to consider an important shortcoming in regulations — formal compliance — as follows:

> " … If the authorities are unable to assess the substantive conditions for operating an airline, or they do not have sufficient authority to do so, the supervision and the resulting measures must be carried out purely on formal grounds. Instead of broad assessment, this merely leads to the judging of violations committed by individuals, and it is not possible to come to grips with fundamental factors in the organization and operative environment that endanger safety … "

The report's conclusion on the scope and reach of regulatory compliance as a tool in pursuing safety, as it applies not only to the accident under investigation but to the aviation system as a whole, leaves no room for misunderstanding:

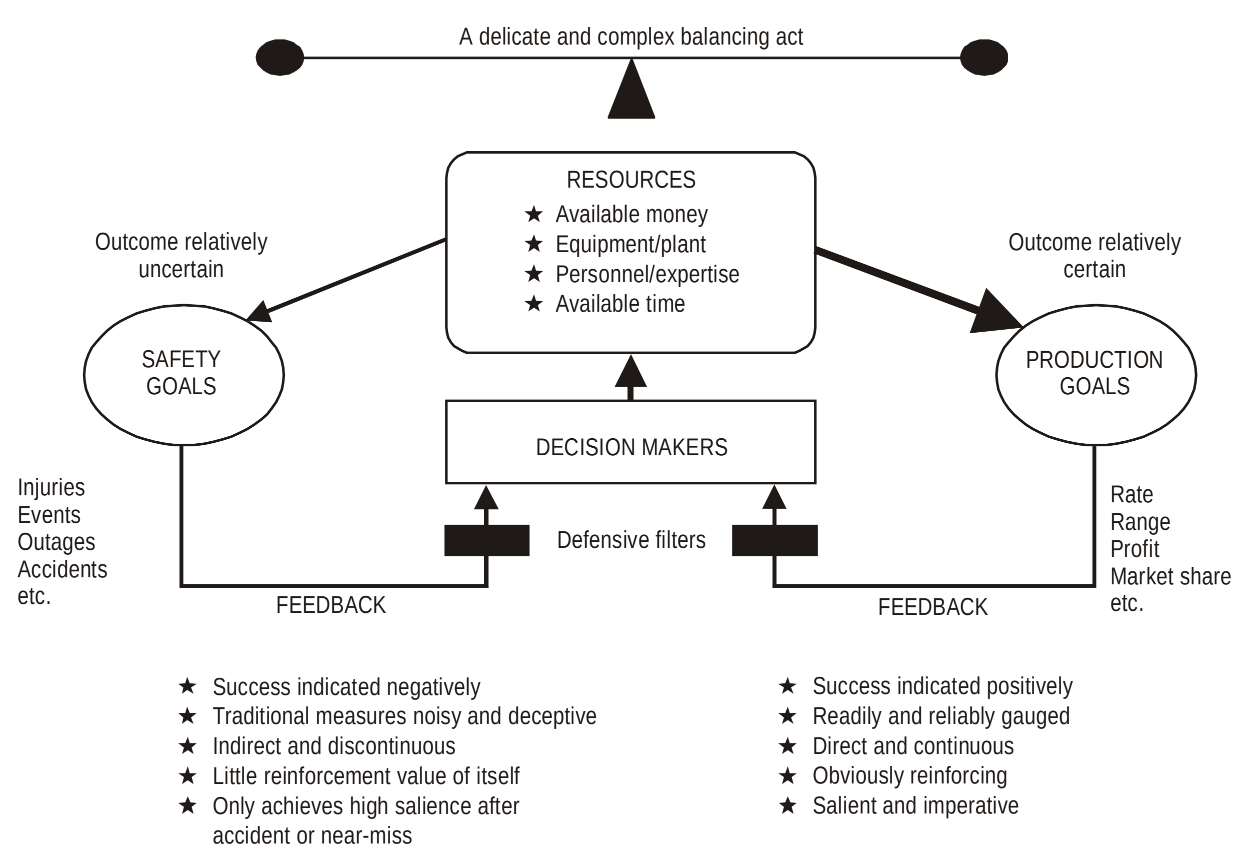
> " … in the course of the investigation, no particular reason arose to question in general the sufficient competence of the pilots or other operational personnel. What is primarily at issue is the company's poor safety culture … Because of this, measures that are directed by the National Board of Aviation at the licenses and ratings of individual pilots would scarcely affect the safety of the company's flight operations unless, at the same time, one can ensure that the company management adopts the proper attitude and has sufficient qualifications for carrying out its functions." (16)

ALLOCATION OF RESOURCES

2.19 Organizations in sociotechnical systems have to allocate resources to two distinct objectives: production and safety. In the long term, these are clearly compatible goals; but given that resources are finite, there are likely to be many occasions when there will be short-term conflicts of interest. Resources allocated to the pursuit of production (Figure 2-1) could diminish those available to safety and vice versa (17). When facing this dilemma, organizations with inadequate structures may emphasize production management over safety or risk management. Although a perfectly understandable reaction, it is ill-advised and contributes to additional safety deficiencies. The King's Cross underground fire investigation report states:

> " … The Chairman of London Regional Transport … told me that whereas financial matters were strictly monitored, safety was not … smoke detectors were not installed since the expense was not [felt to be] justified; water fog equipment had been installed in 1948 and could not be used because of rust problems … In my view, he was mistaken as to his responsibility."

The dilemma of allocation of resources may be further complicated by local perceptions of what constitutes a risk and by cultural considerations regarding the value safety has in the eyes of a society. It has been advanced that the number of accidents occurring in one country largely reflects the accident rate its population is ready to tolerate; in terms of safety, investment is made only as is necessary to maintain this rate. The tolerance rate and the ensuing allocation of resources to pursue safety vary considerably across the community.



Source: James Reason. 1990. *Human Error*. Cambridge University Press.

Figure 2-1. A summary of some of the factors that contribute to fallible, high-level decision-making

ACCIDENTS IN COMPLEX TECHNOLOGICAL SYSTEMS

2.20 In concluding this comparison between human beings and organizations, we will now consider the brain, or *management*. In order to understand how decision-makers' actions or inactions influence safety, it is necessary to introduce a contemporary view on accident causation.[3] As a complex sociotechnical system, aviation requires the precise co-ordination of a large number of human and mechanical elements for its functioning. It also possesses elaborate safety defences. Accidents in such a system are the product of the conjunction of a number of enabling factors, each one necessary but in itself not sufficient to breach system defences. Because of constant technological progress, major equipment failures or operational personnel errors are seldom the root cause of breakdowns in system safety defences. Instead, these breakdowns are the consequence of human *decision-making* failures which occur primarily within managerial sectors.

3. For a full discussion on this subject, see Digest No. 7, *Investigation of Human Factors in Accidents and Incidents*, ICAO Circular 240.

2.21 Depending upon the immediacy of their consequences, failures can be viewed as ***active failures***, which are errors and violations having an immediate adverse effect, generally associated with the operational personnel (pilot, controller, mechanic, etc.); or ***latent failures***, which are decisions or actions, the consequences of which may remain dormant for a long time. Latent failures become evident when triggered by active failures, technical problems or adverse system conditions, breaking through system defences. Latent failures are present in the system well before an accident and are most likely bred by decision-makers, regulators and other people far removed in time and space from the event. Those at the human-machine interface, the operational personnel, are the inheritors of defects in the system, such as those created by poor design, conflicting goals, defective organizations and bad management decisions. They simply create the conditions under which the latent failures can reveal themselves. Safety efforts should be directed at discovering and solving these latent failures rather than by localized efforts to minimize active failures. Active failures are only the proverbial tip of the iceberg.

2.22 The human contributions to accidents are illustrated in Figures 2-2 and 2-3. Most latent failures have their primary origin in errors made by the decision-makers. Even in the best run organizations, a number of important decisions will prove to be unsafe by virtue of being made by humans who are subject to human biases and limitations. Since some of these unsafe decisions cannot be prevented, steps must be taken to detect them and to reduce their adverse consequences. Fallible decisions in line management may take the form of inadequate procedures, poor scheduling or neglect of recognizable hazards. They may lead to inadequate skills, inappropriate rules or poor knowledge or they may be revealed by poor planning or workmanship. Fallible decisions may also be caused by a lack of resources.

2.23 The response of management to safety information is vital, since safety cannot be enhanced unless corrective action is timely and effective. This response may vary from ***denial actions***, by which "offenders" are dismissed or the validity of their observations challenged; to ***repair actions***, in which "offenders" are disciplined or relocated and dangerous items of equipment modified to prevent specific recurrence of an observed failure; to ***reform actions***, in which the problem is acknowledged and global action taken, leading to an in-depth reappraisal and eventual reform of the system as a whole (18). These actions relate to the three-level response discussed in 1.10.

