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HUMAN FACTORS DIGEST No. 7

INVESTIGATION OF HUMAN FACTORS IN ACCIDENTS AND INCIDENTS

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INTRODUCTION

1. Human Factors are involved in most aviation occurrences. Thus, to advance aviation safety, we must improve our ability to identify the involvement of Human Factors in accidents and incidents. By doing so we can learn more from these experiences and implement new and better measures to prevent repetitive occurrences. We cannot prevent humans from making errors, but we can certainly reduce the frequency and minimize the consequences. This is one fundamental reason behind ICAO's accident prevention programme.

2. This digest has three purposes:

— to provide investigators and investigation authorities, civil aviation regulatory authorities, company/corporate management, and other aviation personnel with information on the need for and purpose of the investigation of Human Factors;

— to outline a methodology for investigating Human Factors in aircraft accidents and incidents; and

— to describe how the information gathered should be reported.

3. The digest is intended to complement the ICAO *Manual of Aircraft Accident Investigation* (Doc 6920). The philosophical approach outlined in this digest should be understood when applying the practical guidance provided in the investigation and prevention manuals. The field of Human Factors also encompasses medical issues; however, the thrust of this digest is on the non-medical aspects.

4. The primary focus of the digest is on the events which led up to the occurrence and not on post-accident events, such as search and rescue or survivability issues. It will not include guidance for handling post-mortems, toxicological examinations and injury pattern analysis. These special areas are discussed in the *Manual of Aircraft Accident Investigation* and the *Manual of Civil Aviation Medicine* (Doc 8984). Nevertheless, the investigator is expected to be familiar with the physiological as well as the psychological aspects of human performance.

5. Through the international Standards and Recommended Practices (SARPs) set forth in Annex 13 to the Chicago Convention and related guidance material, ICAO has assisted States in the accident investigation and prevention field. There is a continued emphasis on objectivity in investigation and prevention. Improvements in the investigation of Human Factors in accidents and incidents will add significantly to this effort.

6. This digest includes the following:

- *Chapter 1* discusses the need for and the purpose of Human Factors investigation; addresses some of the obstacles to Human Factors investigation; discusses the nature of human error and accidents; and provides a systems approach model by which the scope of the Human Factors investigation can be determined.

- *Chapter 2* addresses the conduct of the Human Factors investigation; discusses the organization and management of the investigation; details who should conduct the investigation, what information should be collected, where it can be found, and presents a discussion on how to analyse the information collected.

- *Chapter 3* discusses the reporting of accidents and incidents with the emphasis on the treatment of Human Factors information, the identification of hazards and the development of safety action to prevent recurrence.

- *Appendix 1* provides examples of Human Factors Checklists.

- *Appendix 2* provides guidance in Witness Interviewing Techniques.

- *Appendix 3* presents a sample listing of Explanatory Factors — a proposed expansion of the ADREP Manual.

- *Appendix 4* provides a listing of available accident/incident data bases.

- *Appendix 5* presents a list of recommended readings.

7. This digest was prepared with the assistance of the ICAO Flight Safety and Human Factors Study Group. Particular recognition goes to the Transportation Safety Board of Canada for its support and diligent work in producing the initial draft.

8. Six other Human Factors digests have been published including:

- 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); and

- Digest No. 6 — *Ergonomics* (Circular 238).

Chapter 1

NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION

BACKGROUND

1.1 As evidenced by investigation records dating back to the 1940s, Human Factors are involved in the majority of aviation accidents and incidents. Regardless of the actual percentage, there is little disagreement among government and industry experts over the importance of Human Factors as a primary element in the causes of accidents and incidents. In spite of this knowledge, and the notion that "to err is human", progress has been slow in adopting a uniform approach to the investigation of Human Factors in aviation occurrences. When no tangible technical evidence was found to explain the occurrence, investigators and their authorities sometimes found it difficult to deal with Human Factors issues. The unfortunate result has been described by George B. Parker, Associate Professor of Safety at the University of Southern California, as the Law of Exception: *If we have ruled out everything except the pilot, the cause must be pilot factor.*

1.2 Accident investigation reports usually depict clearly **what** happened and **when**, but in too many instances they stop short of fully explaining **how** and **why** the accidents occurred. Attempts to identify, analyse, and understand the underlying problems that led to the breakdowns in human performance and thus to the accidents are sometimes inconsistent. By stating that a pilot did not follow the rules implies that the rules are well-founded, safe, and appropriate. Hence, the investigation reports often limit conclusions to phrases such as "pilot error", "failed to see and avoid", "improper use of controls", or "failed to observe and adhere to established standard operating procedures (SOPs)." This narrow focus is but one of many obstacles to the effective investigation of Human Factors.

1.3 Below are listed other common obstacles, along with solutions which can eliminate them.

OBSTACLES AND SOLUTIONS

Obstacle: The need to investigate Human Factors issues has not been readily accepted. One may hear comments, such as "Human Factors is an area that is too *soft*", "human nature cannot be changed", or "it is too difficult to prove conclusively that these factors contributed to the accident".

> **Solution**: More education, describing how experimental research has managed to eliminate many speculative elements in the field of Human Factors, with scientifically supported documentation. For example, research has shown empirically the advantages of effective cockpit communication, a recognition that has translated directly into courses in crew resource management and pilot decision-making.

Obstacle: The reluctance to investigate Human Factors may stem from a lack of understanding of what the term "Human Factors" encompasses. Unfortunately, some investigators believe themselves ill-equipped because they are not medical doctors or psychologists. The field of Human Factors extends well beyond the physiological and the psychological; ironically, most investigators, unbeknownst to themselves, have a broad awareness of the subject which they apply in an informal manner.

> **Solution**: Better Human Factors training for investigators will develop a more thorough understanding of what the investigation of Human Factors entails.

Obstacle: Investigators may mishandle questions related to the performance of crew members, air traffic controllers, maintenance personnel, and others. This can happen when the investigator has not established an atmosphere of objectivity and trust, and those whose performance is being questioned feel threatened by or antagonistic towards the investigator. In the worst case, crew members or other interested parties may withhold valuable information and assistance from the investigation authority.

> **Solution**: Investigators should ensure that people understand the objective of the process — to prevent recurrence — and the method by which the investigator intends to achieve this objective. If there is a possibility of misunderstanding, this information should be discussed openly at the beginning of the investigation.

Obstacle: There is often a natural reluctance on the part of witnesses (for the purposes of this digest these include peers, supervisors, management and spouses) to speak candidly about the deceased. Also, investigators may be somewhat reluctant to ask questions which may be interpreted as unfavourable by a relative, friend or colleague.

> **Solution**: Well planned interviews are required. By comparing the information obtained through these interviews to information gathered by other means in the investigation process, a more complete explanation can be achieved.

Obstacle: Balancing an individual's right to privacy with the need to uncover and report on the factors involved in the accident is another difficulty. On the one hand, information from the cockpit voice recorder (CVR), air traffic control (ATC) recordings, and witness statements may be essential in determining how and why the accident occurred. On the other hand, these same sources often contain sensitive personal information about involved individuals who would naturally want such information protected.

> **Solution**: Accident investigation authorities should provide a degree of protection to such sources (see Annex 13, Chapter 5). Depending on an individual State's laws, this protection may need to be legislated. Investigation authorities will have to be discriminating, publishing only that information which is essential to the understanding of the accident and which promotes prevention.

Obstacle: The investigation philosophy adopted by the management of the investigation authorities is very important. Investigators will be hampered in their efforts to conduct a full systematic investigation if the management for whom they work do not believe in the importance of investigating Human Factors in accidents and incidents. Without management support, there is little doubt this field will continue to be neglected.

> **Solution**: Knowledge of Human Factors and an understanding of how to apply this knowledge in an investigation offers the investigation authority a greater opportunity to identify root causes which may not have been recognized previously. Furthermore, it offers States' administrations a constructive means for handling controversial human performance issues. Some of the key methods by which investigators and their managers can promote the investigation of Human Factors lie in keeping abreast of current literature, attending Human Factors courses and seminars, and applying concepts such as those outlined in this digest.

Obstacle: In many States, the regulatory authority also has the responsibility for investigating accidents and incidents. The absence of an independent investigation authority has the potential for creating a conflict of interest within the organization. There could be an unwillingness on the part of the regulators to investigate those issues that are related to their role as regulators. This situation could also cause the travelling public to view the regulator's investigative findings with scepticism.

> **Solution**: Some States have created an independent investigative body whose sole mission is to determine the causes of accidents and make safety recommendations to prevent their recurrence. Such a body is free to make findings and recommendations without encumbrance.

Obstacle: The rush of media and litigants to find someone to blame to suit their own objectives may result in premature conclusions. For example, the pilot is sometimes made the scapegoat to reassure the public that an individual has been found responsible.

> **Solution**: Investigators must be diligent in promoting the philosophy that only after a full, systematic investigation has been completed can all the causes be determined.

Obstacle: The determination of conclusions and causes by the investigation authority can inadvertently apportion blame, fault or liability. To the extent that this happens, the potential for preventing future accidents and incidents may be diminished. How States publish their findings thus becomes a crucial part of the process of preventing accidents.

> **Solution**: Accident investigation reports which concentrate on identifying underlying problems instead of laying blame will contribute far more to the prevention of accidents. However, while every effort should be made to avoid assigning fault or liability, the reports must not refrain from reporting objectively and fully on the causes merely because fault or liability might be inferred from the report.

Obstacle: There is a general lack of accepted international guidance material in this field.

> **Solution**: With the publication of this digest, it is anticipated that the most significant obstacles to the investigation of Human Factors will be eliminated. By applying the approach outlined in this digest, investigators and their authorities should feel more confident in conducting these investigations.

1.4 Despite these obstacles, attitudes are changing. Government and industry experts are emphasizing the value of investigating Human Factors in aviation accidents and incidents as part of the over-all aim of accident prevention and improved safety. ICAO recognizes this change in emphasis as a positive step taken by States to improve investigation procedures, techniques and prevention.

THE NATURE OF ACCIDENTS AND INCIDENTS

1.5 The investigation of Human Factors in aircraft accidents and incidents should be an integral part of the entire investigation and its resulting report. Humans do not act alone; they are but one element of a complex system. Often, the human is the last barrier that stops the sequence of events from causing an accident. However, when events combine and interact together to cause a catastrophe, the investigation authority must ensure that all elements of the complex system are investigated to understand why the accident happened. A systematic search for the "Why" is not intended to pinpoint a single cause, nor is it intended to assign blame or liability, nor even to excuse human error. Searching for the "Why" helps identify the underlying deficiencies that might cause other incidents or another accident to happen.

1.6 The formal definition of an accident is useful in determining the criteria for reporting the occurrence to the investigation authority and in identifying when an investigation should be conducted. The extent of an investigation will be governed by the investigation authority's legislative mandate. The investigation authority may not be able to investigate every occurrence in depth.

DEFINITION OF AN ACCIDENT AND INCIDENT

1.7 ICAO Annex 13, Chapter 1 defines an accident as:

> "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which a person is fatally or seriously injured … , the aircraft sustains damage or structural failure … , or the aircraft is missing or is completely inaccessible".

An incident (which will be discussed later) is defined as:

> "an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation".

SYSTEMS APPROACH TO THE INVESTIGATION OF HUMAN FACTORS

1.8 Having decided to initiate an investigation, the investigating authority must take an all-encompassing view of the occurrence if it expects to fulfil the purpose of the investigation. Adopting a systems approach to the investigation of accidents and incidents helps the investigator to identify the underlying causes in the complex air transportation system. It allows a better understanding of how various components of the system interacted and integrated to result in an accident, and in so doing points the way to remedial action. Many different approaches exist to help investigators identify the components at work and to analyse the information gathered. The following paragraphs present one such approach, one proposed by James Reason[1] on accident causation and depicted graphically in Figures 1-1 and 1-2.

1.9 James Reason views the aviation industry as a complex productive system. One of the basic elements of the system consists of the **decision-makers** (upper management, the company's corporate body or the regulatory body), who are responsible for setting goals and for managing available resources to achieve and balance two distinct goals: the goal of safety, and the goal of on-time and cost-effective transportation of passengers and cargo. A second key element is **line management** — those who implement the decisions made by upper management. For upper-management decisions and line management actions to result in effective and productive activities by the workforce involved, certain **preconditions** have to exist. For example, equipment must be available and reliable, the workforce has to be skilled, knowledgeable and motivated, and environmental conditions have to be safe. The final element — **defences** or safeguards — is usually in place to prevent foreseeable injury, damage or costly interruptions of service.

1. James Reason, "Human Error", Cambridge University Press, New York, 1990, p. 302. This summary of James Reason's approach and concepts is adapted from the original book, as well as from Captain Daniel Maurino's review of this approach. Captain Maurino's paper, "Management and Flight Safety", was presented at the ICAO Regional Flight Safety and Human Factors Seminar, in Douala, Cameroon in May 1991.