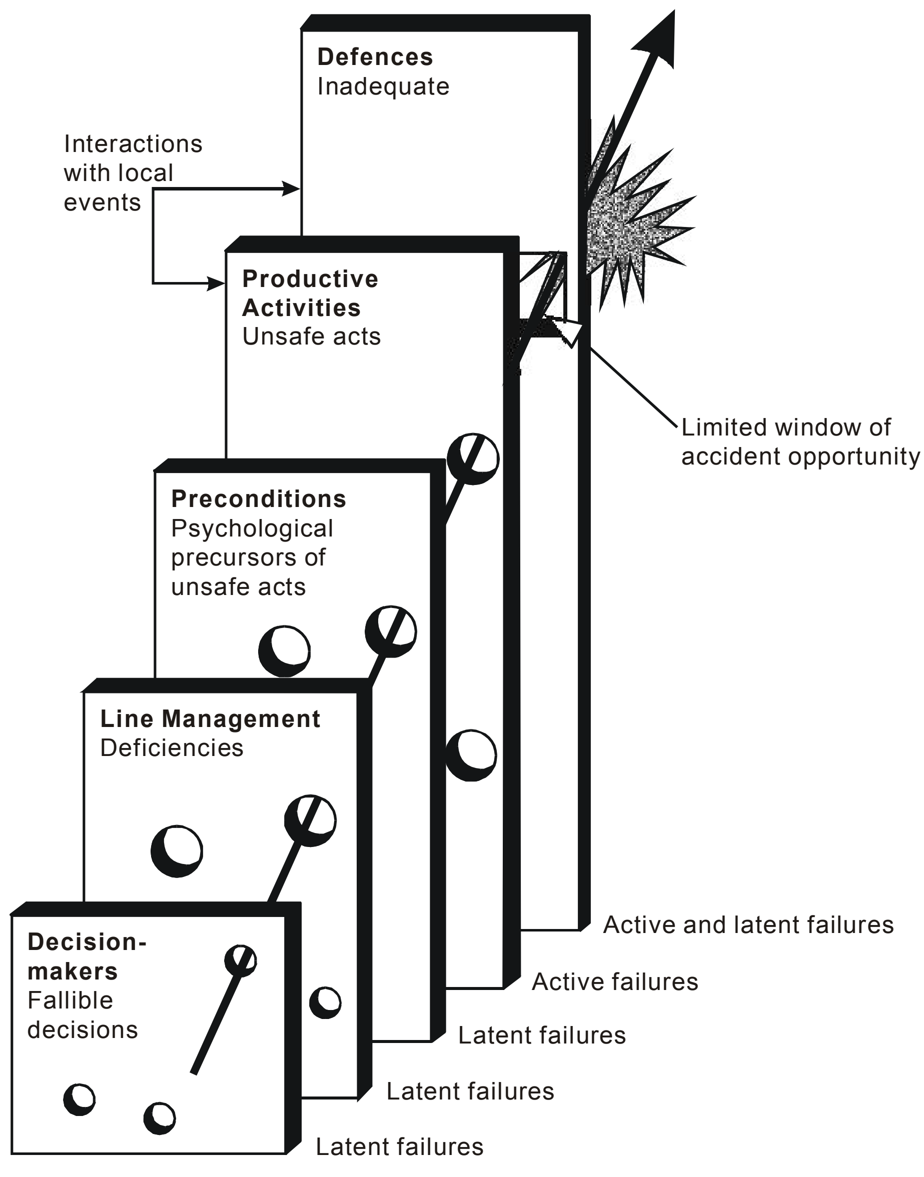
2.24 On 26 September 1989, a Fairchild Metro III on a scheduled flight from Vancouver to Terrace, British Columbia, Canada, with two pilots and five passengers on board crashed one quarter mile to the west of the destination airport while the crew was attempting to carry out a missed approach procedure in IMC. The aircraft was destroyed by the impact and a post-crash fire. All seven occupants were fatally injured in the crash (19). Analysis of the performance of the flight crew suggested lapses in the application of technical and psychomotor skills. It also identified breakdowns in flight deck activities and co-ordination of tasks. These are the active failures which, combined with adverse weather conditions, triggered the accident. The investigating authority, however, decided to broaden the scope of the investigation, thus unveiling some of the latent failures which set the stage for this accident:

- Despite its history, the company had been granted a waiver to operate large passenger aircraft under a less stringent operating standard. The regulatory authority had authorized the company and its pilots, through the mechanism of a waiver, to apply the standards of less stringent operating requirements (i.e. applicable to small aircraft under 12 500 pounds gross weight) rather than the more restrictive standards applicable to large aircraft above 12 500 pounds gross weight. This implied reduced training requirements and less frequent proficiency checking.

- The company involved had a questionable record with regard to regulatory compliance. In the two years previous to the accident, government regulators had issued three suspensions or cancellations of the company's operating certificate. The certificate had been reinstated without on-site inspection by the regulatory authority to ensure that corrective actions had been adopted by the company.

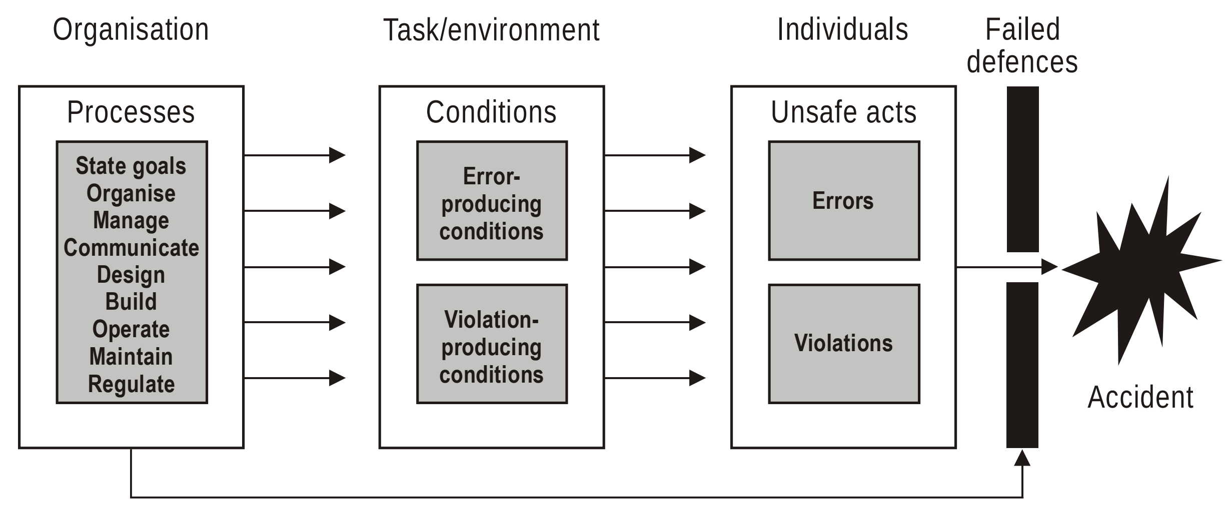
- The company did not employ standardized procedures. Interviews with company pilots indicated that there was often confusion among pilots about what operational directives were in place.

- The regulatory authority definitions and descriptions detailing the visual references required to carry out a circling approach were ambiguous and open to misinterpretation.



Source: James Reason. 1990. *Human Error.* Cambridge University Press.

Figure 2-2. Human contribution to accidents in complex systems



Source: James Reason. "Collective Mistakes in Aviation: 'The Last Great Frontier'", *Flight Deck,* Summer 1992, Issue 4.

Figure 2-3. The basic elements of an organizational accident

2.25 Discussing the accident with commendable introspection, the regulatory authority correctly identifies the reform actions required by concluding in its periodic safety newsletter: " … in the context of system safety, one might argue that organizational deficiencies related to training, standards and risk management led two relatively unseasoned pilots, typical products of the flight training system in this country, to commit a variety of transgressions that, clearly, were within the means of their company and the government to prevent." (20)

2.26 On the night of 2 December 1984, a gas leak from a pesticide plant devastated the Indian city of Bophal in the worst industrial disaster on record. More than 2 500 people were killed, and more than 200 000 were injured. The immediate cause of the leak was an influx of water into a methyl isocyanate (MIC) storage tank. The leak was the result of "botched maintenance, operator error, improvised bypass pipes, failed safety systems, incompetent management, drought, agricultural economics and bad government decisions" (21). The analysis of the Bophal disaster is a regrettable textbook example of the concepts advanced by this chapter:

> "Bophal's plant rigid organizational structure … was one of the three primary causes of the accident … the Bophal plant was plagued by labour relations and internal management disputes … for a period of fifteen years prior to the accident, the plant had been run by eight different managers … many of them came from different backgrounds, with little or no relevant experience."

> "The discontinuity of the plant management, its authoritative and sometimes manipulative managerial style and the non-adaptive and unresponsive organizational system, collectively contributed to the accident. The latter element, i.e., organizational rigidity, was primarily responsible for not

responding and taking the necessary and corrective course of actions to deal with the five reported major accidents occurring at the plant between 1981 and 1984 … crisis often occur because warning signals were not attended to … ”

“The Bophal plant’s organizational culture should also be held responsible for not heeding many operational warnings regarding safety problems … Bophal’s monolithic organizational culture, as the plant’s operational milieu, only fostered the centralization of decision-making by rules and regulations or by standardization and hierarchy, both of which required high control and surveillance … ”

“Many key personnel were being released for independent operation without having gained sufficient understanding of safe operating procedures … ” (22)

THE TRAITS OF A SAFE ORGANIZATION

2.27 What are, then, the traits of a safe organization? In general terms, safe organizations:

- pursue safety as one of the objectives of the organization and regard safety as a major contributor in achieving production goals;
- have developed appropriate risk management structures, which allow for an appropriate balance between production management and risk management;
- enjoy an open, good and healthy safety corporate culture;
- possess a structure which has been designed with a suitable degree of complexity, standardized procedures and centralized decision-making which is consistent with the objectives of the organization and the characteristics of the surrounding environment;
- rely on internal responsibility rather than regulatory compliance to achieve safety objectives; and
- respond to observed safety deficiencies with long-term measures in response to latent failures as well as short-term, localized actions in response to active failures.

References

(1) Smircich, Linda. 1983. “Concepts of Culture and Organizational Analysis”. *Administrative Science Quarterly*, 28, 339-358.
(2) Westrum, R. 1988. “Organizational and Inter-organizational Thought”. World Bank Workshop on Safety Control and Risk Management, Washington D.C.
(3) Wood, Richard H. 1991. *Aviation Safety Programs — A Management Handbook.* IAP Incorporated, Casper, Wyoming, USA.
(4) Transport Canada, 1991. Company Aviation Safety Officer Manual, Vol. 1.
(5) Pope, John A. 1989. “Questions, More Questions”. Flight Safety Foundation, *Flight Safety Digest*, January 1989, 1-4.

(6) Helmreich, Robert L. 1992. "Human Factors Aspects of the Air Ontario Crash". Commission of the Inquiry into the Air Ontario Crash in Dryden, Ontario. Technical Appendices.

(7) Hofstede, G. 1980. "Motivation, Leadership and Organization: Do American Theories Apply Abroad?" *Organizational Dynamics*, Summer 1980, 42-63.

(8) Adler, Nancy J. 1991. *International dimensions of organizational behaviour* (2nd. edition). Boston: PWS-Kent Publishing Company.

(9) Turner, B., N. Pidgeon, D. Blockley and B. Toft. 1989. "Safety Culture: Its Importance in Future Risk Management". The Second World Bank Workshop on Safety Control and Risk Management. Karlstad, Sweden.

(10) Turner, B. 1989. "How Can We Design a Safe Organization?" Second International Conference on Industrial and Organizational Crisis Management. New York University, New York, USA.

(11) Canadian Aviation Safety Board, 1986. Aviation Occurrence Report No. 84-H40006.

(12) Meshkati, Najmedin. 1991. "Human Factors in Large-scale Technological Systems' Accidents: Three Mile Island, Bhopal and Chernobyl". *Industry Crisis Quarterly* 5, 133-154.

(13) Fennell, D. 1988. Investigation into the King's Cross Underground Fire. The Department of Transport. London, HMSO

(14) Hendrick, Hal. 1991. "Ergonomics in Organizational Design and Management". *Ergonomics*, Vol. 34, No. 6, 743-756.

(15) National Transportation Safety Board, 1991. Aircraft Accident Report AAR-91/09.

(16) Ministry of Justice, Major Accident Report No. 2/1988, Helsinki, 1990. Aircraft Accident Report, Embraer 110 Bandeirante, OH-EBA, in the vicinity of Ilmajoki Airport, Finland, November 14, 1988.

(17) Reason, James. 1990. *Human Error*. Cambridge University Press.

(18) Reason, James. 1990. Op. cit.

(19) Transportation Safety Board of Canada, 1990. Aviation Occurrence Report No. 89H0007.

(20) Transport Canada, 1991. Aviation Safety Newsletter ASL 3/91.

(21) Reason, James. 1990. Op. cit.

(22) Meshkati, Najmedin. 1991. Op. cit.

Chapter 3
MANAGEMENT'S CONTRIBUTION TO SAFETY

INTRODUCTION

3.1 In 1986, a major aircraft manufacturer completed a world-wide airline operators survey with a view to helping control what was dubbed "crew-caused accidents". The ensuing report became widely publicized and a milestone within the airline training community since it provided valuable information applicable to flight crew training. (1) Although, by its nature, the survey focused narrowly on flight crews, the researchers were confronted with evidence which suggested that there was more than just crew error to safe airline operations.

3.2 The report indicates that one characteristic of the airlines identified as safer was *management emphasis on safety*. These airlines:

> " … characterize safety as beginning at the top of the organization with a strong emphasis on safety and this permeates the entire operation. Flight operations and training managers recognize their responsibility to flight safety and are dedicated to creating and enforcing safety-oriented policies … There is a method of getting information to the flight crews expeditiously and a policy that encourages confidential feedback from pilots to management … This management attitude, while somewhat difficult to describe, is a dynamic force that sets the stage for standardization and discipline in the cockpit brought about and reinforced by a training programme oriented to safety issues."

3.3 Three years later, in an address given before the Aero Club of Washington, D.C., on 28 March 1989, an internationally recognized advocate of safety through management asserted:

> "Management attitudes can be translated into concrete action in many ways. Most obvious are the fundamentals: the provision of well-equipped, well-maintained, standardized cockpits; the careful development and implementation of, and rigid adherence to, standardized operating procedures; and a thorough training and checking program that ensures that the individual pilots have the requisite skills to operate the aircraft safely. These actions build the foundations upon which everything else rests." (2)

The crash of a De Havilland DHC-6-300 Twin Otter on 28 October 1989 into high terrain, near Halawa Bay, Molokai, Hawaii, while attempting to continue a VFR flight into deteriorating VMC provides an instructive example of "management failure". The aircraft accident report includes the following conclusion:

> "In summary, the Safety Board concludes that [the company's] management provided inadequate supervision of its personnel, training and flight operations. The numerous deficiencies evident during the investigation

relative to the IFR training of the pilots, the reduced ground school training, the lack of CRM training, the captain's known behavioural traits, and the policy of not using the weather radar systems installed on the airplanes, were the responsibility of the airline's management to correct. The failure of the management personnel to correct these deficiencies contributed to the events that led to this accident." (3)

3.4 The quotations in the previous paragraphs set the underlying rationale for this chapter and demonstrate the critical contribution of management to sociotechnical systems safety, which is the objective of this digest. Before addressing *what* management can do, however, it is pertinent to discuss *why* management should act on safety.

WHY MANAGEMENT SHOULD TAKE AN ACTIVE STANCE ON SAFETY

3.5 Aside from the moral considerations regarding potential injury or loss of human life and preservation of property, management should act because of the economics of aviation safety. Chapter 2 discussed the dilemma of dividing finite resources between production and safety goals. Although seemingly incompatible in the short-term, these goals are perfectly compatible when considered from a long-term perspective. It is a recognized generalization that the safest organizations are often the most efficient. There are inevitable trade-offs between safety and finance. However, safe organizations do not allow these trade-offs or apparent incompatibilities to reduce the safety standards below a *minimum standard* which is defined beforehand and thus becomes one of the objectives of the organization. (4)

3.6 When contemplating trade-offs between safety and production, management should evaluate the financial consequences of the decision. Since this trade-off involves risk, management must consider the cost involved in accepting such risk, i.e. *how much will it cost the organization to have an accident*. While there are insured costs (those covered by paying premiums to insurance companies) which can be recovered, there are also uninsured costs which cannot, and they may be generally double or triple the insured costs. Typical uninsured costs of an accident include (5):

- insurance deductibles
- lost time and overtime
- cost of the investigation
- cost of hiring and training replacements
- loss of productivity of injured personnel
- cost of restoration of order
- loss of use of equipment
- cost of rental or lease of replacement equipment
- increased operating costs on remaining equipment
- loss of spares or specialized equipment
- fines and citations
- legal fees resulting from the accident
- increased insurance premiums
- liability claims in excess of insurance
- loss of business and damage to reputation
- cost of corrective action

3.7 Those in the best position to effect accident prevention by eliminating unacceptable risks are those who can introduce changes in the organization, its structure, corporate culture, policies and procedures, etc. No one is in a better position to produce these changes than management. Therefore, the economics of aviation safety and the ability to produce systemic and effective change underlie the justification for management to act on safety.[1]

WHAT MANAGEMENT CAN DO TO TAKE AN ACTIVE STANCE ON SAFETY

3.8 In a document such as this digest which is directed to such a wide audience in different States, in different sizes of organizations and, most importantly, in different structures of organizations, it is impossible to be prescriptive about management actions in relation to safety. There are, nonetheless, a few general principles which apply anywhere; these are discussed in the balance of this chapter.

3.9 ***Allocation of resources***. From the simplest of perspectives, management's most obvious contribution to safety is in the allocation of adequate and necessary resources to safely achieve the production goals of the organization. The issues underlying this allocation are discussed in 2.18 as well as in the opening paragraphs of this chapter. In practical terms, the first quotation in 3.3 can be viewed as a listing of the "most wanted" items management should pursue when deciding on the allocation of resources.

3.10 ***Safety programmes and safety feedback systems***. There are other activities involving allocation of resources which are not as obvious but are nevertheless equally important. These activities are discussed in-depth in the *Accident Prevention Manual* (Doc 9422) and are mentioned briefly in this chapter. The most important is the implementation, continued operation and visible support of a company safety programme. Such programmes should include not only flight operations safety, but also maintenance safety, ramp safety, etc. The programme should be administered by an independent company safety officer who reports directly to the highest level of corporate management. The company safety officer and his or her staff must be quality control managers, looking for corporate safety deficiencies rather than pointing fingers at individual errors. To discharge their responsibilities, safety officers need information which may come from several sources: internal safety audits which identify potential safety hazards, internal incident reporting systems, internal investigation of critical incidents as well as performance monitoring programmes — both for the company and the industry. The possible feedback loops of an internal audit system and their relative values in terms of prevention are discussed in 3.14. An often-overlooked source of information is the participation in industry-wide safety fora, such as conferences and workshops organized by international associations. Armed with the information thus obtained, the safety officer may then implement a programme of disseminating critical safety information to all personnel. The stage for setting a safety-oriented organizational climate is thus set.

3.11 ***Standard operating procedures***. There is an even more subtle activity that management can undertake to contribute to safety. The development of, implementation of and adherence to standardized operating procedures (SOPs) have recently been recognized as a major contribution by management to safety. Failure to conform to sound SOPs has indeed been linked to numerous accidents and incidents. There are Human Factors considerations related to SOPs which concern both the underlying philosophy and the design of such procedures. *Procedures* are specifications for conducting predetermined actions; they specify a progression of actions to assist operational personnel in achieving their tasks in a manner which is logical, efficient and, most importantly, error-resistant. Procedures are not produced in a vacuum nor are they inherent

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1. For additional background on this subject, see J. Lederer, C. O. Miller and C. F. Schmidt, *"The Economics of Safety in Civil Aviation (Planning Study)"*, FAA Technical Report ADS-7, Dec. 1963.

in the equipment; they are based on a broad concept of operation. There is a link between procedures and philosophy, which Wiener and Degani have called "The four Ps of operations": Philosophy, Policies, Procedures and Practices. (6)

3.12 These researchers contend that, by establishing a *philosophy* of operations, management states how it wants the organization to function. Such philosophy can only be established by the highest corporate level. From philosophy, *policies* can be developed. Policies are broad specifications of the manner in which management expects tasks to be accomplished — training, flying, maintenance, exercise of authority, personal conduct, etc. Policies are usually dictated by line management. The *procedures*, normally developed by supervisors, determine how tasks will be accomplished. The procedures must be designed to be consistent with the policies, which must be consistent with the over-all guiding philosophy. Lastly, management must effect the quality control to make sure that *practices* in the operational environment do not deviate from written procedures. Any attempt to shortcut this process may well produce inconsistent procedures, which will breed doubts among the operational personnel about the preferred behaviour management expects from them to accomplish their task (Figure 3-1).

3.13 Philosophies, policies and procedures must be developed with due consideration for the operational environment in which they will be used. Incompatibility of the procedures with the operational environment can lead to the informal adoption of unsafe operating practices. External activities, type of operation and the layout of the cockpit or workstation are factors to be considered when evaluating the operational environment in which SOPs will be used. Feedback from operational situations, through the observed practices of or reports from operational personnel, is essential to guarantee that the bridge between the Ps and the operational environment remains intact.

3.14 The example of the Ground Proximity Warning System (GPWS) Policy, as instituted by one operator (7), illustrates this point:

- *Philosophy:* it is a corporate goal to be a safe and secure airline, as stated in the corporate mission and goals.