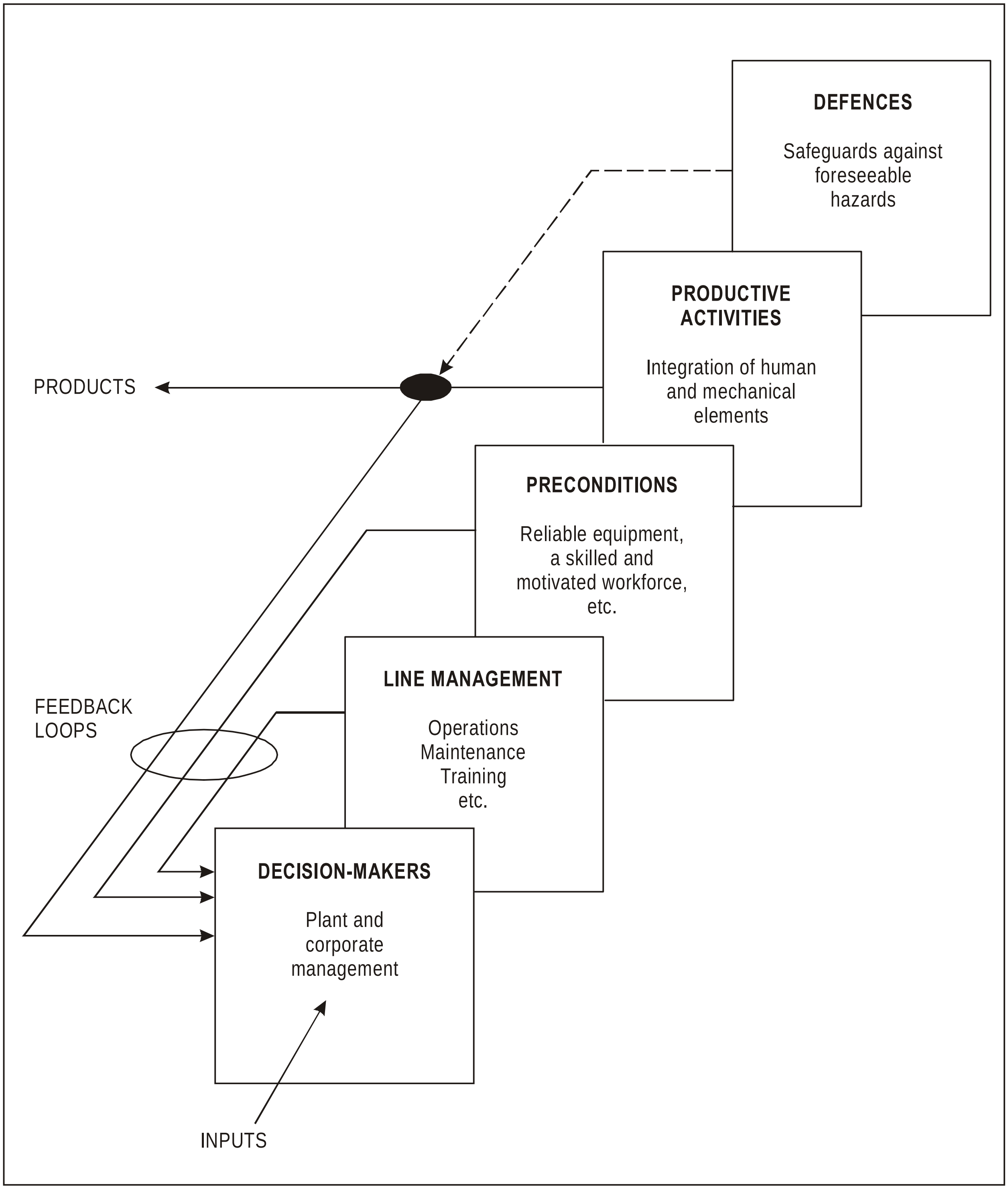

Figure 1-1. The basic components of any productive system
(*Source:* James Reason, *Human Error*, 1990. United Kingdom: Cambridge University Press)

1.10 Illustrated in Figure 1-2 is Reason's model of how humans contribute to the breakdown of these complex, interactive and well-guarded systems to produce an accident. In the aviation context, "well-guarded" refers to the strict rules, high standards and sophisticated monitoring equipment in place. Because of technological progress and excellent defences, accidents seldom originate exclusively from the errors of operational personnel (front-line operators) or as a result of major equipment failures. Instead, they result from interactions of a series of failures or flaws already present in the system. Many of these failures are not immediately visible, and they have delayed consequences.

1.11 Failures can be of two types, depending on the immediacy of their consequences. An **active failure** is an error or a violation which has an immediate adverse effect. Such errors are usually made by the front-line operator. A pilot raising the landing gear lever instead of the flap lever exemplifies this failure type. A **latent failure** is a result of a decision or an action made well before an accident, the consequences of which may lie dormant for a long time. Such failures usually originate at the decision-maker, regulator or line management level, that is, with people far removed in time and space from the event. A decision to merge two companies without providing training to standardize operating procedures illustrates the latent failure. These failures can also be introduced at any level of the system by the human condition — for example, through poor motivation or fatigue.

1.12 Latent failures, which originate from questionable decisions or incorrect actions, although not harmful if they occur in isolation, can interact to create "a window of opportunity" for a pilot, air traffic controller, or mechanic to commit an active failure which breaches all the defences of the system and results in an accident. The front-line operators are the inheritors of a system's defects. They are the ones dealing with a situation in which technical problems, adverse conditions or their own actions will reveal the latent failures present in a system. In a well-guarded system, latent and active failures will interact, but they will not often breach the defences. When the defences work, the result is an incident; when they do not, it is an accident.

ACCIDENT SCENARIO

1.13 Let us apply the main principles of Reason's model to a complex accident scenario to provide a better understanding of how humans contribute to a breakdown of the aviation system. The following fictitious scenario, based on real-life events, fully illustrates all of the system components:

- *In the late hours of a summer Friday evening, while landing on a runway heavily contaminated with water, a twin-engine jet transport aircraft with four crew members and 65 passengers on board overran the westerly end of the runway at Anytown City airport. The aircraft came to rest in the mud a short distance beyond the end of the runway. There were no injuries to crew or passengers, and there was no apparent damage to the aircraft as a consequence of the overrun. However, a fire started and subsequently destroyed the aircraft.*

- *Anytown City is a popular summer resort. The predominant weather for a typical summer day is low stratus and fog in the early morning, which gradually develops into convective cloud as the air warms. Severe thunderstorms are common in the early afternoon and persist until the late evening hours. The whole region where Anytown City is situated is "thunderstorm country" during summer.*

- *The runway at Anytown is 4 520 feet long. It is a relatively wide runway with a steep downward slope to the west. It is served by a low-power, short-range, non-directional beacon (NDB), unreliable in convective weather. Runway lighting is low-intensity, and there are no approach lights or visual approach aids. It is a classic "black-hole" approach during night landings.*

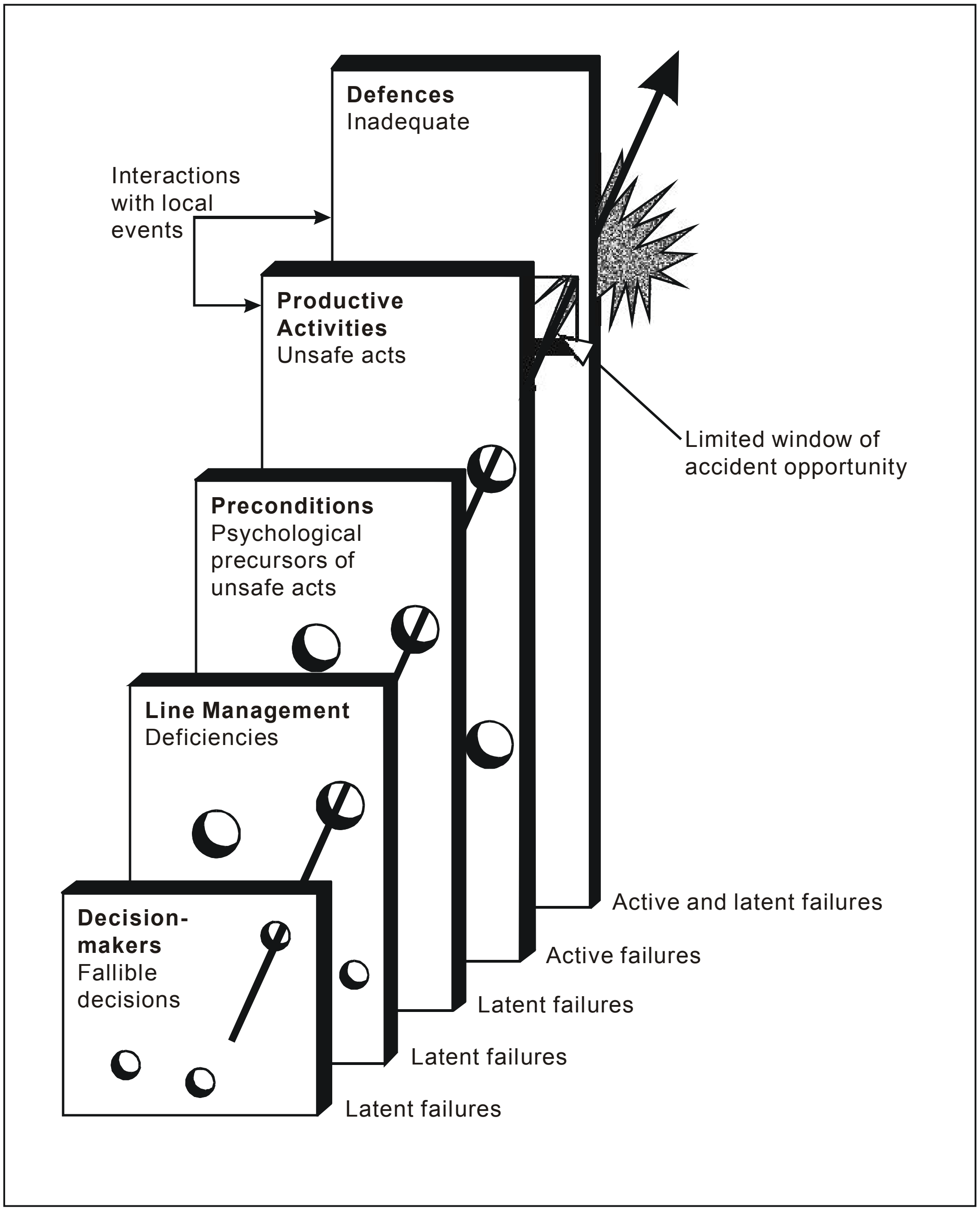

Figure 1-2. Modified version of James Reason's model of accident causation, showing the various human contributions to the breakdown of a complex system
(*Source:* James Reason, *Human Error*, 1990. United Kingdom: Cambridge University Press)

- *The flight had originated at the airline's main base, 400 km away. This was the second-to-last flight for the flight crew that day. They had reported for duty at 1130 hours and were due to be relieved at 2200 hours. The crew had been flying a different schedule for the last three weeks. This was the beginning of a new four-day schedule on another route. It had been a typical summer afternoon, with thunderstorms throughout the entire region. Anytown City had been affected by thunderstorms during the early afternoon. No forecast was available, and the captain had elected to delay the departure.*

- *The flight schedule was very tight, and the captain's decision to delay created a number of additional delays for subsequent flights. The dispatcher working the flight did not bring to the flight crew's attention the need to consider a contaminated runway operation at Anytown, and did not review the landing performance limitations with them. After a long delay, the captain decided to add contingency fuel and depart.*

- *Visual conditions were present at Anytown, although there were thunderstorms in the vicinity of the airport, as well as a persistent drizzle. With no other reported traffic, they were cleared for a night visual approach. After touchdown, the aircraft hydroplaned and overran the end of the runway slightly above taxiing speed.*

- *The captain was a very experienced pilot. He had been with the airline for many years, accumulating several thousand hours of flying time as a first officer in two other types of large jet aircraft. However, he had limited experience with the aircraft type he was flying the night of the accident. He had not had the occasion to fly into Anytown before because the larger aircraft types he had been flying previously did not operate into Anytown. This was his first month as a captain. He was a well-balanced individual, with no personal or professional behavioural extremes.*

- *At the time of the accident the first officer was very inexperienced. He had recently been hired by the airline and had only been flying the line for about a month. He had flown into Anytown on two other occasions with another captain, but only during the day. His training records indicated standard performance during induction into the airline's operations.*

1.14 Initially, the investigation would focus on determining what actually happened at Anytown. It was learned that it had rained heavily at the airport and that there was standing water on the runway. Readout of the flight recorders disclosed that the captain flew the approach with excess airspeed which resulted in the airplane touching down smoothly, but well beyond the touchdown zone, and then hydroplaning off the end. It was also determined that the captain neglected to consult the performance charts in the aircraft flight manual for the correct landing distance on a wet runway. Also, the first officer did not make the required callouts during the approach.

1.15 These unsafe flight crew actions could in and of themselves explain the overrun and focus the investigation on a conclusion of "crew error" as a cause for the accident. However, if one were to investigate further into the company's operational procedures and practices and look upstream for other factors influencing the crew's performance, one could identify additional active and latent failures which were present during the flight. So the investigation should not stop at the point where the *crew* made errors.

1.16 If the investigation were to determine whether any other unsafe acts occurred in the operation, it would discover that not only did the dispatcher fail to brief the captain on potential problems at the airport (as required by company procedure), but that the company's agent at Anytown had not reported to the dispatcher at headquarters that heavy rain had fallen. Inspection of the runway revealed poor construction, paving and lack of adequate drainage. It was also discovered that maintenance and inspection of the NDB was not in accordance with prescribed procedures. Over the past month, other flight crews had reported on several occasions that the ground aid had given erratic indications during instrument approaches; no attempt had been made to rectify the problem.

1.17 With these facts in mind and by referring to the Reason model, it can be seen that the actions of other front-line operators were also unsafe and had an influence upon the performance of the flight crew and the outcome of the flight. These activities can be classified as active failures and are also linked to line-management and decision-makers' performance.

1.18 Next, the investigation should determine if there were any adverse pre-conditions under which the flight crew had to operate. These can be listed as follows: 1) a night non-precision instrument approach to an unfamiliar airport; 2) a poorly lit, short, wide and steeply sloping runway; 3) poor runway pavement and drainage; 4) a lack of reliable information on the performance of the NDB; 5) a lack of reliable information about the wind conditions; 6) a flight schedule which allowed only a 15-minute turnaround at Anytown; 7) an arrival delayed by two hours, compromising crew duty-time requirements; 8) an aircraft not equipped with thrust reversers; 9) an inadequately trained flight crew, inexperienced in the type of aircraft and at the airport; and 10) inadequate crash, fire, and rescue services.

1.19 The Reason model classifies these pre-conditions as latent failures, many of which lay dormant for some time before the accident and which were the consequences of line management and decision-maker actions or inactions. For example, pairing two pilots who were inexperienced in the type of aircraft and allowing the captain to operate into an unfamiliar airport with a non-precision approach procedure was the result of unsafe decisions made by line management. Also, the failure to follow up on reported discrepancies with the NDB and the failure to conduct adequate inspections of the airport indicate either a lack of awareness of the safety implications or a tolerance of hazards by the decision-maker's line management and the regulatory authority. The investigation found that pilots were not briefed on the use of performance charts for contaminated runways, nor did they practice hydroplaning avoidance techniques. These discrepancies can be attributed to both line and upper management's failure to provide adequate training.