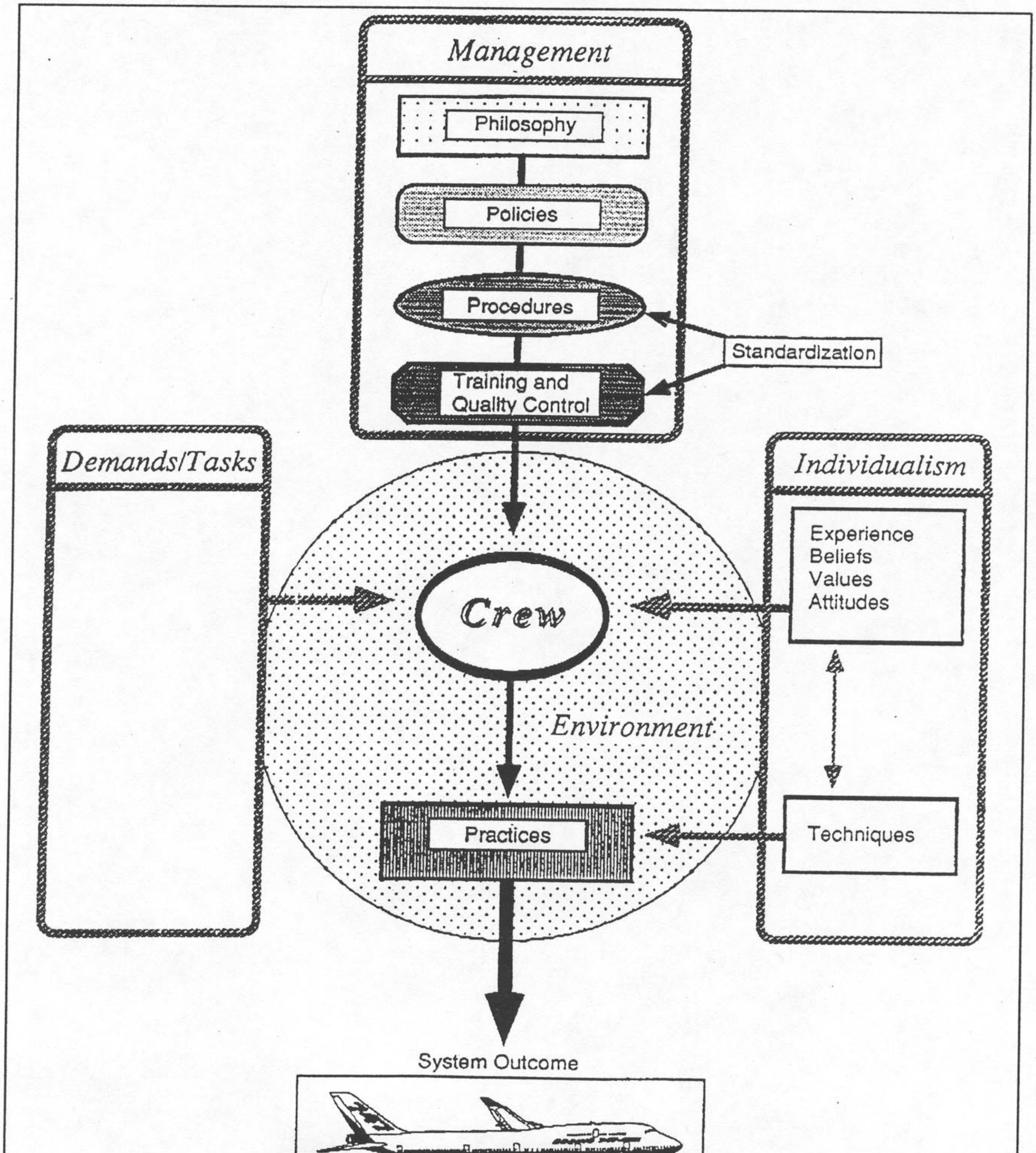
- *Policy:* in the event of a full, or partial, "Pull-up" or other hard (red) warning, the following action must be taken promptly:

  a) Below MSA (Minimum Safe Altitude)
  Announce "PULL-UP Go-Around"
  Immediately complete the pull-up manoeuvre in all circumstances.

  b) At and Above MSA
  Immediately assess aircraft position, altitude and vertical speed. If proximity to MSA is in doubt, take action as in a) above.

- *Procedure:* GPWS pull-up manoeuvre is described in fleet-specific manuals. Describe the call-outs by the handling pilot and the non-handling pilot — procedures at and below MSA and procedures above MSA; define MSA during climb and descent in case of ambiguities and include additional operational information deemed appropriate for the crews to observe the GPWS Policy.

- *Practices:* do flight crews observe the policy and follow the procedure in operational conditions?

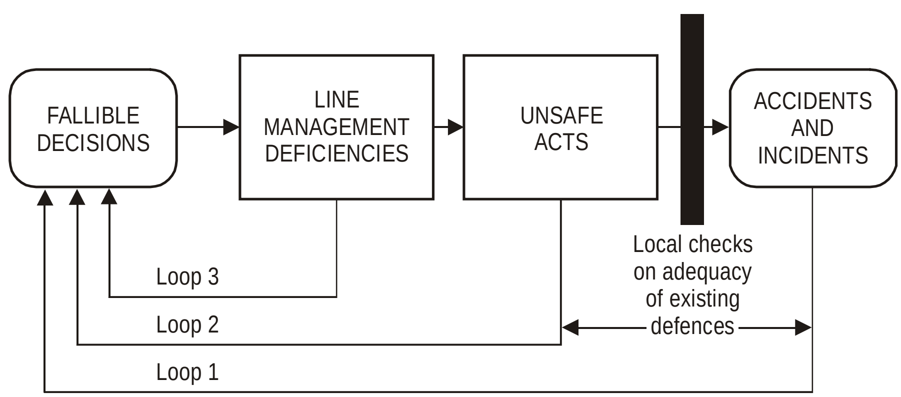


Source: A. Degani and E. Wiener. 1991. "Philosophy, Policies, Procedures and Practices: The Four P's of Flight Deck Operations". Proceedings of the Sixth International Symposium on Aviation Psychology, Columbus, Ohio, USA.

Figure 3-1. The four Ps

3.15 In the GPWS example discussed above, the operator's original policy mandated an immediate pull-up upon receipt of *any* GPWS warning, regardless of altitude and position of the aircraft. Operational feedback obtained through the operator's internal safety information system, however, indicated that during the first calendar year after this policy was implemented, GPWS alerts had not been followed by a pull-up in 60% of occasions. This was due to a variety of reasons, including false and nuisance warnings. Of particular concern was the fact that pull-ups had not been initiated on 20% of occasions *when the warning had been genuine*. An obvious discrepancy between the three first Ps and the last one — Practices — was evident. The safety services of the operator determined that the reason for this discrepancy between philosophy, policy, procedures and practice centred around the unreliability of the technology which resulted in false and nuisance warnings. In some cases, warnings had been triggered at 37 000 ft flying in cruise, immediately after take-off, when there were no obstacles in the flight path or in holding patterns, with other aircraft 1 000 ft below the host GPWS. This feedback data and its analysis led the operator to review its GPWS policy and amend it to that included in 3.14, with the immediate intent of ensuring compliance with the policy on all occasions.

3.16 ***Internal feedback and trend monitoring systems***. The previous paragraph illustrates the importance of the feedback from the "front end", that is, from day-to-day operations, so that management can effect the control of the operations that policies and procedures support. Figure 3-2 depicts three possible feedback loops. (8) *Loop 1* feeds back a company's accident statistics. In most cases, the information supplied is too late for control, because the events that safety management seeks to eliminate have already occurred. *Loop 2* carries information about unsafe acts observed in daily operations. However, unsafe acts represent only the tip of the iceberg since many actions that cause accidents cannot be recognized as such in advance. This information is usually disseminated at the lower levels of the organization, i.e. operational personnel and supervisors. *Loop 3* provides the greatest opportunity for proactive control of safety.



Source: adapted from James Reason. 1990. *Human Error.* Cambridge University Press.

Figure 3-2. Internal feedback and trend monitoring systems

3.17 ***Risk management***. The feedback loops, and loop 3 in particular, allow managers to assess the level of risks involved in the operations and to determine logical approaches when deciding to act upon them. The concept of risk management is discussed in the *Accident Prevention Manual* and is introduced in this digest in 1.10. The basic theory is based on the following assumptions: (9)

- There is always risk. Some risks can be accepted, some — but not all — can be eliminated and some can be reduced to the point where they are acceptable.

- Decisions on risk are managerial decisions; hence the term "risk management".

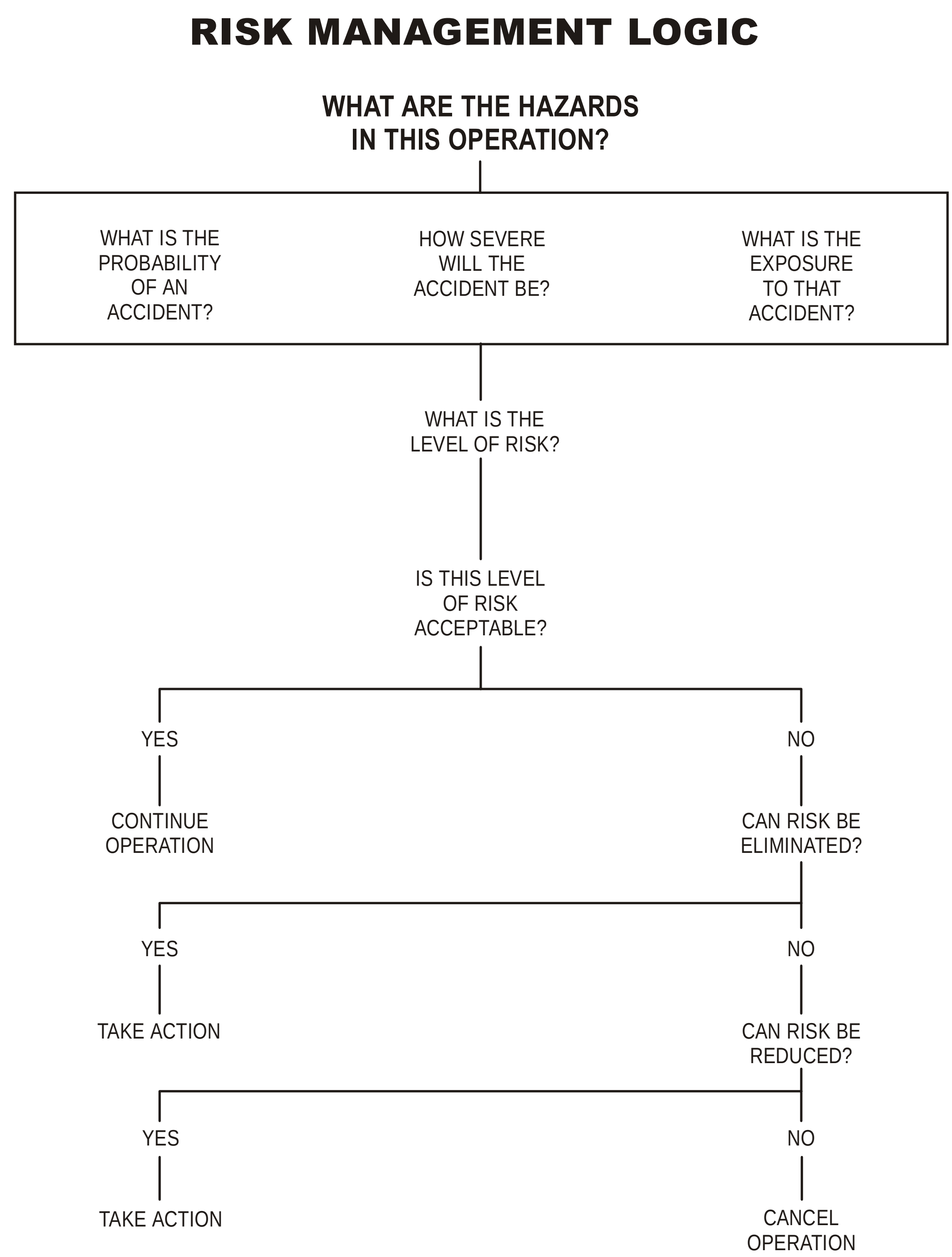
- Risk management decisions follow a logical pattern.