1.20 At the roots of this occurrence were other "fallible decisions" made by both upper management levels within the company and in the regulatory authorities. Management had decided to operate a scheduled service at an airport with known deficiencies in facilities (poor lighting and approach aids, inadequate weather services). More importantly, they chose to operate without the required level of crash, fire and rescue services available at the airport. In addition, management selected this type of airplane for this route out of marketing and cost considerations, despite its unsuitability for all-weather operations at Anytown. Compounding the problem was the decision by the regulatory authority to certify the airport for scheduled air transport operations in spite of its significant safety deficiencies.

1.21 In Figure 1-3, the active and latent failures identified in this accident are depicted using Reason's model. The model portrays the interactive nature of the failures and how they defeated the defences that one might expect to find within this organizational and operational environment. It also depicts the critical importance of identifying latent failures as they relate to the prevention of future accidents.

1.22 In summary, this approach to the investigation of Human Factors encourages the investigator to go beyond the unsafe actions of front line operators to look for hazards that were already present in the system and which could contribute to future occurrences. This approach has direct implications for the prevention activities of operators and regulators, who must identify and eliminate or control latent failures.

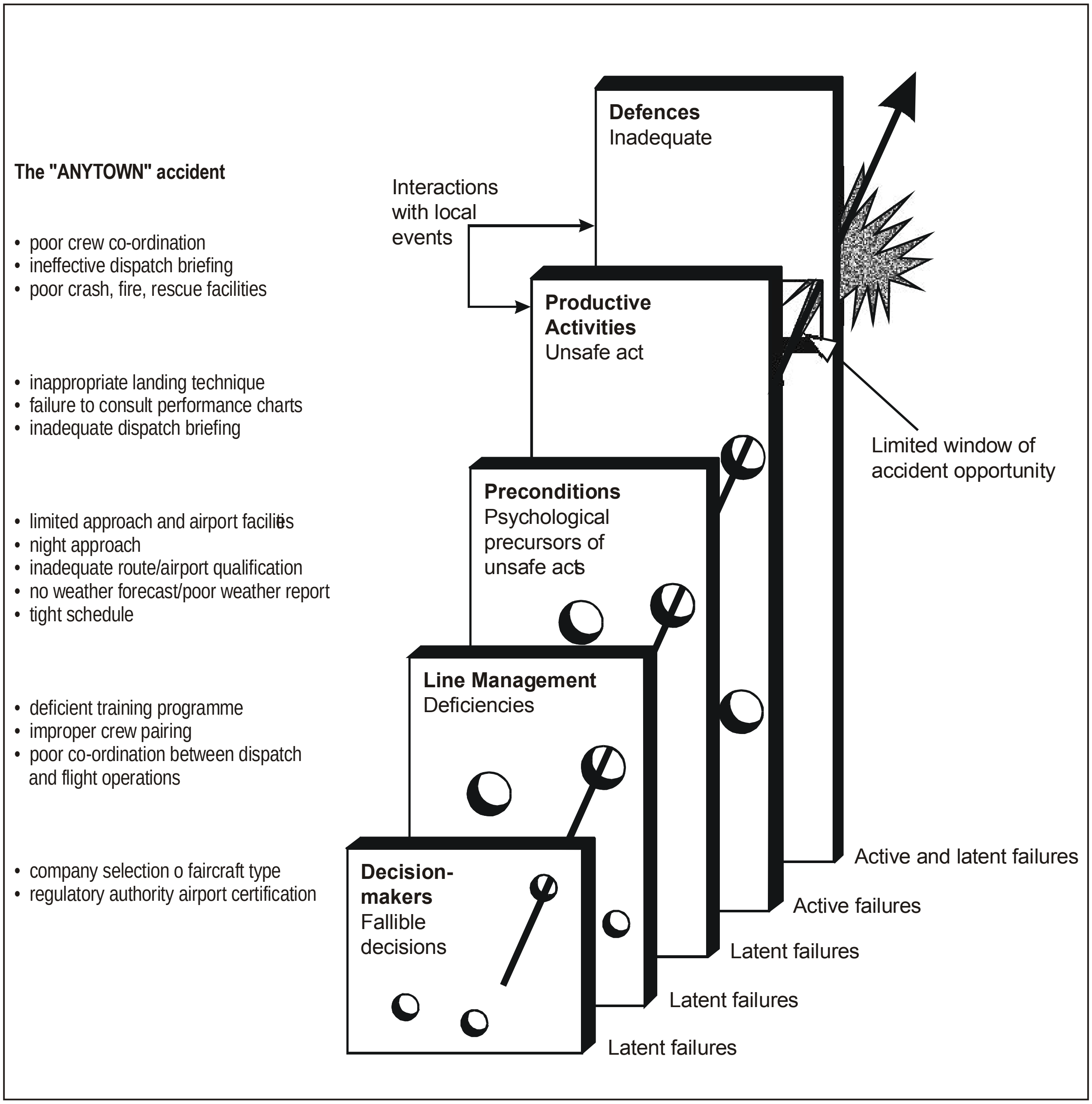

Figure 1-3. How the "Anytown" accident fits the modified version of James Reason's model of accident causation

INVESTIGATION OF INCIDENTS

1.23 Most accidents, such as the Anytown one, originate in actions committed by reasonable, rational individuals who were acting to achieve an assigned task in what they perceived to be a responsible and professional manner.[2] These and other individuals had probably committed these same unsafe acts before *without* negative consequences because the conditions existing at the time did not favour the interaction of flawed decisions or deficiencies present in the system. Under different circumstances, the consequences of the Anytown situation might have been an incident rather than an accident.

1.24 Many incidents occur every day which may or may not require reporting by the investigation authority; some come very close to being accidents. Because there is no injury or little damage, these incidents might not be investigated. The need for an investigation by either the investigation authority or the operator must be emphasized, however, because an incident investigation can often produce better accident prevention results than can an accident investigation.

1.25 In an incident, injury, damage and liability are generally reduced, and there is less associated publicity. As a result, more information is available and the atmosphere is less adversarial. Investigators and Human Factors specialists have a better opportunity to identify the underlying human performance issues involved. There is thus more likelihood of determining why the incidents occurred and, equally, how the defences in place prevented them from becoming accidents.

1.26 Knowledge of incidents, whether they are investigated in depth or not, provides significant insight into accident prevention. This realization has led to the establishment of several confidential safety deficiency reporting systems, and the evidence emerging from these constitutes a rich source of data on Human Factors in aviation.

CONCLUSIONS

1.27 An accident or incident is not solely the result of an action taken by one individual. The potential for an accident is created when human actions and latent failures present within an organization or the air transport system interact in a manner which breaches all of the defences.

1.28 The purpose of investigating Human Factors is to identify why actions lead to the breakdown in defences and result in accidents. This requires determining the related latent failures present at all levels of the organization (including the upper levels of management) and of the aviation system of which it is a part. It goes without saying that it is equally important to determine how these unsafe actions could have been prevented. We cannot prevent humans from making errors, but we can reduce the frequency of these errors and limit their consequences. This is the essence of prevention activities and highlights the importance of investigation and reporting of incidents.

2. Besco, R.O., "Why Pilots Err: What can we do about it?", paper published in *Forensic Reports,* Vol. 4, No. 4 (1991), pages 391-416.

Chapter 2
CONDUCT OF THE INVESTIGATION

GENERAL

2.1 The investigation of Human Factors is an integral part of the investigation of an accident or incident. The collection and analysis of Human Factors information should be just as methodical and complete as the collection and analysis of information pertaining to the aircraft, its systems, or any of the other traditional areas of investigation. The size and scope of the investigation of Human Factors will depend on the circumstances of the occurrence; it can involve one investigator who may also be responsible for all other aspects of the investigation, or one or more investigators dedicated solely to the investigation of Human Factors. Whether the investigation is large or small, many of the guidelines in this digest apply to both situations. The success of the investigation into Human Factors will depend on how well it is integrated and co-ordinated with the other elements of the investigation, and will require effective and efficient management of available resources through the application of basic management principles. The investigation itself should be viewed as a process requiring trained and disciplined investigators who apply skills in a systematic way.

2.2 This chapter provides guidelines to be used to integrate the investigation of Human Factors with the over-all investigation. It will look at who should conduct the investigation — a single investigator or a team — and outline what information should be collected, where to find it and how to analyse it.

WHO SHOULD INVESTIGATE?

2.3 Most accidents and incidents are investigated by investigators who are trained as generalists. For years, these generalists have been investigating highly technical and complex aspects of occurrences, including areas of Human Factors. Where necessary, specialists are consulted to provide specific assistance and guidance, but by and large the data gathering and analysis are conducted by the generalist investigators. ICAO sees no reason why this principle should not continue to apply to the investigation of Human Factors in aviation occurrences.

2.4 In view of the growing complexities of aviation, investigators must be knowledgeable of and skilled in the application of Human Factors principles and sound data-gathering and analysis techniques. They need not be physicians, psychologists, sociologists or ergonomists. The essential qualifications of a good Human Factors investigator are those of any good investigator. As outlined in ICAO's *Manual of Aircraft Accident Investigation* (Doc 6920), investigators must possess a sound working knowledge of aviation and of the factors which affect operations as a whole. This knowledge must be complemented by technical skill, an inquisitive nature, dedication, diligence, patience, humility, integrity and logic. The measure of the good Human Factors investigator is not his or her professional qualifications in behavioural sciences, but rather the ability to determine, with the help of specialists if necessary, what information is relevant, to ask the right questions, to listen to the answers and to analyse the information gathered in a logical and practical way.

2.5 In order to adequately prepare generalist investigators to investigate Human Factors, it is essential that they receive appropriate training. Such training should include guidance on the interdisciplinary nature of this type of investigation, fundamental areas of examination, data that should be collected, data sources, data collection methods including interview techniques, and analysis techniques. Training should also include general guidance on the type of specialists who are available to assist, where they can be found and when it would be appropriate to employ them. Given this level of training, the experienced accident investigator should be able to conduct all but the most specialized aspects of the Human Factors investigation.

THE SINGLE INVESTIGATOR

2.6 The single investigator assigned to investigate an accident or incident has the challenge of setting priorities and managing available time to cover effectively all areas of the investigation, including Human Factors.

2.7 As in any investigation, it is important for the investigator to take immediate steps to preserve evidence at the site and elsewhere. The single investigator will probably rely heavily on other authorities such as the police or airport officials. Good preplanning of the response is needed; the *Manual of Aircraft Accident Investigation* provides detailed guidance in this area. Once these initial steps have been taken, the investigator can begin to organize the investigation with the reasonable expectation that information which could be significant to its outcome, including areas of Human Factors, will be available for examination and analysis. At the outset, high priority must be assigned to the collection of information or evidence likely to disappear or to be forgotten, disturbed or unavailable soon after the accident.

2.8 The single investigator will also need to plan and prioritize the remaining work. Periodic assessments of progress are particularly important for the single investigator if precious time and resources are to be used effectively.

THE HUMAN FACTORS INVESTIGATOR

2.9 When one investigator on a team is assigned to conduct the Human Factors portion of an investigation, the organizational task is less complex but the same basic principles apply. There must be close co-operation and interaction with all other investigation team members, as much of the information and data relevant to the investigation of the Human Factors aspects will actually be collected by investigators working in other areas.

THE HUMAN FACTORS GROUP

2.10 Depending on the circumstances of the accident, it may be desirable to establish a Human Factors Group under the direction of the Investigator-in-charge. Normally, such groups are established as a part of a large investigative team effort in response to a complex major aircraft accident. Although any investigator on the team may have some role in the investigation of Human Factors, the Human Factors group is responsible for co-ordinating the investigation of the human performance elements, ensuring that appropriate and sufficient data are collected, and synthesizing the results in a meaningful way.

2.11 The composition of the Human Factors Group will be governed by the nature of the occurrence. Because individuals whose performances are being examined are usually pilots, air traffic controllers, maintenance engineers, dispatchers, and operations managers, similarly qualified individuals are well suited to participate in the examination. As the investigation progresses, it may be advisable to alter the composition of the Human Factors Group, or to combine groups to provide sufficient expertise in relevant areas under examination.

2.12 Information collected by other members of the investigation team (such as operations, air traffic control, structures, systems, power plants, flight recorders, aircraft performance, etc.) is also required to reconstruct the sequence of events before actions and the performance of the front-line operators involved can be examined thoroughly. The Human Factors group must be able to rely on the assistance and expertise of these other groups.

WHAT INFORMATION SHOULD BE COLLECTED?

2.13 In general, the data that must be collected fall into two broad areas: information which will enable investigators to construct a detailed chronology of each significant event known to have occurred prior to and, if appropriate, following the occurrence (this chronology must place particular emphasis on the behavioural events, and what effect they may have had on the accident events sequence); and information which will permit investigators to make reasonable inferences about factors which may have influenced or motivated a particular accident-producing behaviour. In terms of the Reason model, this is information which describes the "pre-conditions" under which front-line operators were working.

2.14 In addition, other information may be needed for statistical or other special purposes. Investigators must follow national guidelines as well as those of ICAO (see ICAO's *Accident/Incident Reporting Manual*, Doc 9156) to meet such requirements.

2.15 Investigators must collect information which encompasses the decisions, actions and behaviour of **all** the people concerned with the occurrence — not only front-line operators. Investigators must also identify the conditions under which these decisions, actions and behaviour were carried out. These conditions would include the organizational structure and the policies, procedures and practices under which activities were performed. It is through such an approach that a full understanding can be gained of how the "window of opportunity" for an accident or incident was created.

THE SHEL MODEL

2.16 In addition to Reason's model, the conceptual SHEL model will facilitate the data collection task by providing a systematic approach to identifying problems (see ICAO Human Factors Digest No. 1 for a complete description of the SHEL model). First developed by Professor Edwards in 1972, and later modified by Hawkins (see Figure 2-1), it is an expanded version of the man-machine-environment model in ICAO's *Accident Prevention Manual* (Doc 9422). The SHEL model addresses the importance of human interaction and the use of written information and symbology, and helps the investigator apply the Reason model on accident causation, which treats the accident as an outcome of a series of interactive and enabling events.

2.17 Each component of the SHEL model (software, hardware, environment, liveware) represents one of the building blocks of Human Factors studies. The liveware, or the human element, is the centrepiece of the model, representing the most critical and flexible component. It does have limitations, however, most of which are predictable in general terms.