3.18 The first step in the risk management process is to make an accurate assessment of hazards (*hazard assessment*); otherwise, decisions will be made on the basis of inaccurate information. One way to assess hazards is to subjectively evaluate them based on probability of occurrence, severity when they occur and exposure to them. The second step is to make an assessment of the risk involved (*risk assessment*) and determine whether the organization is prepared to accept that risk. Again, the crucial points are the accuracy of the information about the nature of the hazard and the willingness to use this information. The third step involves finding those hazards that can be eliminated (*hazard elimination*) and eliminating them. If none of the identified hazards can be eliminated, then the fourth step is to look for the hazards that can be reduced (*hazard reduction*). The objective is to reduce the exposure to a particular hazard: reduce the probability that it will occur, or reduce its severity when it does occur. In some cases, the risk can be reduced by developing means for safely coping with the hazard.

3.19 It must be kept in mind that judging acceptable risk is a subjective, social and legal activity that will vary among different cultures and societies and even among organizations within a single culture or society. It follows, according to this line of reasoning, that safety is *judged, not measured*. If, based on an accurate assessment of the hazards, the risks are judged to remain high and unacceptable and, after serious consideration to hazard elimination or reduction, the total risk remains unacceptable, then the obvious decision is to cancel the operation (short term) or to modify the system to bring risks to an acceptable level (longer term). There is room for short-term change around loops 1 and 2, but the long-term changes lie around loop 3 where unsafe organizational structures can be modified and unsafe corporate cultures changed. The importance of this risk management process is that it allows management to clearly see the results of action or inaction. Figure 3-3 illustrates the conventional risk management logic.

3.20 In large organizations such as airlines, the costs associated with loss of human life and physical resources dictate that risk management is essential. In order to produce recommendations that do not run counter to the goals of the organization, a systems approach to risk management must be followed. Such an approach, in which all aspects of the organization's goals and available resources are analysed, offers the best option for ensuring that recommendations concerning risk management are realistic and complementary to the purposes of the organization (10).

3.21 A loop is thus closed. This chapter presents the opinions of the prevention, research and training communities regarding what management can do to contribute to safety. They complement the background and justification provided by the first two chapters. There is growing consensus that management must play an active role in achieving aviation system safety. There is also consensus on the need for change and progress, with solid evidence strongly supporting new approaches to the relationship between management, organizations and safety. The case for dealing with management factors and organizational accidents seems to be beyond reasonable challenge.



Source: Richard H. Wood. 1991. *Aviation Safety Programs — A Management Handbook*. IAP Incorporated, Casper, Wyoming, USA.

Figure 3-3. Risk management logic

References

(1) Lautman, L. G., and P. Gallimore. 1989. "Control of Crew-caused Accidents". Flight Safety Foundation, *Flight Safety Digest*, October 1989.
(2) Lauber, John K. 1989. "Human Performance and Aviation Safety — Some Issues and Some Solutions". *Airline Pilot*, June 1989.
(3) National Transportation Safety Board, 1990. Aircraft Accident Report AAR-90/05.
(4) Wagenaar, W., P. Hudson and J. Reason. 1990. "Cognitive Failures and Accidents". *Applied Cognitive Psychology*, Vol. 4, 273-294.
(5) Wood, Richard H. 1991. *Aviation Safety Programs — A Management Handbook.* IAP Incorporated, Casper, Wyoming, USA.
(6) Degani, A., and E. Wiener. 1991. "Philosophy, Policies, Procedures and Practices: The Four P's of Flight Deck Operations". Proceedings of the Sixth International Symposium on Aviation Psychology, Columbus, Ohio, USA.
(7) British Airways Ground Proximity Warning System Policy, 4 January 1993.
(8) Reason, James. 1990. *Human Error*. Cambridge University Press.
(9) Wood, Richard H. 1991. Op. cit.
(10) Hill, Maury. 1993. *An Assessment of Conventional Risk Management, Human Reliability Assessment and System Analysis, and their Role in Complex Man-Machine Systems.* Montreal, Canada.

Chapter 4
ORGANIZATIONAL ACCIDENTS: A CASE STUDY

INTRODUCTION

4.1 The review of an accident from an organizational perspective is the method selected to illustrate how accidents in modern technological systems result from the insidious accumulation of delayed-action failures; from collective rather than individual mistakes. This chapter reviews evidence produced by the investigation and concentrates on systemic failures and organizational deficiencies existing at the time of the accident. These bred latent failures which eventually combined with active failures and a very particular environment to break system defences and thus generate the accident.

4.2 The facts surrounding the accident are deceptively simple: the flight crew descended their large transport aircraft to low altitude in an unfamiliar environment quite different to that in which the airline conducted its regular operations and flew at low level into an area of dubious weather conditions, colliding with high ground. The official investigation, conducted according to the provisions of Annex 13, put the responsibility for the accident squarely upon the shoulders of the captain, absolving the airline and the civil aviation administration from any responsibility. A commission of inquiry, set up by the State's government subsequent to the release of the official investigation report, completely absolved the captain, placing responsibility for the accident entirely on the airline and the civil aviation administration. These conflicting views as to the causes of the accident generated more evidence than is usual in "routine" accident investigations. This evidence enables an organizational analysis of the accident.

4.3 From a systems perspective, it is of no concern to allocate blame for an accident. Given the fact that error is a normal component of human behaviour, the target must be those system failures which foster human error. Indeed, it is suggested that both the official investigation and the commission of inquiry reports are correct. The flight crew failed in their role as the last line of defence. However, their behaviour reflected the expected behaviour which any flight crew would have displayed in similar circumstances and in light of the existing knowledge. This should not negate the fact that through their actions or inactions they triggered the accident. It is equally true, however, that there was an aviation system with deficiencies and failures which fostered flawed decision-making by part of the flight crew. The quotation from the Report of the Dryden Commission of Inquiry included in 1.8 applies perfectly to this accident (text in italics added):

> " … the captain, as pilot-in-command, must bear the responsibility for the decision [*to descend to a low altitude in an unfamiliar and potentially hostile environment*] on the day in question. However, it is equally clear that the air transportation system failed him by allowing him to be placed in a situation where he did not have all the necessary tools that should have supported him in making the proper decision."

4.4 This review must not be construed as a negative reflection on or an unwarranted criticism of the airline or any of the other organizations involved, of their devotion to safety, nor of any event surrounding the accident and its investigation. This analysis may apply to most operators and organizations in the present aviation system. Indeed, even the best run organizations are not immune to the insidiousness of systemic latent failures, hence the importance of an awareness of them. This review emphasizes where system safeguards failed and has the benefit of more than ten years of progress both in Human Factors and safety thinking. Action upon failed safeguards can realize the greatest safety benefits.

4.5 The sources and reference materials include:

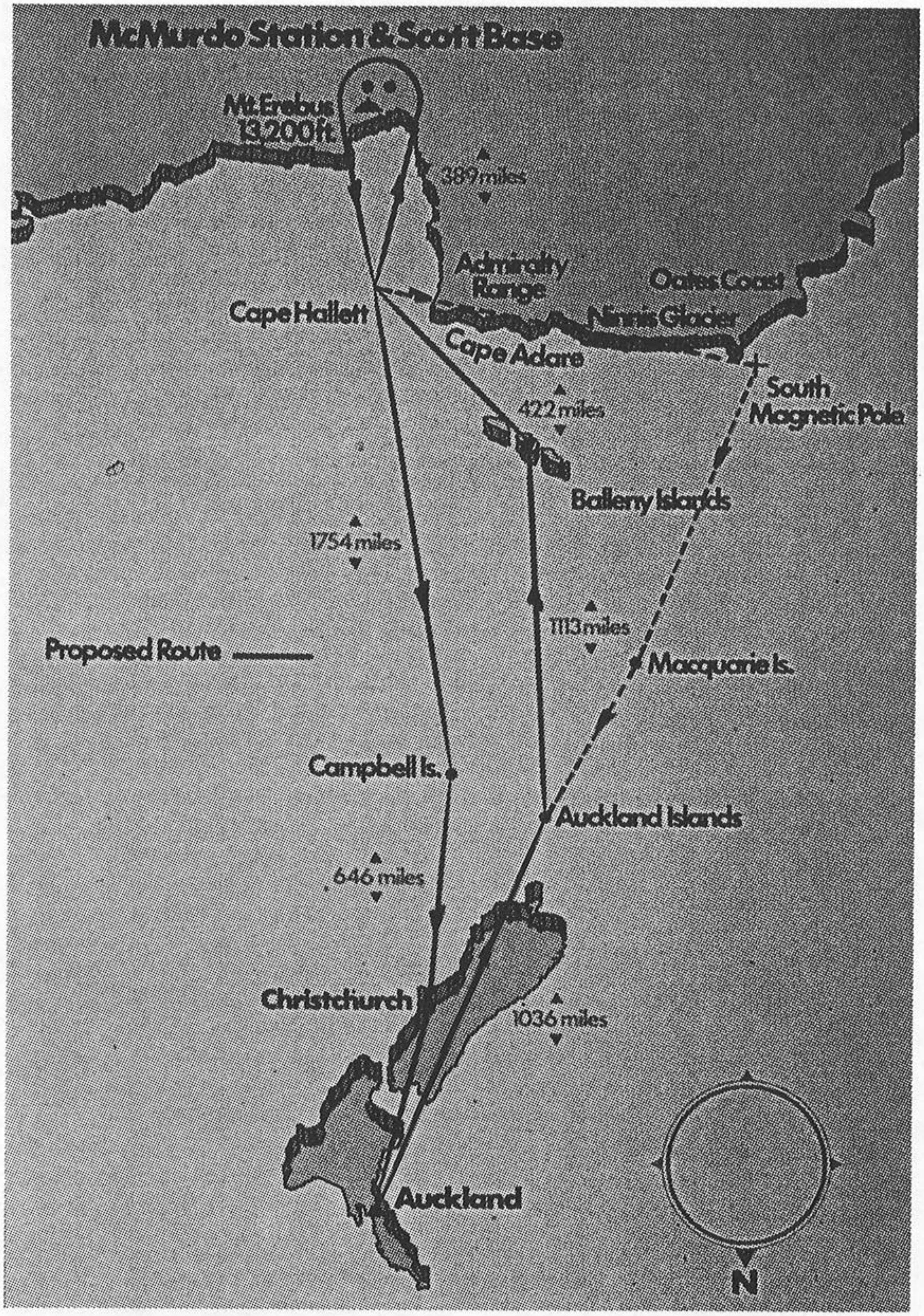
- Aircraft Accident Report No. 79-139, Office of Air Accidents Investigation, Ministry of Transport, Wellington, New Zealand, 1980.
- Report of the Royal Commission to inquire into The Crash on Mount Erebus, Antarctica, of a DC10 Aircraft, Wellington, New Zealand, 1981.
- "Impact Erebus", Capt. Gordon Vette, Aviation Consultants Ltd., Newtown, Auckland, New Zealand, 1983.
- "Erebus", Capt. Neil Johnston, *The Log*, December 1985.
- *The Erebus Papers*, Stuart Macfarlane, Avon Press, Auckland, New Zealand, 1991.
- "Collective Mistakes in Aviation: `The Last Great Frontier'", Prof. James Reason, *Flight Deck*, Summer 1992.