2.18 The central human component does not act on its own; it interacts directly with each of the others. The edges of this human block are not simple and straight, so other blocks must be carefully matched to them if stress and eventual breakdown (an accident) are to be avoided. The investigation of Human Factors must identify where mismatches between components existed and contributed to the occurrence, and so the data collected during the investigation should permit a thorough examination and analysis of each of the SHEL components.

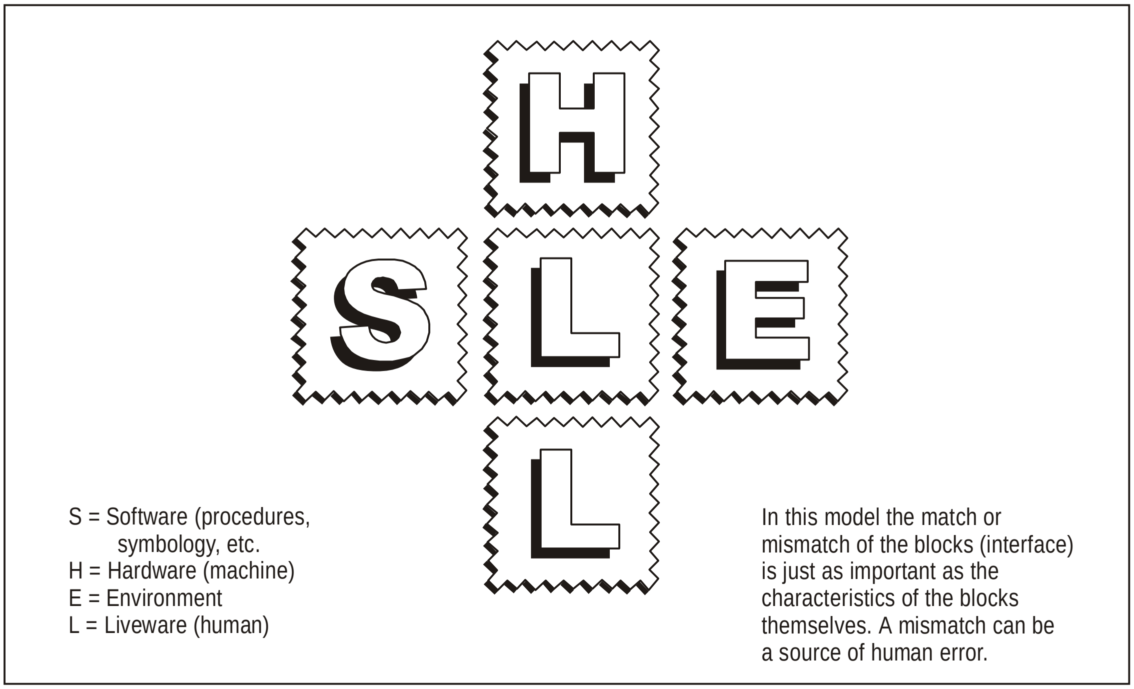

Figure 2-1. The SHEL model (adapted from Hawkins, 1975)

2.19 The following description of the components and interfaces will help investigators collect data to achieve a thorough Human Factors investigation. Where appropriate, data from the Anytown scenario are included.

Liveware — the individual

2.20 The liveware component — the individual — is the centrepiece of the SHEL model. The data that should be collected to address this central component can be broken down into four categories: physical, physiological, psychological and psychosocial.

Physical factors deal with the physical capabilities and limitations of the individual. Included are the individual's anthropometric (basic physical) attributes, physical condition, physical strength, motor skills and visual, auditory and other senses.

Task — Determine:

- was the individual physically capable of performing the required task?
- what physical impediments or limitations to successful performance were present? and
- how did these physical or sensory limitations create difficulties or illusions that affected the task?

Anytown: The investigation did not disclose any evidence of physical factors that would have played a role in degrading the performance of the captain, first officer, or other operator.

Physiological factors deal with the individual as a complex organism encompassing a large array of systems. Included are the individual's general health, as well as nutrition, disease, tobacco, alcohol or drug use, stress and fatigue levels, and general lifestyle considerations.

Task — Determine:

- was the individual physiologically fit to perform the required task?
- how did physiological fitness influence the individual's performance and judgement?
- how did the individual's ability to handle stress, fatigue or disease affect actions, behaviours and judgement? and
- was the individual affected by any type of physiological deprivation?

Anytown: Other than the suggestion that fatigue and stress would be factors to consider, the investigation did not reveal any evidence of other physiological factors that might have adversely affected the crew's or other operators' performance.

Psychological factors determine what individuals bring with them to work situations as a result of their acquired knowledge and experience and their mental capabilities. Included are training, knowledge, experience and planning; perceptions, information processing, attention span and workload; personality, mental and emotional state, attitudes and mood.

Task — Regarding training, knowledge, experience and planning, determine:

- was the individual's training, knowledge and experience sufficient, relevant and applicable to the situation?
- how did the nature and recency of the experience, training, or knowledge influence the individual's self-confidence, ability to complete the actions or perceived level of workload?

Task — Regarding perceptions, information processing, attention span and workload, determine:

- was there an inaccurate perception or mental representation of the task to be performed?
- did the individual suffer from any misperceptions, delayed perceptions, or illusions caused either by the visual or vestibular system or by circumstances surrounding the flight?
- did the level of attention required or the amount of information to be processed exceed the individual's own limitations?
- did the individual's ability to handle the events cause biases in judgement and change the perceived workload level?

Task — Regarding personality, mental and emotional state, attitudes and mood, determine:

- was the individual psychologically fit for the task?
- what do the facts indicate about the individual's attitudes towards work, others and self?
- how did these attitudes influence motivation, quality of work and judgement?
- how did personality and mental state influence the individual's approach to the situation?
- how did the individual's ability to cope with stress and to respond to emergencies influence the event sequence?

Anytown: The evidence suggests that several areas should be examined more closely. These areas are training and knowledge, perceptions, information processing, workload and perhaps attitude. Although it was reported initially that the captain was a well-balanced individual with no personal or professional behavioural extremes, it would be useful to gather more information concerning his ability to handle the captain's higher level of responsibility. The fact that he had not yet flown with other first officers would, however, make an assessment of his performance as a captain difficult. Examination of some of these psychological factors would also apply to the first officer, the dispatcher and the Anytown agent.

Psychosocial factors deal with the pressures brought to bear on an individual by the social system (non-work environment). Included are events and stresses (e.g. a death in the family or financial problems) as well as relationships with others (family, friends and peers).

Task — Determine:

- did psychosocial factors motivate or influence the individual's approach to a situation or the ability to handle stress or unforseen events? did they contribute to the degree of fatigue experienced?

Anytown: The investigation did not reveal any evidence of psychosocial factors having had a negative effect on the flight crew's actions. However, the Anytown company agent had been separated from his family for an extended period, a situation which had lowered his motivation.

Liveware-liveware interface

2.21 The liveware-liveware interface is the relationship between the individual and any other persons in the workplace. Staff-management relationships also fall within the scope of this interface, as corporate climate and company operating pressures can significantly affect human performance. Data requirements span such subjects as human interactions, communication (verbal and non-verbal) and visual signals.

Task — Determine:

- did the interaction or communications with other people in the work environment influence the performance of individuals, their attitudes, their level of stress, their perceived task demands and workload levels?
- did verbal and non-verbal communication, or the lack thereof, influence the sequence of actions in an inappropriate or irreversible manner?
- did visual signals replace, support or contradict oral information?
- how would you evaluate the crew's interactions and compatibility in terms of personality, experience level and working habits?
- how did the crew work together; how did they make use of their resources?
- did management policies regarding personnel issues affect working conditions, experience and knowledge level of employees?

- were policies and standards existing, available, current and adequately implemented, accepted, monitored or supervised?
- how did the supervisor-employee ratio influence the operation?
- what was the union's influence on policies, workers and management?
- what kind of operational environment did management promote, and how did it affect employees' decision-making and choice of actions?

Anytown: There is ample evidence that the liveware-liveware interfaces should be explored, starting with those between the flight crew, the captain and the dispatcher, and between the dispatcher and the company agent in Anytown. Additional interrelationships to be examined include personnel in the training department, the company's check pilots and line management in the training and operations departments.

Liveware-hardware interface

2.22 The liveware-hardware interface represents the relationship between the human and the machine. Data requirements span such subjects as cockpit and workstation configuration, display and control design, and seat design and configuration.

Task — Determine:

- how did interactions between the individual and the equipment influence information-processing capabilities?
- how did design or layout influence response time, action sequencing, habit patterns, workload or orientation?

Anytown: There are some physical features of the aircraft which could have been factors in the accident. Activation of its alternate braking system requires abnormal body movements. Deployment of the ground spoilers requires using handles on the thrust levers which are similar to thrust reverser handles. In addition, it is known that, because of its lower-pressure tires, this aircraft is more prone to hydroplaning than are the other types on which the captain was more experienced.)

Liveware-software interface

2.23 The liveware-software interface reflects the relationship between the individual and supporting systems found in the workplace. Data requirements span such subjects as regulations, manuals, checklists, publications, standard operating procedures and computer software design.

Task — Determine:

- were manuals, checklists, maps, or any written documents readily available? adequate? used?
- were the format, content and vocabulary used consistent from one document to another? were they easy to understand and use, logical and appropriate?

- how did written or computerized information induce errors, influence response time or generate confusion?
- how did computer displays and keyboard compatibility cause confusion, influence response time or hide blatant errors?
- how did automation affect the individual's actions and workload, work conditions, attitudes towards work and mental representation of the task?

Anytown: The evidence points to several potential problems regarding the adequacy of training material, quick-reference data pertaining to the landing performance of the aircraft on contaminated runways, training information, manuals and checklists for dispatchers and agents, etc.

Liveware-environment interface

2.24 The liveware-environment interface is the relationship between the individual and the internal and external environments. The internal environment is that of the immediate work area, including temperature, ambient light, noise and air quality. The external environment includes both the physical environment outside the immediate work area as well as the broad political and economic constraints under which the aviation system operates. Data requirements include weather, terrain and physical facilities, infrastructure and economic situation.

Task — Determine:

- were there any environmental factors which might have led the individual to take shortcuts or make biased decisions or which might have created illusions by affecting vestibular, visual or auditory perceptions?
- were there any indications that the weather or dispatch, hangar, gate, or aerodrome infrastructure caused delays leading to shortcuts, reduced safety margins or limitations on the individual's choice of actions?
- were there economic or regulatory pressures which biased decision-making?

Anytown: There is evidence that the external environment in which the flight crew were operating could have contributed to visual illusions during the instrument approach. Weather conditions played a role in the captain's decision to delay the flight and degraded the stopping performance of the airplane. Also, the runway layout and condition was conducive to standing water. There were problems with dispatch and there was probably induced pressure on the captain to land at the airport on the first approach because he had delayed the flight schedule substantially. This latter factor should also be taken into account under physiological factors (potential stress).

HOW MUCH INFORMATION IS ENOUGH?

2.25 In conducting the investigation of Human Factors, the question "how much data is enough?" frequently arises. How many peers, relatives and supervisors of the pilot should be interviewed? How far back in time should personal activities be investigated? To what extent should interpersonal relationships (including spousal) be examined? At what point does past behaviour cease to influence current behaviour? How high in management should the investigation progress?

2.26 In dealing with Human Factors issues, the dividing line between relevancy and irrelevancy is often blurred. Data that initially may seem to be unrelated to the occurrence, could prove to be extremely relevant after relationships between particular events or elements have been established. Clearly, good judgement is necessary in order to determine the relevancy of information obtained during the investigation.

2.27 It has often been said that accident investigators only gather facts during the course of their investigation and do not analyse until all the facts, conditions and circumstances of the accident have been obtained. While this may appear to be an objective approach to an investigation, it is not realistic. "Actually, nothing is more detrimental to the field phase of an investigation than the pretence that all pertinent facts can be discovered without a selective, analytical process."[1] Although a standardized methodology has not been adopted, investigators have recognized the necessity for some form of ongoing reasoning process.

2.28 G.M. Bruggink describes the analytical reasoning process as theorizing — "to arrive by reasoning at possible explanations of known or suspected accident facts." He states that the reasoning process forms the basis for the development and integration of promising avenues of investigation, and suggests that the level of confidence placed on these explanations will depend on the weight of the available evidence.[2]

2.29 Clearly, there is a limit to how far the investigation of Human Factors can or should go. Pursuit of these aspects of the investigation in the interests of academic research is not the purpose of the investigation and may be counterproductive. Investigators should also remember that it is not necessary for the facts, analysis and conclusions of investigators to stand the test of a court of law, for this is the purpose of judicial inquiry and not accident prevention. The available investigative resources must also be considered when determining the depth and detail of information to be collected. Resource limitations may mean that investigative efforts may concentrate on only the principal individuals, and that fewer data may be collected on the more peripheral individuals involved in an occurrence.

2.30 Finally, in determining the depth and detail of information to collect, the purpose of investigating Human Factors must not be forgotten. The task is to explain how the causal event sequence was initiated and why it was not interrupted before the mishap — WHY, not who was to blame. If the data does not help to explain these questions, then it is not relevant.

USE OF CHECKLISTS

2.31 Checklists are not strict protocols for the rigid step-by-step conduct of an investigation of Human Factors, but are instead useful aids in organizing and conducting the investigation of Human Factors. They can help verify the thoroughness of the investigation of the relevant Human Factors issues, and assist the investigator to organize and prioritize the gathering of evidence. However, since most occurrences are by nature unique and diverse, investigators must be flexible in their use of checklists.

2.32 Numerous checklists have been prepared by different investigation organizations. Three examples are shown in Appendix 1: the first example was designed to assist investigators in focusing investigation and analysis on the most relevant areas; the second example provides a more detailed breakdown of information to be collected, based on the SHEL model; the third example was designed to assist investigators in developing an understanding of the personnel selection, training and experience issues relevant to the occurrence under investigation.

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1. "The Role of Analysis in the Fact-finding Process", Society of Air Safety Investigators, *Forum*, 1975.
2. Ibid.

INFORMATION SOURCES

2.33 Information relevant to an aviation occurrence can be acquired from a variety of sources. Primary sources relating specifically to Human Factors include hardware evidence, paper documentation, audio and flight recorder tapes and interviews, direct observation of aviation personnel activities and simulations. Secondary sources include aviation occurrence data bases, reference literature and Human Factors professionals and specialists.

Primary sources

2.34 Hardware evidence is most often associated with the aircraft but may also involve other work stations and equipment used by aviation personnel (eg. air traffic controllers, aircraft maintenance and servicing personnel). Specific sources include aircraft wreckage, similarly configured aircraft, manufacturer's data, company records and logs, maintenance and servicing equipment, air traffic control facilities and equipment, etc.

2.35 Paper documentation spans the complete spectrum of SHEL interfaces. Specific sources include: personal records and logbooks; certificates and licenses; company personnel and training records; aircraft flight manuals; company manuals and standard operating procedures; training manuals and syllabi; company training and operational schedules; regulatory authority records; weather forecasts, records and briefing material; flight planning documents; medical records; medical and post-mortem examinations (see the ICAO *Manual of Civil Aviation Medicine*, Doc 8984).

2.36 Flight data recordings and ATC radar tapes are invaluable sources of information for determining the sequence of events and examining the liveware-liveware and liveware-hardware interfaces. Within airlines using flight recorder monitoring programmes, there can be a wealth of information about crews' normal operating procedures. In addition to traditional flight data recordings, new-generation aircraft have maintenance recorders and some electronic components with non-volatile memories that are also potential sources of pertinent information. Audio (ATC and CVR) recordings are invaluable sources of information about the liveware-liveware and liveware-hardware interfaces. In addition to preserving personnel communications, audio recordings can also provide evidence on the state of mind of individuals, and possible stress or fatigue. It is essential, therefore, that persons familiar with the crew listen to the recordings to confirm the identity of the speaker (if hot microphones are not used) and to indicate any anomalies in speech pattern or style.

2.37 Interviews conducted with individuals both directly and indirectly involved in the occurrence are also important. Examples of individuals from whom interviews may be required are:

- survivors (flight and cabin crew or passengers), next of kin, neighbours, friends, colleagues, air traffic controllers, eyewitnesses
- ground handlers, dispatchers, weather briefers, aircraft maintenance engineers, baggage handlers, de-icing personnel
- company owner, chief of flight operations, chief pilot, chief instructor, check-pilot, supervisor, former employers, training captains
- chief of maintenance, maintenance engineers, technical specialists, regulatory authorities
- family or personal physician, psychologist, aeromedical examiner.

Knowledge gleaned from such interviews can be used to confirm, clarify or supplement data from other sources. In the absence of measurable data, interviews become the single source of information, and investigators therefore need to be skilled in interviewing techniques. Guidelines on interview techniques are contained in Appendix 2 to this digest.

2.38 Direct observation of actions performed by aviation personnel in the real environment can reveal important information about Human Factors. Observations can be made of flight operations activities, flight training activities, maintenance activities and air traffic control activities.

2.39 Simulations permit reconstruction of the occurrence and can facilitate a better understanding of the sequence of events which led up to it, and of the context within which personnel perceived the events. Computer simulations can be used to reconstruct events by using data from flight recorders, air traffic control tapes and other physical evidence. Often a session in an aircraft flight simulator or reconstruction of a flight in a similar aircraft can offer valuable insights.

Secondary sources

2.40 Not all Human Factors factual information is gathered in the field. After the field phase of the investigation, additional information about Human Factors may be collected, facilitating analysis of the factual information collected in the field. These empirical data come from several sources.

2.41 Aviation safety databases containing accident/incident data or confidential reporting systems and data bases maintained by some aircraft manufacturers are useful sources of information directly related to the aviation operational environment. Examples are: ADREP (ICAO), SIE/IATA, CASRP and ASIS (Canada), ASRS (United States), CAIRS (Australia), CHIRP (United Kingdom).

2.42 Investigators should use database information with caution, however, being sure to know its source and target population, as well as its limitations. They should be familiar with the vocabulary used in a specific database, as no single set of key words is common to all databases. Coding and data entry criteria differ between various databases, which may affect the meaning of retrieved data. See Appendix 4 to this digest for a more detailed discussion of databases and their application to the investigation of Human Factors.

2.43 Basic psychological and sociological references can be good sources of information about general human performance, but they seldom address human behaviour in conditions comparable to the aviation operational environment. In recent years, professionals in the Human Factors field have provided some valuable material addressing aviation operational issues, and Appendix 5 to this digest lists a number of relevant reference documents. Some aviation research agencies will, on request, provide literature review services on selected topics. Additional references can be found in ICAO Human Factors Digest No. 1.

2.44 At any time during an investigation, investigators must be willing to consult professionals outside their area of expertise. These professionals include, but are not restricted to:

- medical officers — to analyse the impact of any medical condition found in the flight crew or other relevant personnel;

- psychologists — to help analyse the impact of environmental, operational and situational factors on motivation and behaviour;

- sociologists — to help evaluate the factors that affect interactions and performance;

- sleep researchers and professionals — to evaluate the quality of rest available to the individual, and the impact on performance of a particular work-rest duty cycle or of circadian factors; and

- ergonomists — to assess the effect of design and layout on the user.

ANALYSIS OF DATA

2.45 Having completed the task of collecting the Human Factors information pertaining to an occurrence, the investigator is faced with the challenge of analysing the data. For the most part, investigators have been quite successful in analysing *measurable* data as it pertains to Human Factors — for example, the strength required to move a control column, lighting needed to read a display, temperature and pressure requirements, etc. Unfortunately, many of the more critical Human Factors do not lend themselves to simple measurement and are thus not entirely predictable. As a result, much Human Factors information does not allow an investigator to draw indisputable conclusions.

2.46 The logic necessary to analyse less tangible phenomena necessarily differs from that required in other areas of the investigation. It has been argued that, traditionally, investigators are comfortable using deductive argument which produces "conclusive evidence of the truth …", because their conclusions are self-evident.[3] When the validity of the conclusions cannot be tested conclusively, and they must deal instead with analysis based on probabilities and likelihoods, investigators become cautious and reluctant. Caution may be commendable, but investigators must adopt strategies for overcoming reluctance.

2.47 Several other identified problems which investigators must consider when analysing Human Factors information are:

- how to assess relevancy of certain behaviour or actions deemed abnormal or non-standard;

- how to weigh sensitivity and privacy considerations;

- how to avoid speculation.

2.48 Deductive methods are relatively easy to present and lead to convincing conclusions. For example, a measured windshear produced a calculated aircraft performance loss, leading to the conclusion that the windshear had exceeded the aircraft performance capability. In another example, the engine failed because the turbine blade failed, because of metal fatigue which was not detected during inspection, because the inspection procedure was inadequate.

2.49 Such straight-line cause and effect relationships cannot be easily established with Human Factors issues, such as complacency, fatigue or distraction. For the purposes of this discussion, these aspects are referred to as "intangible" human performance factors, as opposed to readily measurable Human Factors such as hearing, eyesight, heart attack, drug or alcohol impairment, etc.

2.50 For example, if an investigation revealed that a pilot made an error leading to an accident, and if conditions conducive to fatigue, or a distracting conversation, or evidence of complacency were present, it

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3. Ronald L. Schleede, "Application of a Decision-making Model to the Investigation of Human Error in Aircraft Investigation", ISASI Forum, 1979.

does not necessarily follow that the error was made because of these conditions. There will inevitably be some degree of speculation involved in arriving at the conclusions, and their viability is only as good as the reasoning process used by the investigator and the weight of evidence available.

2.51 Because it involves probabilities and likelihoods, inductive reasoning is less precise than deductive reasoning. (In this context, "probability" is not meant to imply the precision of mathematical probability; instead, it is used in the way a lay speaker might state some conclusion as being certain, probable, possible or unknown). Inferences are drawn on the most probable or most likely explanations of behavioural events, and a conclusion reached by inductive reasoning cannot be tested conclusively. Inductive conclusions can be challenged, depending on the weight of evidence supporting them. Accordingly, they must be based upon a consistent and accepted reasoning method.

2.52 To ensure that all reasonable possibilities are considered while at the same time reducing the investigator's task to manageable levels, the Australian Bureau of Air Safety Investigation has successfully applied the following similar step-by-step reasoning process to deal with the less tangible Human Factors evidence. In the following discussion, "empirical knowledge" refers to experimental findings which have gained general acceptance within the Human Factors research community. It is assumed that the investigator has a sound basic knowledge of Human Factors, and that the evidence gathered in the investigation is complete. Following the description of each step is a brief illustration from the Anytown accident.

STEP 1: TEST FOR EXISTENCE

2.53 The first step in the process is aimed at establishing the probability of the **existence** of some Human Factors condition.

- Considering all of the evidence available, establish what Human Factors issues should be considered.

  Anytown: After applying a checklist, the investigator decided that there was at least some evidence of 17 different Human Factors issues, such as: fatigue, misinterpretation of visual cues, inadequate information flow, training deficiencies, scheduling pressure, confusing control layout, cockpit lighting, stress, distractions, etc.

- Weighing the relative importance of all of these possibilities, determine those issues that should be examined in detail.

  Anytown: After examining the 17 possible factors, the investigator decided that some, such as cockpit lighting, were not important. There remained 9 issues requiring examination in detail.

- Establish what is empirically known about each of these issues and the underlying causes.

  Anytown: The investigator reviewed Human Factors reference material to confirm what is known about the 9 key issues; a human performance specialist provided advice on visual illusions.

- Compare the circumstances of the occurrence against the empirical knowledge.

  Anytown: Evidence pertaining to the 9 key issues was compared to the corresponding reference material.

- Determine the probability that one or more of these Human Factors conditions existed.

  Anytown: Visual illusion was determined to be highly probable as a factor in the accident because of the conditions that existed and the flight path of the aircraft.

STEP 2: TEST FOR INFLUENCE

2.54 The second step is aimed at establishing the probability that a particular Human Factors condition **influenced** the sequence of events leading to an occurrence.

- Examine what is empirically known about the effects of the Human Factors conditions determined in Step 1 to exist.

  Anytown: The visual illusion which the pilot was probably experiencing (black hole) has been studied extensively and is known to cause a characteristic approach path.

- Compare the actions and performance of the people involved in the occurrence against the empirical knowledge.

  Anytown: The initial approach path recorded on the flight data recorder closely matched the typical black hole approach path. Cockpit voice recorder evidence showed that the crew believed that the approach path was accurate.

- Determine the probability that the actions and performance of personnel were affected by the Human Factors conditions which existed.

  Anytown: "At the time of the occurrence, the pilot-in-command probably experienced a visual illusion induced by the absence of visual cues on the night approach." Note the use of qualifying probability language. It was concluded that the captain misjudged the initial approach path because of the illusion.

- Determine the probability that the condition did contribute to the sequence of events leading to the occurrence.

  Anytown: Late in the approach the crew detected that they were below the desired approach path. In their attempts to reestablish a safe approach path they built up excessive airspeed, which contributed to the overrun. "It is probable that the visual illusion contributed to the pilot's misjudgement of the approach path."

STEP 3: TEST FOR VALIDITY

2.55 The steps outlined above rely on an accumulation of evidence which may not allow indisputable conclusions to be drawn, but which will often allow conclusions of probability. In some ways the use of conclusions of probability is similar to the legal profession's use of circumstantial evidence, requiring the development and testing of hypotheses. The strength of this approach is that it forces the investigator to draw conclusions in a systematic way on the basis of empirical knowledge and verifiable evidence from which there are no indisputable conclusions, and ensures that the investigator considers all likely factors.

2.56 The analysis of Human Factors must take into account the accident prevention objective of the investigation. It has been established that occurrences are seldom the result of a single cause. Thus, if the accident prevention aim of an investigation is to be achieved, the Human Factors analysis must acknowledge that although individual factors may seem insignificant when viewed in isolation, they can produce a sequence of unrelated events that combine to produce an accident. The view of an interactive aviation industry system suggested by James Reason provides an excellent framework from which investigators can achieve a thorough analysis of Human Factors at all levels. The Human Factors analysis must not focus on the active failures of front-line operators alone but must include an analysis of the fallible decisions at all levels which interacted to create the “window of opportunity” for an accident to occur.

Chapter 3
REPORTING AND PREVENTIVE ACTION

GENERAL

3.1 Having completed the gathering and analysis of the relevant facts, the investigator must prepare the report of the investigation. This chapter discusses report writing in general, with emphasis on Human Factors issues, and provides the investigator with a method for reporting which expands upon guidance contained in the ICAO *Manual of Aircraft Accident Investigation*.

3.2 Prior to writing the report, the investigator should consider who will read it. Accident/incident reports attract a varied readership, and each reader looks at the report from a different perspective. Industry readers will read the report to ensure that it is technically correct; those who were directly involved in the occurrence will be concerned with their own accountability; the travelling public will want to be assured that problems have been identified and are being dealt with; the media will want to extract the more sensational elements; and litigants will be looking for who is liable. In writing the report, the investigator should be sensitive to the different motivations, striving for technical accuracy, but ensuring that the language used can be understood by the layperson and that statements of blame or liability are avoided.

3.3 Most importantly, the investigator must keep in mind the fundamental purpose of the investigation: the prevention of accidents and incidents. So, in addition to reporting the causes of an occurrence, the report should serve as a means to identify the hazards uncovered during the course of the investigation and whether they were handled effectively or ineffectively by the operator and regulator. Also, the report must offer recommendations that aim at either eliminating or controlling those hazards. The report also serves as a tool to educate the aviation community — to be effective, it should be written so that the reader, be it pilot, mechanic, manager or regulator, can recognize and relate to the hazards reported and adopt appropriate preventive strategies.

3.4 The investigator should also understand that the most important reader is the person responsible for the implementation of the report's safety recommendations. If that person is not convinced by the report, preventive actions will not likely be taken.

3.5 Richard Wood, in discussing aircraft accident report writing at an International Society of Air Safety Investigators (ISASI) conference in Munich in 1989, stated that "everyone who participated in the investigation understands the accident — or they think they do — but the written report is going to be the basis for prevention, not the investigator's recollections. If the report is not adequate, it really doesn't make any difference how good the investigation was."[1] He further points out that a poor report can undermine a good investigation because the decision-makers are not going to react to a report that is flawed or poorly substantiated. When writing an accident report, investigators should consider the following statement taken from the ICAO *Manual of Aircraft Accident Investigation*:

---

1. Richard Wood, "Aircraft Accident Report Development", *Forum*, Vol. 22, No. 4, 1989.

> It is … most important that the "Final Report" is complete and accurate, not only for the sake of proper recording, but also because prevention studies can only be of value if they are based on complete and accurate information.