THE EVENTS

4.6 On 28 November 1979, a DC10-30 aircraft on a special sightseeing flight over the Antarctic collided into the northern slopes of Mount Erebus, a 12 455-ft active volcano on Ross Island, while flying at an altitude of 1 500 ft above sea level. The aircraft was completely destroyed by the impact and subsequent fire, and all occupants perished. The aircraft had departed from Auckland, New Zealand, and proceeded via South Island New Zealand, Auckland Islands, Balleny Islands and Cape Hallet, with McMurdo Station as the final destination before returning to New Zealand (Figure 4-1). A landing was not scheduled at McMurdo; the sightseeing would be limited to low-level flying around the southern peninsula of Ross Island, where the most significant human activity in Antarctica is found.

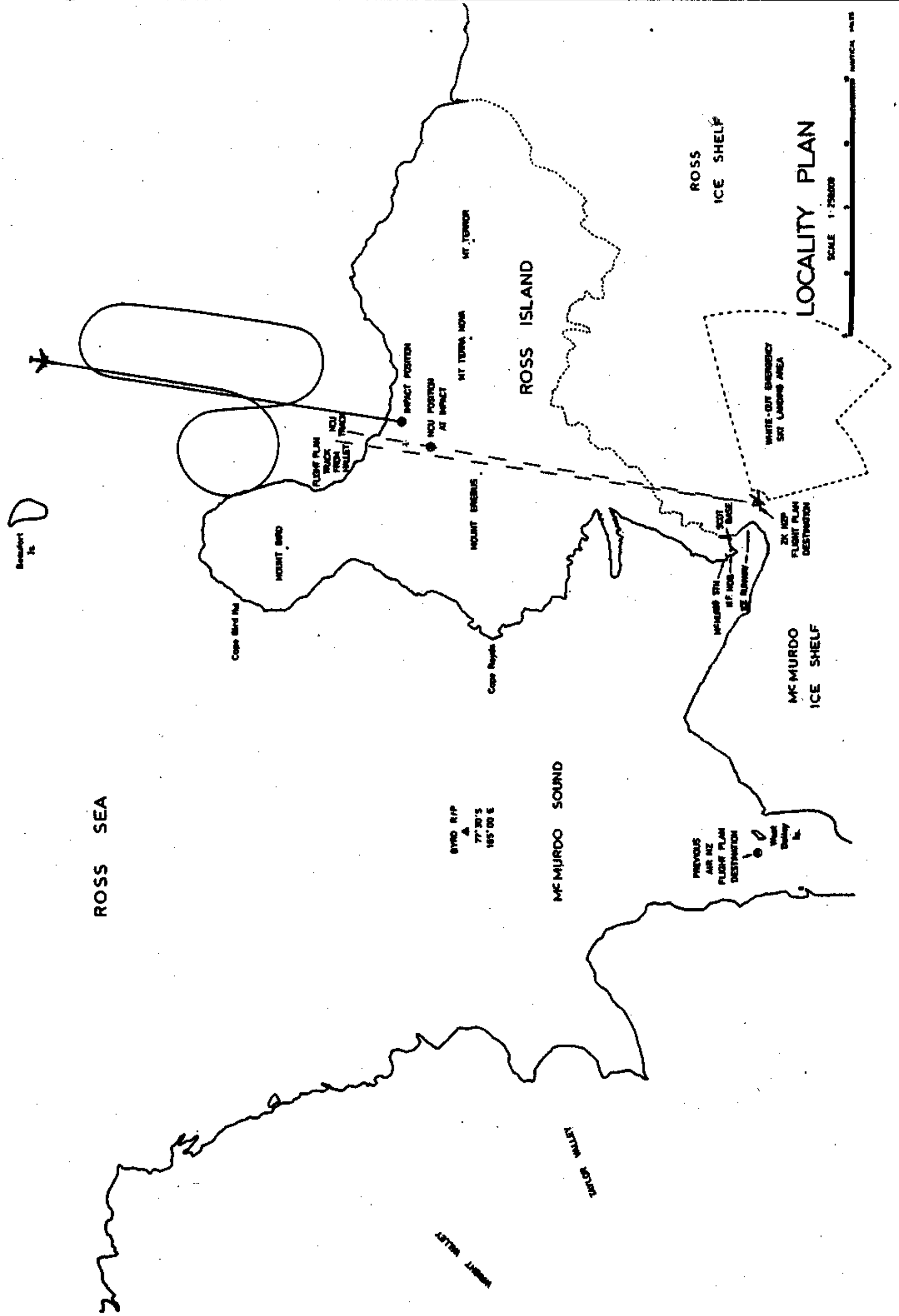
4.7 Ross Island was reportedly overcast with a base of 2 000 ft, with some light snow and a visibility of 40 miles and clear areas some 75 to 100 miles northwest of McMurdo. Approximately 40 miles north of McMurdo the flight encountered an area along its track with sufficient breaks in the overcast to allow for a visual descent below the cloud deck. The flight requested and obtained from the United States Navy Air Traffic Control Centre (Mac Centre) clearance for a visual descent and to visually proceed to McMurdo, with a request to keep Mac Centre advised of the aircraft altitude. The automatic tracking feature (NAV track) of the Area Inertial Navigation System (AINS) was disconnected and a "manual", orbiting descent in visual conditions to an altitude of 2 000 ft was accomplished. It thereafter continued to 1 500 ft to enhance passenger viewing of the landscape. When the aircraft levelled off, NAV track on the AINS was reselected. Approximately 3 minutes later, the Ground Proximity Warning System (GPWS) came alive with a 500 ft warning. Fifteen seconds later, while the crew was initiating a pull-up, the aircraft collided with the ice slope on Mount Erebus (Figure 4-2).

4.8 This review is worked backwards, i.e. from the accident to the latent failures. Reference should be made to 2.20 through 2.23 and to Figures 2-2 and 2-3. Only a few of each level of failures have been selected for discussion below.



Source: The Erebus Papers, Stuart Macfarlane, Avon Press, Auckland, New Zealand, 1991.

Figure 4-1. Route of Antarctic flights



Source: Aircraft Accident Report No. 79-139, Office of Air Accidents Investigation, Ministry of Transport, Wellington, New Zealand, 1980.

Figure 4-2. Locality plan

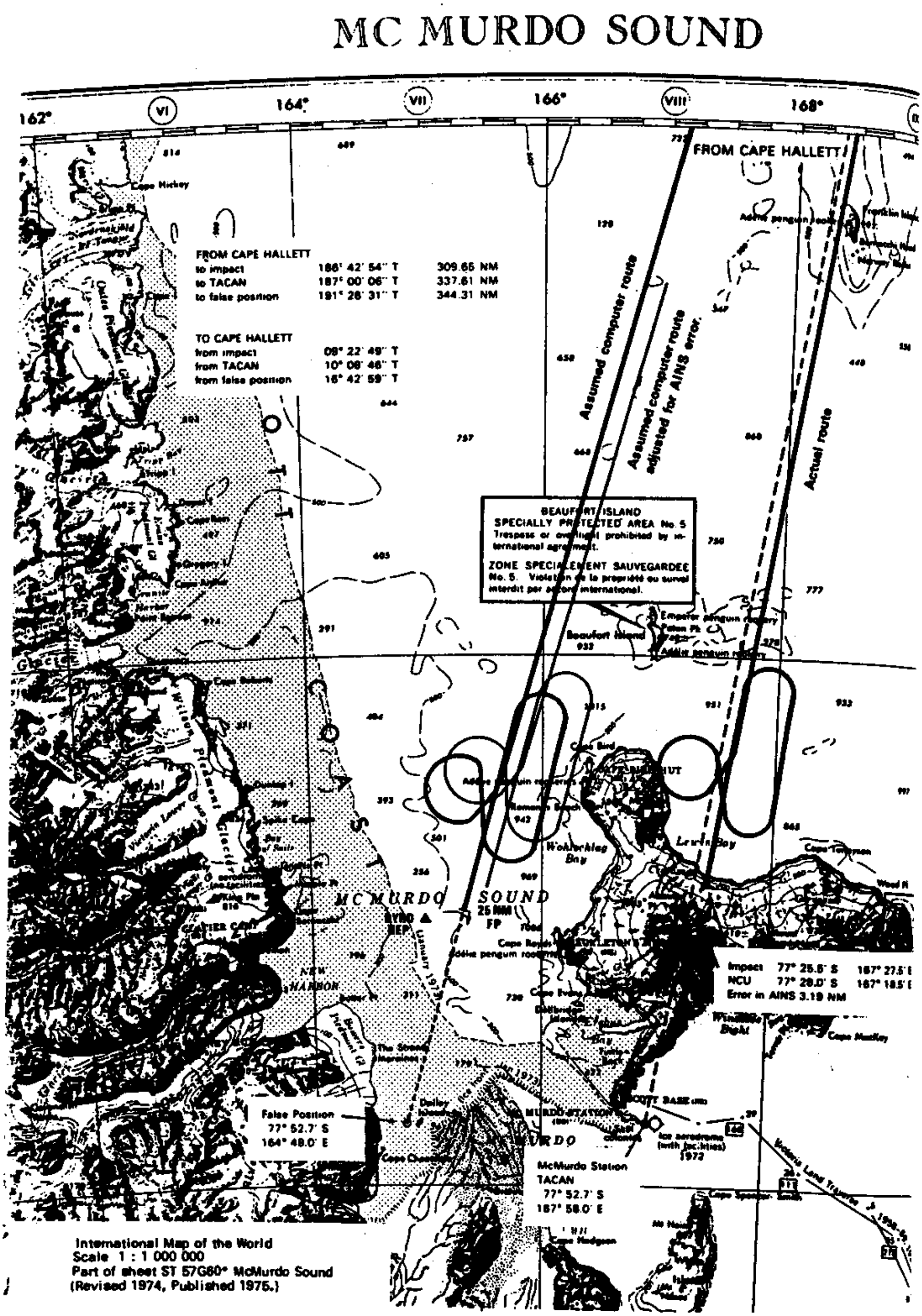
FAILED DEFENCES

4.9 The air transportation system has defences at many levels. There were failures at all levels of the defences which played a part in preventing this controlled flight into terrain. A few of these failures are described below.

- Neither the regulatory authority nor the operator provided the flight crew with sufficient information regarding the peculiar Antarctic phenomenon of sector white-out and altered visual perception. This phenomenon rendered the protection provided by flight under VMC rules ineffective, since it would make an obstacle a few feet ahead invisible if the obstacle were white, even in reported visibilities of 40 miles. Before undertaking Antarctic flights, pilots were alerted during briefings to avoid snow showers and blowing snow. No discussion, however, was included in such briefings regarding the pitfalls of attempting visual separation from terrain under overcast conditions. No warning — or prohibition — was included in the briefing package alerting crews to the dangers of attempting flying VMC over white, textureless terrain under low overcast conditions in polar regions.

- The computer flight plan presented to the pilots during the Antarctic briefing ran from Cape Hallet through the Ross Sea and the centre of McMurdo Sound, a flat expanse of ice forty miles wide, to the Byrd reporting point, some 25 miles west of McMurdo Station, and thence to McMurdo. This closely followed the route used by routine military traffic, and it was the route followed by 7 sightseeing flights during the previous 12 months. This route placed Mt. Erebus 25 miles to the left of the flights. However, on the night before the accident (about six hours before scheduled take-off time), the computer flight plan was modified by the operator's navigation section. The final way-point, rather than Byrd reporting point, was now the intersection of the runways at Williams field, a permanent facility near McMurdo Station used by ski-equipped aircraft. The new track, displaced to the left, lay directly across Mt. Erebus. Neither the captain nor any flight crew member was notified of the change in the final destination way-point. When the crew reselected NAV track, locking the aircraft path to the computer flight plan after the orbiting visual descent, to the best of their knowledge they were heading over a flat expanse of textureless white towards McMurdo Sound. Indeed, they were heading straight towards Mt. Erebus, hidden by the insidious white-out (Figure 4-3).

- The briefing provided to Antarctic crews included reference to two altitudes for the sightseeing area: 16 000 ft to clear Mt. Erebus and 6 000 ft, once within a defined sector around McMurdo, to clear the elevations within that sector. After the accident, these altitudes were the subject of heated controversy. Some flight crews from previous flights viewed them as minimum safe altitudes independent of weather conditions, in which case the accident flight crew had breached explicit restrictions by descending to 1 500 ft. Other flight crews viewed them as cloud break altitudes only, in which case VMC descent to lower altitudes had been within allowable operational specifications. Beyond the controversy, however, the fact that pilots from previous Antarctic trips held conflicting views as to the binding nature of these altitudes clearly illustrates that the instructions provided to flight crews during the briefing had not been clear enough. Unclear lines of communication foster flawed decision-making by operational personnel.



Source: "Impact Erebus", Capt. Gordon Vette, Aviation Consultants Ltd., Newtown, Auckland, New Zealand, 1983.

Figure 4-3. Actual and believed flight paths

- The flight crew had been informed that the McMurdo NDB, located by the Station, was not available, leaving the TACAN (a military navigation aid incompatible with civilian equipment except for its DME portion) as the only ground-based aid available. During the briefing of the accident crew, one briefing officer experienced considerable difficulty in ascertaining the real status of the NDB. In fact, the NDB was transmitting, but it had been withdrawn from publication; the U.S. Navy had made the decision to stop maintaining it, but rather than shutting it down, the NDB had been left transmitting until it failed. Thus, for practical purposes, the NDB was available as a further supporting aid. Unclear lines of communication prevented the flight crew from using it.

- The planning for Antarctic flights stipulated that before being assigned as pilot-in-command, captains would undertake one familiarization flight under the supervision of another captain who had already visited Antarctica. This sensible precaution aimed at ensuring that at least one flight deck crew member was familiar with the alien environment in which the operation would be conducted. In fact, line-indoctrination is a standard practice in airline operations. While flight crew rostering of earlier flights observed this requirement, it was eventually discontinued. The justification for this decision was that the briefing fulfilled all familiarization requirements. Neither the captain of the accident flight nor the two first officers had ever been to the Antarctic before.

- The U.S. Navy Support Force in Antarctica had informed the State's civil aviation authority that air traffic control, flight following and weather forecasting support from McMurdo Station would be available on a limited basis and as advisory information only for commercial flights. (Air traffic control/flight following would take the form of location advisory of local aircraft and position relay only.) This was based on current Navy regulations as well as on limited resources at McMurdo. Whether this state of affairs was fully appreciated by flight crews is open to discussion. Antarctic crews were in fact briefed to deal with McMurdo ATC as they would with any other ATC, in spite of the prevailing restrictions. ATC is one of the system's primary defences. Any limitations in the provision of services debilitate system defences, and even more so if such limitations are unknown to its users.

UNSAFE ACTS

4.10 During the final stages of the flight, after the decision to descend below 16 000 ft was made, the crew arguably committed several unsafe acts which eventually precipitated the accident:

- They attempted visual separation from terrain in white-out conditions.

- They continued to attempt visual separation from terrain while flying towards an area which, according to the CVR transcript, appeared to cause doubts as to the possibility of maintaining visual conditions.

- They did not react to the fact that, in spite of the proximity to McMurdo, they could never establish contact through VHF radio, maintaining all communications exchanges through HF radio. This might have suggested some obstacle (i.e. high ground) between their position and McMurdo.

- They did not cross-check the track which would have led them to the centre of McMurdo Sound and the Byrd Reporting Point against the actual track and that displayed in the AINS.

4.11 Aside from these issues, there is one unsafe act in particular which would not be explicable unless addressed within proper context: how could an experienced captain and his equally experienced crew misperceive the dangers and pitfalls associated with low-level polar flying in the conditions existing on the day of the accident? The captain was held in high esteem by managers and peers alike, who regarded him as a conscientious and conservative professional. His teammates were, by all accounts, equally experienced, conscientious and knowledgeable. Available evidence suggests that the crew performed as an intact team, working in co-ordination until the last minute.

4.12 Several factors may have prompted the crew to descend to a low altitude and continue flying under the prevailing conditions:

- The flight crew was unaware of the dangers of sector white-out. They assumed that, since they had good lateral visibility, the vastness of white ahead of them represented an unobstructed path, consistent with the 40-mile visibility report by McMurdo, which would allow them to maintain VMC. They may have assumed that, in line with the briefing they had received, as long as they stayed away from snow showers or blowing snow, they would be safe from white-out conditions.

- The flight crew knew that previous Antarctic flights had descended to low altitudes in VMC and had conducted their sightseeing safely, maintaining visual separation from detectable obstacles.

- The flight crew believed that the track ran across down the centre of McMurdo Sound, with Mt. Erebus well to the left of the track; this was reflected by the fact that, after level off at 1 500 ft, they re-engaged NAV track on the AINS. This belief may have been further reinforced by the (erroneous) identification of landmarks — unfortunately coincident with their assumed track — provided by an experienced Antarctic commentator highly familiar with the region who was riding in a jump seat.

ERROR-PRODUCING CONDITIONS

4.13 The error-producing conditions which led the flight crew to make flawed decisions and to commit unsafe acts are a by-product of the failures in the systems' defences. They include critical gaps in the regulatory and operational safety net, ambiguity in the Antarctic operating procedures, inadequate information about the insidiousness of white-out, inexperience (in the Antarctic environment) and training deficiencies.

4.14 The briefing prepared by the operator and approved by the regulatory authority included most of the relevant information to familiarize flight crews with the Antarctic flights, including a flight simulator detail. In broad terms, the briefing represented a framework which, had all its provisions been observed and applicable to the realities of the Antarctic flights, would have ensured the necessary safety in these flights. There were, however, error-producing ambiguities in the briefing package which contributed to a failure of system safety defences and which remained undetected until the accident.

4.15 The Antarctic flights were predicated on a set of requirements, some of which turned out to be difficult to reconcile with the sightseeing nature of these flights. In practice, the mismatch between these requirements and the reality of the situation induced crews to deviate from them in order to provide passengers with a good view and thereby achieve the objective of the flights. The two altitudes constitute one example. They were not the best possible altitudes for sightseeing and previous Antarctic flights had descended below these altitudes. If intended as *minimum safe altitudes*, such descents constituted a deviation from established procedures. These descents for low-level sightseeing were public knowledge and had not been challenged by the operator or the authority. This acquiescence became an error-inducing condition; it must have influenced the accident crew's belief that they were not deviating from any rule when descending below these altitudes.