STRUCTURE OF THE REPORT

3.6 Once the Whats and Whys of the occurrence have been determined, it is relatively easy to prepare the report. Report writing is not a blind voyage of discovery wherein one writes down everything one knows about the occurrence in the hope that, by the time the end of the report is reached, the facts will speak for themselves and the conclusions will logically flow from the text. To write a good report, the investigator must acquaint the readers with the facts, conditions, and circumstances of the occurrence in an orderly fashion, and analyse the information so that the conclusions and recommendations can be understood. To do this successfully, the investigator, like any technical writer, will have to prepare a detailed outline before starting to write, and will probably want to work through several drafts to achieve a good result.

3.7 The investigator preparing the final report must be guided by the format in the appendix to Annex 13: Section 1 — Factual Information; Section 2 — Analysis; Section 3 — Conclusions and Causes; and Section 4 — Safety Recommendations, as described below.

3.8 In Section 1 — **Factual Information**, the investigator describes What happened and includes information pertinent to the understanding of the circumstances surrounding the occurrence. There are 18 subsections that give the writer sufficient flexibility to structure the flow of pertinent information. The subsections should be thought of as an organizational tool that allows the information gathered during an investigation to be arranged in a logical manner and to be included in various sections. To be included in Section 1, the information should a) provide an understanding of how the occurrence happened; b) present in general terms the role of operational personnel involved and their qualifications; and c) provide the facts and background of hazards identified, both related and unrelated to the causes of the occurrence.

3.9 Human Factors information and issues should appear in most of the subsections of Section 1, set down in the standard format as appropriate. Thus:

- the sequence of events and actions of the crew, front-line operators, ATC personnel, ground crew, etc, as far as can be constructed, are described in sub-section 1.1 — *History of the Flight*. This sub-section is intentionally limited in scope in order to quickly orient the reader to the circumstances.

- experience, training, qualifications, duty and rest periods of the crew are included in sub-section 1.5 — *Personnel Information*. Information about operational personnel who had significant roles in the occurrence, be they maintenance staff, supervisory staff, management, or regulatory personnel, should also be included in this sub-section with appropriate sub-titles.

- aircraft design, certification, airworthiness, maintenance and mass and balance issues that may have had an impact on the operation of the aircraft are described in sub-section 1.6 — *Aircraft Information*.

- communications, navaids, weather, pathological issues, etc. — all elements that may have an impact on the crew's ability to operate safely — are covered under specific sub-sections.

- sub-section 1.17 — *Additional Information* — provides a place to include information that cannot be readily included in any of the previous sub-sections. It is suggested that the investigator structure this section so that a sub-section 1.17.1 can present factual information in a format similar to the SHEL model. All the interfaces with the central Liveware component can be discussed in this sub-section. For instance, using the Anytown example, the investigator could expand on the liveware-liveware interface problems which surfaced in the interactions between the captain and first officer, under an appropriate heading such as "Crew Co-ordination". This is also the appropriate sub-section for a discussion of a liveware-hardware limitation such as the suitability of the aircraft type for the operation and the attendant demands placed on a flight crew. Problems with written information (for example, the lack of standard operating procedures) can be addressed in the context of a liveware-software limitation. The investigator can also deal with liveware-environment limitations, such as management's decisions with respect to crew selection, pairing, standardization and training, scheduling, etc. Regulatory issues can be addressed, such as the lack of an adequate monitoring process within the regulatory agency for certifying new routes. If the investigator uses the SHEL model as a tool to aid in the gathering of information during the investigation phase, the writing of this section becomes an extension of that process.

  As discussed in Chapter 2 of this digest, the investigator needs to present the empirical evidence to support the analysis of those Human Factors deemed influential in the occurrence. A sub-section 1.17.2 can provide the appropriate place for additional information of this nature. For instance, using the Anytown example, the investigator would discuss the empirical evidence pertinent to visual illusions.

3.10 In all parts of Section 1, only facts and factual discrepancies and hazards should be identified. One way to show the presence of a discrepancy is to compare the known events to a recognized aviation standard; for example, a discrepancy in the Anytown occurrence was the fact that the pilot, on landing, did not conform to the recommended technique to avoid hydroplaning. The hazard identified with this discrepancy was the airline company's lack of instruction or requirement to practise the proper techniques to avoid hydroplaning during simulator or flight training. Bearing in mind that many readers of the report may be unfamiliar with aviation standards and practices, it is often necessary to describe the nature of the deviation in some detail.

3.11 In summary, throughout Section 1 of the report the deviations, discrepancies and hazards are compared to a recognized standard or with empirical evidence, thus paving the way for the analysis of their influence in bringing about the accident.

3.12 In Section 2 — **Analysis**, the investigator can concentrate on developing the reasons why the circumstances resulted in the accident, creating the bridge between factual information and conclusions. This portion of the analysis will report the results of the Test for Existence steps for the less tangible Human Factors issues (see 2.53). Gaps in factual information must be filled in by extrapolation from the available information, by making assumptions or by the use of logic. Assumptions used in the course of the investigation must be identified in order to explain clearly the reasoning process. It is equally important to clarify what is not known and could not be determined, as well as to discuss and resolve controversial and contradictory evidence.

3.13 Having established all of the important factual issues making up the occurrence, the investigator must then develop the causal links. All reasonable hypotheses should be stated and evaluated to demonstrate that alternative explanations of the events have been carefully considered. For the less tangible Human Factors issues, the results of the Test for Influence steps will be reported (see 2.54). Richard Wood suggests that each sub-section of the analysis should read "like a mini-accident report" wherein the facts relating to a particular issue are stated, an analysis summarizing the investigator's opinions based on the preceding facts is provided, and conclusions about the relevance to the accident are drawn. Each portion of the analysis should "stand alone as the definitive **analysis** of that subject."[2]

3.14 One way to present the analysis is to follow the order of the information presented in Appendix 1, Part 1. The investigator is free to choose any logical sequence to present the argument in the most effective way, however, and the sequence will often depend on the particular circumstances of the accident or incident.

3.15 Another effective way to present the analysis is through the use of Reason's model as outlined in Chapter 1 of this Digest. Reason's model — like the SHEL model — is a tool, and the two go hand in hand. SHEL is a gathering tool in both the investigation and the presentation of factual information in the report, Reason's model is an analytical framework on which the factual information can be analysed. This model fosters a systematic approach to investigation and encourages the investigator to include a description of the conditions at the time of the occurrence, line management involvement, and the fallible decisions of upper management and the regulator, followed by an analysis of each of these elements in the accident sequence. The model allows the investigator to identify the hazards that combined to create the occurrence and points the way for redress of these hazards. For example, the investigator can begin by giving a description of the defences that were or were not in place and show how the errors committed went unchecked by the defences.

3.16 The use of Reason's model can be demonstrated by the Anytown example. The writer can begin by discussing the unsafe acts committed by the captain and why the defences were unable to prevent the events from taking place:

- the captain did not follow the recommended technique to avoid hydroplaning — had he consulted the performance charts, he would have realized that the runway was not long enough for the prevailing conditions
- the failure by airport personnel to inspect the runway for standing water eliminated one of the defences
- when the regulators certified the airport despite inadequate firefighting equipment, they did not provide a needed defence
- the captain's decision to fly the flight was made without all the available information

These active failures are symptoms of latent failures, i.e. the decisions of upper management and the implementation of those decisions by line management. The captain's performance is a reflection of defective policies of both the airline and the aviation administration managements — policies that included an inadequate training system, tight schedules that if delayed would collapse, the assignment of an unsuitable aircraft to the operation, and the certification of Anytown airport despite its known operational and safety deficiencies. By using Reason's model as a framework, the investigator is able to start with the unsafe acts and show how they developed from decisions far removed in both time and space.

3.17 Once the causation chain has been formulated and causal hazards identified, the writer can turn to other hazards that were non-contributory but which nevertheless warrant safety action.

3.18 Section 3 — **Conclusions**, should flow logically from the analysis. The conclusions stated should be consistent with the analysis and all hazards should be identified appropriately. Important findings

2. Ibid.

may be paraphrases or duplications of the conclusions drawn in the analysis. Investigators must be careful to use the same degrees of certainty in their conclusions as they have established in their analyses.

> *Anytown: The conclusion reached in the analysis on the role of the illusion could be repeated verbatim: "It is probable that the visual illusion contributed to the pilot's misjudgement of the landing." It would be inconsistent and intellectually dishonest to remove the word "probable" and state this particular conclusion as a certainty.*

3.19 Sometimes the circumstances of the accident are such that no firm conclusion can be drawn about causes. Some of the more likely hypotheses should be discussed, but the investigator should have no hesitation to state that the causes remain undetermined.

3.20 The ICAO *Manual of Aircraft Accident Investigation* states that "The expression of causes should be a concise statement of the reasons why the accident occurred and not an abbreviated description of the circumstances of the accident." It remains a problem that many cause statements in accident reports are not really causes on which safety recommendations can be made, but rather merely brief descriptions of the accident. The expression of causes may also have other shortcomings — for example, sometimes only one or a small number of causal factors receives emphasis to the detriment of other factors which could be equally important in terms of accident prevention. Also, there is a tendency to highlight the active failures of the persons closest to the event rather than to establish a complete explanation of why the accident occurred.

3.21 The expression of causes should be based on the following principles:

- all causes should be listed, usually in chronological order;
- causes should be formulated with corrective and preventive measures in mind;
- they should be linked and related to appropriate safety recommendations; and
- causes should not apportion blame or liability.

3.22 A few States have used a format that eliminated the problems associated with the expression of cause statements by simply not making such statements. Instead, their conclusions section comprises a listing of all findings considered factors in the occurrence under the heading "cause-related findings". This is followed by a listing, under the heading "other findings", of all those hazards which did not contribute to the occurrence but which nonetheless need to be addressed.

3.23 The use of probability language may be called for when stating findings relating to human performance. When the weight of the evidence is such that a definitive statement cannot be made, investigators should state findings as positively as possible, using the appropriate degree of confidence and probability in their language.

ACCIDENT PREVENTION

3.24 According to the ICAO *Accident Prevention Manual*, accident prevention must aim at all hazards in the system, regardless of their origin. If we are to prevent accidents, follow-up action must be taken in response to the hazards identified in the course of accident and incident investigations. ICAO Annex 13 places considerable emphasis on such accident prevention measures. Recommendation 7.1 states that:

At any stage of the investigation of an accident or incident, wherever it occurred, the accident investigation authority of the State conducting the investigation should recommend to the appropriate authorities, including those in other States, any preventive action which needs to be taken promptly to prevent similar occurrences.

3.25 Regarding Section 4 of the final report — **Safety Recommendations**, the ICAO *Manual of Aircraft Accident Investigation* states:

Include here any safety recommendation made for the purpose of accident prevention and state, if appropriate, any resultant corrective action. Irrespective of whether recommendations are included as an integral part of the report or presented separately (dependent upon State procedures), it should be borne in mind that the ultimate goal of a truly effective investigation is to improve air safety. To this end the recommendations should be made in general or specific terms in regard to matters arising from the investigation whether they be directly associated with causal factors or have been prompted by other factors in the investigation.

3.26 While the emphasis is on formulating recommendations, the more difficult task is clearly identifying the hazards warranting follow-up safety action. The focus of the investigator at this point must be on problem definition, as only after the problem has been clearly identified and validated can reasonable consideration be given to corrective action.

3.27 The Reason model, as illustrated in Figure 3-1, provides guidance in the formulation of preventive measures just as it provides guidance for accident investigation. Since many of the psychological precursors and unsafe acts are results of decisions made further up the line, it makes sense to concentrate preventive measures on hazards created or ignored by the higher levels of management. If the report focuses on the specific error of an individual while failing to consider higher-level decisions, it will do nothing to address the underlying responsibilities for identifying, eliminating or mitigating the effects of hazards.

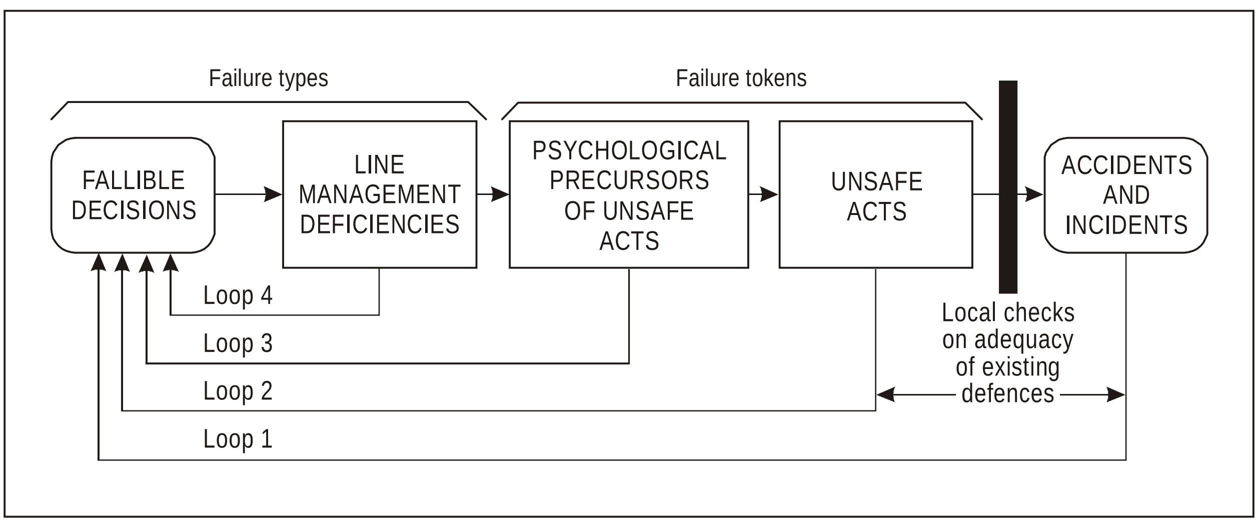

Figure 3-1. Preventive measures in accident occurrences can be paralleled to James Reason's approach to the role played by feedback loops in the control of safe operations

3.28 How effective companies, manufacturers or regulators are at identifying, eliminating or mitigating hazards is dependent upon the response strategy they adopt. There is a choice of three:

- **deny** that there is a problem;
- **repair** the observed problem to prevent its recurrence; or
- **reform** or optimize the system as a whole.

Each strategy has its own typical set of actions. A denial strategy may involve dismissing the pilot or producing a pilot-error statement; it deals only with the unsafe act and looks no further for explanation. A repair strategy recognizes the immediate problem and attempts to rectify it through actions such as retraining the person who committed the unsafe act or modifying dangerous items of equipment. A reform strategy admits that there are problems beyond the unsafe act level and systematic action is taken, leading to reappraisal and eventual reform of the system as a whole.

3.29 When companies, regulators, and accident investigators adopt a reform strategy, they turn their attention to loops 3 and 4 in Figure 3-1. Deficiencies at these higher levels — including those which had nothing to do with the accident in question — deserve greatest attention in the investigation and report-writing phase. Because the causal connection is frequently tenuous, it is often a challenge to establish that a hazardous situation was created at this level. It should also be noted decision-makers do not always receive the feedback that they need to make sound decisions — such feedback is sometimes filtered by line management, resulting in unintended consequences for the organization and its personnel.

3.30 The problem of identifying a causal connection between a hazard and high-level management can be overcome through a systematic investigation, the appropriate research of other similar operations and examination of safety data bases. For example, using the Anytown airport scenario, it may be determined that co-ordination between pilot and co-pilot was poor, partly because both pilots were inexperienced on aircraft type and with the operation. Disciplining or dismissing them would do nothing to eliminate the problems of crew pairing, not only in the company but in the aviation system at large. But to establish the existence of this hazard, the investigator would probably have to allude to several other accidents where a link had been established between crew co-ordination problems and higher-level corporate decisions with respect to crew pairing. Having established a common hazard for this type of operation would then lead directly to a variety of preventive strategies for dealing with such operational hazards, strategies which could be implemented and monitored.

3.31 The amount of time required to validate a safety hazard varies. When dealing with clear-cut factual findings such as errors in publications, material deficiencies through design errors, etc., the validation phase may be relatively short. However, for potential safety hazards involving areas of Human Factors (e.g. the effects of fatigue on crew performance, the consequences of a company's putting pressures on pilot decision-making, etc.) validation can be time-consuming, as factual evidence is often more difficult to acquire, and the effects of their interrelationships more difficult to assess. The difficulty was illustrated by the NTSB investigation into the Fairchild Metro III accident at Bayfield, Colorado in 1988. Toxicology tests revealed traces of cocaine and cocaine metabolite in the pilot. A major human performance issue was to examine the possible effect cocaine usage had on the accident sequence. The scientific data on the behavioural effects of cocaine exposure were limited, and assessment of the effects on performance was complicated when inadequate rest and a long duty day were added to the equation. Individual differences also had to be acknowledged in determining the effects of the interrelationship of these factors. This issue is still unresolved.

3.32 For many human performance phenomena, the evidence from a single occurrence may be insufficient to validate a safety hazard. Hence, the investigator must evaluate the data available from similar occurrences (perhaps on a worldwide basis) to demonstrate the probable impact of a particular phenomenon on human performance in the investigation in question. A comprehensive review of the professional literature may be warranted. In extreme cases additional formal study by specialists may be justified in order to validate the existence of a hazard.

3.33 With a clear understanding of the problem, the investigator can formulate and assess various alternative courses of action to remedy the problem. The draft recommendation should be considered for its technical feasibility, acceptability by the aviation community, practicality and ease of implementation. In assessing alternative courses of action, consideration must also be given to the most appropriate recipient for the recommendation.

3.34 Safety recommendations should not be considered as authoritative edicts by the investigating body. Since the investigator cannot be omniscient, blind obedience by the regulator in implementing recommendations could bring great harm to the industry. For example, the investigator is seldom in a good position to assess the economic feasibility of implementing a particular safety measure, and the agency receiving a safety recommendation should be given considerable latitude in choosing the most appropriate course of action. The investigating agency should be satisfied if the identified safety deficiency is adequately addressed, whether or not recommendations were specifically followed. Hence, the actual wording of recommendations should be quite general, in order to give the action agency sufficient room to manœuvre. Richard H. Wood states it this way:[3]

> "A well thought-out recommendation should achieve two goals:
>
> a) It should clearly focus attention on the problem, not on the suggested solution to it. This should eliminate the possibility that the problem will be rejected along with the recommendation; and
>
> b) The recommendation should be flexible enough to permit the action agency some latitude in precisely how that objective can be achieved. This is particularly important if all the salient facts are not yet available and some additional examination and testing appears necessary.
>
> In other words, the recommendation should focus on **what** needs to be changed, rather than **how** to do it."

Richard Wood has also noted that safety recommendations can generally be classified into one of three levels:

- a **level one** safety action completely removes the offending safety hazard;
- a **level two** safety action modifies the system so as to reduce the risk of the underlying hazard; and
- a **level three** safety action accepts that the hazard can be neither eliminated nor reduced (controlled), and therefore aims at teaching people how to cope with it.

The aim should always be to eliminate safety hazards; unfortunately, when dealing with hazards deriving from Human Factors, the tendency has been to prescribe level three coping strategies.

3.35 Since safety hazards with respect to many Human Factors may be extremely difficult to validate, it may be wise to recommend further study of the perceived hazard by more competent authorities.

3. Richard Wood, "How Does the Investigator Develop Recommendations?", *Forum*, Vol. 12, No. 3, 1979.

In this way, the investigator can proceed with the confidence that the investigation report is not the final word on particularly difficult safety issues. Industry's recognition of the importance of crew resource management (CRM) illustrates this point. In a number of one State's accident investigation reports, the hazards resulting from the lack of effective flight deck management were identified and recommendations made. The problem was thus validated through the investigation and analysis of many accidents, and this validation led to some of the larger airlines not only recognizing there were potential problems in the cockpit, but also designing and implementing CRM courses to improve cockpit co-ordination. Other airlines, realizing the value of CRM training, then began to instruct their flight crews, using the courses developed by the larger companies, and CRM training is now widely accepted and available.

CONSULTATION WITH STATES

3.36 The consultative process is one in which the final report is circulated in draft form to the States involved in the investigation, giving them an opportunity to comment on it and thus ensuring its completeness and accuracy and pre-empting criticism after public release. This process should not be seen as an opportunity to cloud the issues, nor as a forum for litigation, but rather as a process whereby the States involved can take positive steps toward ensuring that the report adequately reflects the accident sequence, identifies the safety hazards present and recommends appropriate remedial action for the promotion of accident prevention. This is a valuable process which also could be practised within a State when dealing with interested parties in a domestic occurrence.

3.37 ICAO Annex 13, Chapter 6, outlines the consultation procedure for the draft Final Report. Some States have legal provisions set down for this process, which facilitate its implementation.

DATA BASE REQUIREMENTS

3.38 As previously mentioned, seldom do the events of a single accident or incident convincingly demonstrate the presence of a fundamental safety hazard with respect to Human Factors. Usually, such hazards are only validated through the analysis of similar occurrences. For such a validation process to be effective, all relevant information from previous similar occurrences would have to be adequately recorded for future reference. Indeed, one of the many reasons why progress has been slow in initiating appropriate preventive actions for many Human Factors issues is inadequate reporting of this type of information.

3.39 Whether or not the Human Factors data gathered in an investigation are clearly linked to the causes of the specific occurrence, they should be recorded in a Human Factors data base to facilitate future analysis. For ICAO Contracting States, the principal data base for recording such information is ADREP, a system which records a series of factors describing *what* happened as well as a series of factors explaining *why* it happened.

3.40 Since human error or shortcomings in performance are usually factors in accidents, ADREP provides a sound framework for recording Human Factors data. Unfortunately, to date ADREP has not been consistently used to record pertinent data from incidents or even from some State's accidents.

3.41 There are other data bases available to support the investigation of Human Factors. For example, the Aviation Safety Reporting System in the United States has compiled the data from over 100 000 voluntary reports of hazards by pilots and air traffic controllers; most of these have a human performance element. Other States with voluntary reporting systems are similarly developing specialized data bases which have a high Human Factors content. Universities and research organizations also compile highly specialized data bases for analysing particular Human Factors phenomena within the context of their research efforts. While such data bases may provide a useful adjunct to the investigator in analysing a particular occurrence, they are not suitable repositories for the data arising out of the investigation — only ADREP satisfactorily provides a comprehensive world-wide means of recording accident/incident data to facilitate a better understanding of the explanatory factors.

3.42 On a world-wide basis, there is a continuing requirement to provide better means of recording Human Factors data in a user-friendly format if we are to learn from the lessons of others. Given the frequency of Human Factors elements in accidents and incidents, it is imperative that we facilitate future safety analysis through better data reporting.

Appendix 1
HUMAN FACTORS CHECKLISTS

The sample checklists which form this Appendix are based on checklists used by three different ICAO States. Although each checklist reflects a different approach to the investigation of Human Factors, all three have the goal of assisting the investigator to identify the relevant factors and focus analysis on germane issues. Any one, or even all three, may be adapted for use by the investigator.

CHECKLIST A

To determine the relevant areas warranting further Human Factors investigation/analysis, rate the importance of each factor by indicating the appropriate weighting value beside each item.

0 = Not contributory
1 = Possibly contributory
2 = Probably contributory
3 = Evidence of hazard

BEHAVIOURAL FACTORS

A. Faulty planning (pre-flight, in-flight) ______

B. Haste (hurried departure, etc.) ______

C. Pressing the weather ______

D. boredom, inattention, distraction ______

E. Personal problems (familial, professional, financial) ______

F. Overconfidence, excessive motivation (“get-home”itis) ______

G. Lack of confidence ______

H. Apprehension/panic ______

I. Violation of flight discipline (risk-taking) ______

J. Error in judgement ______

K. Delay ______

L. Complacency, lack of motivation, etc. ______

M. Interpersonal tension ______

N. Inadequate stress coping ______

O. Drug abuse ______

P. Alcohol/hangover ______

Q. Personality, moods, character ______

R. Memory mindset (expectancy) ______

S. Habit patterns ______

T. Perceptions or illusions ______

U. Bush pilot syndrome ______

MEDICAL FACTORS

A. Physical attributes, conditioning and general health ______

B. Sensory acuity (vision, hearing, smell, etc.) ______

C. Fatigue ______

D. Sleep deprivation ______

E. Circadian disrhythmia (jet lag) ______

F. Nutritional factors (missed meals, food poisoning, etc) ______

G. Medication(s) (self-prescribed) ______

H. Medication(s) (doctor-prescribed) ______

I. Drug/alcohol ingestion ______

J. Altered consciousness ______

K. Reaction time or temporal distortions ______

L. Hypoxia, hyperventilation, etc. ______

M. Disbarisms, trapped gases, etc. ______

N. Decompression ______

O. Motion sickness ______

P. Disorientation, vertigo ______

Q. Visual illusions ______

R. Stress ______

S. Hypothermia/hyperthermia ______

T. Other acute illness(es) ______

U. Pre-existing disease(s) ______

OPERATIONAL FACTORS

A. Personnel selection ______

B. Limited experience ______

C. Inadequate transition training ______

D. Lack of currency/proficiency ______

E. Inadequate knowledge of A/C systems ______

F. Inadequate knowledge of A/C life support systems ______

G. Company policies and procedures ______

H. Supervision ______

I. Command and control relationships ______

J. Company operating pressures ______

K. Crew compatibility ______

L. Crew training (e.g. cockpit resource management) ______

M. Inadequate flight information (A/C manuals, flight planning, etc.) ______

TASK-RELATED FACTORS

A. Tasking information (briefing, etc.) ______

B. Task components (number, duration, etc.) ______

C. Workload tempo ______

D. Workload saturation ______

E. Supervisory surveillance of operation ______

F. Judgement and decision-making ______

G. Situational awareness ______

H. Distractions ______

I. Short-term memory ______

J. False hypotheses (vs. expectancy, habit, etc.) ______

K. Cockpit resource management ______

EQUIPMENT DESIGN FACTORS

A. Design/location of instruments, controls ______

B. Lighting ______

C. Workspace incompatibility ______

D. Anthropometric incompatibility ______

E. Confusion of controls, switches, etc. ______

F. Misread instruments ______

G. Visual restrictions due to structure ______

H. Task oversaturation (complex steps) ______

I. Inadvertent operation ______

J. Cockpit standardization (lack of) ______

K. Personal equipment interference ______

L. In-flight life support equipment ______

M. Effects of automation ______

N. Seat design/configuration ______

O. Aerodrome design and layout ______

P. Conspicuity of other aircraft, vehicles etc. ______

ENVIRONMENTAL FACTORS

A. Weather ______

B. Air turbulence ______

C. Illusions (white-out, black hole, etc.) ______

D. Visibility restriction (glare, etc.) ______

E. Work area lighting ______

F. Noise ______

G. Acceleration/deceleration forces ______

H. Decompression ______

I. Vibration ______

J. Heat/cold ______

K. Windblast ______

L. Motion (dutch roll, snaking, etc.) ______

M. Smoke, fumes in cockpit ______

N. Oxygen contamination ______

O. CO poisoning or other toxic chemicals ______

P. Radiation ______

Q. Electrical shock ______

R. Flicker vertigo ______

S. Air Traffic Control ______

INFORMATION TRANSFER FACTORS

A. Adequacy of written materials (availability, understandability, currency, etc.) ______

B. Misinterpretation of oral communications ______

C. Language barrier ______

D. Noise interference ______

E. Disrupted oral communication ______

F. Intra-crew co-ordination ______

G. Crew/ATS communication ______

H. Timeliness/accuracy of verbal communications ______

I. Cockpit crew non-verbal communications ______

J. Cockpit warnings, horns, chimes, etc. ______

K. Cockpit instrument displays1 ______

L. Airport signals, marking and lighting ______

M. Ground/hand signals ______

OTHER PERSONNEL FACTORS

Air Traffic Control

A. Attention (vigilance, forgetfulness, etc.) ______

B. Fatigue vs workload ______

C. Communications (phraseology, rate of speech, pronunciation etc.) ______

D. Working environment (lighting, noise, visibility, etc.) ______

E. Equipment/display layout and design ______

F. Judgement ______

G. Training and currency ______

H. Co-ordination and back-ups ______

I. Supervisory presence ______

J. ATC policies and operating procedures ______

Vehicle Operators

K. Selection and training ______

L. Working environment (noise, fatigue, visibility, etc.) ______

M. Command and control, supervision ______

Aircraft Line-Servicing Personnel

N. Selection and training ______

O. Availability of relevant information ______

P. Operating pressures ______

Q. Supervision ______

SURVIVABILITY FACTORS

A. Crashworthiness of design ______

B. Post-accident life support equipment (exits, chutes, life vests, ELTs, medical kits, etc.) ______

C. Command and control procedures ______

D. Crew training ______

E. Passenger briefings and demos ______

B. CHECKLIST BASED ON THE SHEL MODEL

FACTORS RELATING TO THE INDIVIDUAL (LIVEWARE)