4.16 The briefing included an instrument let-down over the McMurdo NDB in order to acquire visual conditions for the sightseeing. This was a U.S. Navy-published instrument approach procedure. When the Navy decommissioned the NDB, the only way the Antarctic flights could descend to the appropriate sightseeing altitudes was under VFR, and the briefing was amended accordingly. Although seemingly simple and straightforward, this amendment contained error-inducing potential under a certain blend of circumstances. It must be borne in mind that this was a commercial flight, dispatched under the strict provisions of IFR operations and operating under VFR at destination. However, VFR confers considerable autonomy and flexibility of decision on the pilot.

4.17 Therefore, when approaching the overcast McMurdo with no navigation aids to execute the let-down and upon finding a large break in the clouds which allowed for descent maintaining visual conditions, the flight crew resorted to the autonomy provided by VFR to accomplish the objective of the flight. This decision was correct within the framework provided by the briefing, the knowledge existing at the time of the accident, the experience obtained from previous Antarctic flights and the operational behaviours all these circumstances generated[1]. Only ATC remained as the last line of defence. However, the decision was probably reinforced by the "clearance" received from McMurdo, which in no way challenged the descent or questioned its appropriateness. With the benefit of hindsight, the decision to descend turned out to be an error. The explanation for the error must be sought, however, far and away from McMurdo Sound and Mt. Erebus.

4.18 Several other error-inducing conditions can be identified. By adding a few words to a quotation from the Report of the Dryden Commission of Inquiry included in 1.8, a clear organizational perspective emerges (text in italics added):

> " … The pilot-in-command made a flawed decision, but that decision was not made in isolation. It was made in the context of an integrated air transportation system that, if it had been functioning properly, should have prevented the decision [*to attempt low altitude visual separation from terrain under the prevailing conditions*] … there were significant failures, most of them beyond the captain's control, that had an operational impact on the events in [*Antarctica*] … the regulatory, organizational, physical and crew components must be examined to determine how each may have influenced the captain's decision."

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1. One further reason why VMC descents elsewhere had to be perceived as "normal constituent" of the Antarctic flights was the fact that there was an alternate Antarctic destination (South Pole via the Ninnis Glacier) for which the only possible descent was VMC. This descent had to be accomplished, of course, well outside the sector defined around McMurdo.

LATENT ORGANIZATIONAL FAILURES

4.19 The analysis of organizational accidents has allowed identification of a number of latent systemic failures. These are limited in number, yet common to all high-technology systems. These latent failures are the real root causes of accidents within the air transportation system. They include lack of top-level management safety commitment, creating conflicts between production and safety goals; organizational deficiencies leading to blurred safety responsibilities; poor communication; poor planning, inadequate control, training deficiencies, poor maintenance management and regulatory failures. Most of these played a part in the chain of events which led to the accident. They are discussed below.

- There is no evidence whatsoever to support any contention of lack of management commitment to safety on the operator's part; the operator's commitment towards safety was obvious. There is, however, evidence which suggests that this commitment was not — at least within the context of this accident — converted into deed. As an example, although the low altitude flying of previous flights which violated what the Antarctic briefing purported to be minimum safe altitudes was widely known, there was no reaction by the operator to these "violations". The assessment of Mr. Justice Hidden (Chapter 1), when reviewing management commitment to safety in the Clapham Junction railway accident, may apply here:

  > "The evidence therefore showed the sincerity of the concern for safety. Sadly, however, it also showed the reality of the failure to carry that concern through into action. It has been said that a concern for safety which is sincerely held and expressly repeated but, nevertheless, is not carried through into action, is as much protection from danger as no concern at all."

- At the time of the accident, the production goals of the Antarctic flights had been fully accomplished. The flights were an unqualified success. The conflict between these production goals and the associated safety goals gives food for thought, in particular in regard to the "tools" available to the crews to discharge their duties. This became obvious after the McMurdo NDB was decommissioned, leaving a VMC descent as the only means to achieve the flights' production goals. The conflict of scheduling commercial flights to conduct sightseeing within a precise sector defined by two navigation aids (NDB/TACAN) and their continuation — without changes in the operational procedures to provide precise guidance under the new state of affairs — after one such aid (the NDB) was decommissioned offers room for doubt. Dropping the practice of rostering two captains and one first officer in favour of one captain and two first officers reduced the safety associated with the concept of redundancy. Similar comments apply to the discontinuation of the requirement for familiarization flights before assuming command of an Antarctic flight.

- The operator had received a communication, directed from the U.S. Navy Support Force in Antarctica to the civil aviation authority, indicating that limited search and rescue (SAR) capability existed over land and very little over water. Although SAR issues were not relevant to the accident, the question of the conflict between production and safety goals arises again. It is a matter of conjecture what the consequences could have been, in terms of loss of life due to exposure, had the accident been survivable.

- There are some indications of blurred safety responsibilities resulting from organizational deficiencies which played a part in this accident. Management officers were aware of descents to low altitudes. However, according to their own evidence, each of them perceived that taking action, in response to what could arguably have been considered violations to operational restrictions, was not part of their responsibilities, but someone else's. Another indication of blurred responsibilities is the evidence provided by the company safety officer; he asserted that, until the accident, he ignored the fact that the track of the flights ran directly over the top of an active volcano.

- That the coordinates of the final way-point were changed by the operator's navigation section a few hours before departure and that neither dispatch nor the flight crew were notified suggest the need to improve some weaknesses in the lines of communication between sectors existing at the time of the accident. The doubts generated by the briefing regarding the minimum altitudes stand as another example. The doubts as to the actual track between Cape Hallet and McMurdo, which were evident during the inquiry, are yet another example. These doubts represent a recurring latent failure: the failure to clearly convey management intentions to operational personnel.

- The operator had conducted several rounds of consultations with organizations operating in the Antarctic before determining the feasibility of the Antarctic flights. Once a decision to proceed with the flights was made and the operation approved by the civil aviation authority, no further contacts were made with these organizations to obtain feedback — based on their experience in Antarctic operations — about the feasibility and soundness of the selected procedures. For example, no contact was made with the U. S. Navy to discuss with McMurdo ATC how the flights would operate, their intended route(s), the descent sector selected, etc. As a consequence, it was determined after the accident that the sector selected for instrument let-down was, from the point of view of the McMurdo ATC equipment limitations, quite unsuitable. Available evidence supports the notion that there might have been room for improvement in the planning of the Antarctic flights.

- The inadequate control and supervision of the Antarctic flight were best evidenced by the controversy surrounding the descents to low altitudes. It is also evident through the fact that over a 12-month period, 7 flights operated into Antarctica with an error in the coordinates of the final destination way-point in the computer flight plan before such error was detected. Furthermore, at the time of the accident, the briefings were conducted based upon a computer flight plan containing these erroneous coordinates and with such coordinates underlined or highlighted.

- The Antarctic briefing was the means to convey to flight crews, through the operator's training system, management's intents and goals as to how the flights should be conducted. This includes both production *and* safety goals. Briefings, if they are to accomplish their objectives, must provide precise information rather than oblique reference. All the relevant operational and safety information should have been part of the Antarctic briefing package. It was not. The major omissions and mistakes have already been discussed: incomplete information in regard to white-out; ambiguous information about what were effectively the minimum safe altitudes; misleading information about the intended route of flight and ambiguous information about the nature and extent of the air traffic services provided, among others. That the briefing failed to produce the desired behaviour attests to its failure and suggests the existence of training deficiencies.

- Lastly, most of these latent organizational failures could have been avoided by enforcing the existing regulations. Regulatory failures were evident in this accident. The Antarctic operation had been scrutinized and approved by the civil aviation authority at the very outset; therefore, there was a failure to notice the incomplete information regarding white-out conditions as well as the lack of any warning or prohibition to attempt visual terrain clearance in such conditions. Approving a route which passed directly over an active volcano can be regarded as another regulatory failure. Further on, as the operations evolved and conditions departed from those originally approved (dropping the requirement for familiarization flights; decommissioning of the NDB, etc.), the regulatory authority made no regulatory changes. A rather passive attitude was also the answer to the much-publicized low-altitude sightseeing flights. If they indeed represented violations of established restrictions, it was within the regulatory authority's role to adopt an active stance on the matter.

CONCLUSION

4.20 The Final Report from the Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario, reads:

> "From a corporate perspective, the commitment to safety management was,
> in the years preceding [the accident] largely cosmetic."

Although harsh, this judgement reflects an extremely pervasive and insidious latent failure in the aviation system: lack of understanding throughout the international aviation community as to what constitutes effective safety management.

4.21 Despite the many warnings in this chapter and throughout the entire digest, some readers may still regard this chapter as an indictment of the airline involved in particular and of the State's operating practices in general. These readers might reassure themselves that their organizations are immune from the failures leading to accidents such as the one discussed here — the "it could not happen here" syndrome. In so doing, not only would they be wrong, but they would also miss the point. Just as error is a normal component of human behaviour, so every organization harbours the potential for latent failures. Just as human error is inevitable, so are fallible management decisions. Just as active failures are inevitable, so are latent failures.

4.22 The key to safety management lies in identifying latent failures and remedying them before they produce an accident. Concluding that the aircraft collided into Mount Erebus because the flight crew flew into deteriorating weather and failed to maintain visual separation with the rising terrain would simply be to ascribe the specific circumstances for an accident which might have occurred elsewhere. Looking into the organizational processes, such as compatibility of goals, lines of communication, quality of control and supervision and relevance of the training system, among others, will make latent failures and organizational deficiencies obvious and prevent occurrences elsewhere.

4.23 Throughout the digest and this chapter, multiple references are made to the *Final Report of the Commission of Inquiry into the Air Ontario Crash in Dryden, Ontario*. The reason is simple: from an organizational perspective, the *Dryden Report* (as it has become universally known) is a benchmark. The *Report of the Royal Commission to inquire into The Crash on Mount Erebus, Antarctica, of a DC10 Aircraft* arrived to conclusions which bear striking similarities to those of Dryden. This comes as no surprise to the alert reader, since both Commissions of Inquiry surveyed the aviation system looking for safety management failures rather than branding a professional body as entirely responsible for aviation safety. The *Erebus Report* and most of its associated literature were produced ten years before Dryden; they generated violent controversy and remained inconspicuously shelved until recently. The *Erebus Report* was, probably, ten years ahead of its time. After all, Chernobyl, Bophal, Clapham Junction, King's Cross and other major high-technology systems catastrophes had yet to happen. They need not have happened. In retrospect, if the aviation community — and the safety community at large — had grasped the message from Antarctica and applied its prevention lessons, Chernobyl, Bophal, Clapham Junction, King's Cross and certainly the Dryden report would not have existed.

— END —

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services (PANS) are approved by the Council for world-wide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

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