1. PHYSICAL FACTORS

Physical characteristics
* height, weight, age, sex
* build, sitting height, functional reach, leg length, shoulder width
* strength, coordination

Sensory limitations

Vision
* visual threshold
* visual acuity (seeing details)
* focus time
* light adaptation
* peripheral vision
* speed, depth perception
* empty field myopia
* glasses, contacts

Others
- * auditory threshold, understanding
- * vestibular (ear senses)
- * smell, touch
- * kinaesthetic (body feelings)
- * g-tolerances

2. PHYSIOLOGICAL FACTORS

Nutritional factors
* food intake 24 hours
* hours since last meal
* dehydration
* on a diet/weight loss

Health
* disease
* fitness
* pain
* dental conditions
* blood donation
* obesity, pregnancy
* stress coping (emotional/ behavioural signs)
* smoker

Lifestyle
* friendships
* relations with others
* change in activities
* life habits

Fatigue
* acute (short term)
* chronic (long term)
* skill (due to task)
* activity level (mental/physical)

Duty
* duration of flight
* duty hours
* leave periods — activities

Sleep
* crew rest, nap duration
* sleep deficit, disruption
* circadian disrythmia (jet lag)

Drugs
* medication over the counter
* medication — prescription
* illicit drugs
* cigarettes, coffee, others

Alcohol
* impairment
* hangover
* addiction

Incapacitation
* carbon monoxide poisoning
* hypoxia/anoxia
* hyperventilation
* loss of consciousness
* motion sickness
* food poisoning
* nauseating fumes
* toxic fumes
* others

Decompression/diving
* decompression
* trapped gas effects
* underwater diving

Illusions

Vestibular
* somatogyral (vertigo)
* somatogravic
* the leans
* coriolis illusion
* elevator illusion
* giant hand

Visual
* black hole
* autokinesis
* horizontal misplacement
* circularvection
* linearvection
* landing illusions
* chain-link fence illusion
* flicker vertigo
* geometric perspective illusion

3. PSYCHOLOGICAL FACTORS

Perceptions

Types
* non perception
* misperception
* delayed perception

Reaction time
* to detect
* to make an appropriate decision
* to take the appropriate action

Disorientation
* situational awareness
* spatial
* visual
* temporal
* geographic (lost)

Attention
* attention span
* inattention (general, selective)
* distraction (internal, external)
* channelized attention
* fascination, fixation
* vigilance, boredom, monotony
* habit pattern interference
* habit pattern substitution
* time distortion

Information Processing
* mental capacity
* decision making (delayed, poor)
* judgment (delayed, poor)
* memory capacity
* forgetting
* co-ordination — timing

Workload
* task saturation
* underload
* prioritization
* task components

Experience/recency
* in position
* in aircraft type, total time
* on instruments
* on route, aerodrome
* night time
* emergency procedures

Knowledge
* competence
* skills/techniques
* airmanship
* procedures

Training
* initial
* on the job
* ground
* flight
* transition, learning transfer
* recurrent
* problem areas
* emergency procedures

Planning
* pre-flight
* in flight

Attitudes/moods
* mood
* motivation
* habituation
* attitude
* boredom
* complacency

Expectations
* mind set/expectancy
* false hypothesis
* "get-home"itis
* risk-taking

Confidence
* in aircraft
* in equipment
* in self
* overconfidence, showing off

Mental/emotional State
* emotional state
* anxiety
* apprehension
* panic
* arousal level/reactions
* self-induced mental pressure/stress

Personality
* withdrawn, grouchy, inflexible
* hostile, sarcastic, negative
* aggressive, assertive, impulsive
* excitable, careless, immature
* risk taker, insecure, follower
* disorganized, late, messy
* anti-authoritative,resigned
* invulnerable, "macho"

4. PSYCHOSOCIAL FACTORS

* mental pressure
* interpersonal conflict
* personal loss
* financial problems
* significant lifestyle changes
* family pressure

FACTORS RELATED TO INDIVIDUALS AND THEIR WORK

1. LIVEWARE-LIVEWARE (HUMAN-HUMAN) INTERFACE

Oral communication
* noise interference
* misinterpretation
* phraseology (operational)
* content, rate of speech
* language barrier
* readback/hearback

Visual signals
* ground/hand signals
* body language

Crew interactions
* supervision
* briefings
* co-ordination
* compatibility/pairing
* resource management
* task assignment
* age, personality, experience

Controllers
* supervision
* briefing
* coordination

Passengers
* behaviour
* briefing
* knowledge of aircraft, procedures

WORKER-MANAGEMENT

Personnel
* recruitment/selection
* staffing requirements
* training
* policies
* remuneration/incentives
* crew pairing, scheduling
* seniority
* resource allocation
* operational support/control
* instructions/directions/orders
* managerial operating pressure

Supervision
* operational supervision
* quality control
* standards

Labour relations
* employee/employee-management
* industrial action
* unions/professional group

Pressures
* mental pressure — operational
* morale
* peer pressure

Regulatory agency
- * standards
- * regulations
- * implementation
- * audit
- * inspection
- * monitoring
- * surveillance

2. LIVEWARE-HARDWARE (HUMAN-MACHINE) INTERFACE

Equipment

Switches, controls, displays
- * instrument/controls design
- * instrument/controls location
- * instrument/controls movement
- * colours, markings, illumination
- * confusion, standardization

Workspace
- * workspace layout
- * workspace standardization
- * communication equipment
- * eye reference position
- * seat design
- * restrictions to movement
- * illumination level
- * motor workload
- * information displays
- * visibility restrictions
- * alerting and warnings
- * personal equipment interference (comfort)
- * data link
- * operation of instruments (finger trouble)

3. LIVEWARE-SOFTWARE (HUMAN-SYSTEM) INTERFACE

Written information
- * manuals
- * checklists
- * publications
- * regulations
- * maps and charts
- * NOTAMs
- * standard operating procedures
- * signage
- * directives

Computers
- * computer software
- * user friendliness

Automation
- * operator workload
- * monitoring task
- * task saturation
- * situational awareness
- * skill maintenance
- * utilization

Regulatory requirements
- * qualification — in position
- * qualification — in management
- * certification
- * medical certificate
- * licence/rating
- * non-compliance
- * infraction history

4. LIVEWARE-ENVIRONMENT (HUMAN-ENVIRONMENT) INTERFACE

INTERNAL
- * heat, cold, humidity
- * ambient pressure
- * illumination, glare
- * acceleration
- * noise interference
- * vibrations
- * air quality, pollution, fumes
- * ozone, radiations

EXTERNAL

Weather
- * weather briefing, FSS facilities
- * weather: actual and forecasts
- * weather visibility, ceiling
- * turbulence (wind, mechanic)
- * whiteout

Other factors
- * time of day
- * lighting/glare
- * other air traffic
- * wind blast
- * terrain/water features obstacles

Infrastructure

Dispatch facilities
- * type of facilities
- * use
- * quality of service

At the gate
- * APU
- * towing equipment
- * refuelling equipment
- * support equipment

Aerodrome
- * runway/taxiway characteristics
- * markings, lighting, obstructions
- * approach aids
- * emergency equipment
- * radar facilities
- * ATC facilities
- * FSS, weather facilities
- * airfield facilities

Maintenance
- * support equipment
- * availability of parts
- * operational standards, procedures and practices
- * quality assurance practices
- * servicing and inspection
- * training
- * documentation requirements

CHECKLIST C — SELECTION, TRAINING AND EXPERIENCE

INTRODUCTION

The purpose of this checklist on selection, training and experience for human factors aspects of accident investigation is to assist the investigator during the field phase in developing a comprehensive factual base on the pilot selection, training and experience issues relevant to the specific accident under investigation.

An effort has been made to present the checklist in a generic format so that investigators can apply it to any modality by substituting “air traffic controller”, “mechanic”, etc., for “pilot”, as appropriate. However, since most accidents are by nature unique and diverse, some degree of discretion will be required to tailor the checklist to particular cases. In this way, the checklist is a dynamic tool, to be modified and updated with use over time.

A. SELECTION

1) When was the pilot selected for this position?

2) How was the pilot selected?
   a) What were the required qualifications? (e.g. experience, education, training and physiological/medical requirements)
   b) Were any examinations required? What? When taken?
   c) What special licences were required?
   d) Were the pilot's qualifications, references and licenses verified by his/her employer prior to selection for employment?

3) Was specific training on this position provided to the pilot before he was selected for it? If yes,
   a) Describe the content of the training.
   b) When was this training?
   c) Who provided this training?

4) Was specific training on this position provided to the pilot after he was selected for it? If yes,
   a) Describe its content.
   b) When was this training given?
   c) Who provided this training?

5) Where any problems ever noted with the pilot's performance after he assumed the duties of this position? If yes,
   a) describe the problems.
   b) When were these observations made?
   c) Who made these observations?
   d) What actions, if any, were taken to correct the problems?

B. PILOT EXPERIENCE

1) What other experience has the pilot had using this specific equipment?

2) What other jobs has the pilot had using other equipment in this modality?

3) What is the total length of time the pilot has worked in this modality?

4) How long has the pilot worked for this specific employer?

5) How long did the pilot work for his previous employers?

6) Was the pilot's previous experience verified by his/her current employer?

7) Has the pilot ever been involved in any other accidents in this modality? If yes,
   a) Describe the circumstances.
   b) When?
   c) What equipment was in use?

8) Has the pilot ever been involved in any other accidents in other modalities? If yes,
   a) Describe the circumstances.
   b) When?
   c) What equipment was in use?

9) Has the pilot ever complained about or reported any problems related to the use of this specific equipment? If yes,
   a) Describe the nature of the complaints or report.
   b) When?
   c) Were any corrective action made? By whom? When?
   d) Have any other similar complaints or reports ever been made? Provide details.

C. PILOT TRAINING

The investigator should review (requesting copies when applicable) training-related records, documents, rule books, manuals, bulletins and pilot examinations.

1) What training has the pilot received on the use of equipment in this modality?
   a) Describe the training: classroom? simulator? on-the-job-training (OJT)? materials used? topics?
   b) When did the pilot receive it?
   c) Who were the instructors and/or supervisors?
   d) How was the pilot's performance evaluated (e.g. check ride, on the road, simulation, paper and pencil examination)?
   e) What was the over-all evaluation of the pilot's performance?
   f) Were any problems noted in the pilot's performance? If yes,
      — What were they?
      — How were they noted and by whom?
      — What corrective actions were taken, if any?

2) Initial training vs. follow-on training using this specific equipment:

a) Has the pilot received training on this equipment from more than one employer? If yes,
   - Which employer provided the initial training?
   - When?
   - How much emphasis was placed on:
     - compliance with Standard Operating Procedures (SOPs)
     - compliance with rules and requirements?
     - use of performance evaluations (e.g. check rides, examinations)?

b) How does the pilot's initial training differ from any follow-on or subsequent training in terms of the following:
   - Compliance with SOPs?
   - Compliance with rules and regulations?
   - Use of performance evaluations (e.g. check rides, examinations)?

c) Do any of these differences appear related to the mishaps?
   - Did the pilot violate any SOPs he had been taught? If yes,
     - What were they?
     - When were they taught?
   - Did the pilot violate any rules or requirements he had been taught? If yes,
     - What were they?
     - When were they taught?
   - Has the pilot ever violated any rules, requirements, or SOPs before? If yes,
     - What were the circumstances?
     - What actions were taken?
   - Has the pilot received any new, recent training that may have:
     - Interfered with his knowledge and skills in using this equipment?
     - Required his use of new, different SOPs under emergency conditions?

3) Other training issues:

a) Has the pilot received any recent training for:
   - Transition to operation of different equipment in this modality?
   - Learning different operations of similar equipment systems?

b) If the pilot has received any recent transition and/or differences training:
   - Describe when and type.
   - Check potential interference from this training with operation of accident equipment.

c) Is the pilot current in all areas of accident equipment operation?
   - Describe areas lacking currency.
   - Describe required exams, certificates or licenses indicating full currency.

d) Rate sufficiency of training on:
   - Emergency situations.
   - Equipment malfunctions.
   - Maintenance reports, complaint procedures, logs.
   - Crew interaction and coordination skills.
   - Degraded conditions (e.g. reduced visibility, high sea state, gusty or high winds, heavy precipitation).
   - Communication procedures.
   - Physiological requirements (e.g. issues related to rest, health, nutrition and use of medication, drugs and alcohol).

e) If simulators or training device were used for training:
   - What specific training was provided in the simulator or training device?
   - What are the major similarities and/or differences between the simulator or training device and the actual equipment?
   - How recent was the training with the simulator or training device?
   - Were any problem areas noted in the pilot's performance?

f) Did the pilot receive training specifically related to the conditions of the mishap (e.g. wind-shear, equipment, malfunction, specific type of emergency, specific weather conditions)? If yes,
   - Describe when and type.
   - How did the pilot perform in training?

g) Was the pilot providing or receiving training at the time of the mishap? If yes,
   - Describe the circumstances in detail.
   - Determine the qualifications of instructor(s) and/or trainee(s) involved.
   - When did this training begin and how long had it been in progress?

Appendix 2
WITNESS INTERVIEWING TECHNIQUES

Interviews conducted with individuals either directly or indirectly involved in an occurrence are an important source of evidence. Information gleaned from such interviews can be used to confirm, clarify, or supplement information learned from other sources. Certainly, in the absence of measurable data, interviews become the single source of information, and investigators need to be well acquainted with the techniques required to ensure effective interviews.

Information gained in interviews will help to determine what happened. More importantly, interviews are often the only way to answer the important “why” questions which, in turn, can facilitate correct and effective safety action.

In most investigations, Human Factors will have to be assessed, and the investigator who dons the Human Factors hat will be faced with interviewing a variety of people. Included within this group are survivors (both crew and passengers), next of kin, friends, colleagues and company management/training personnel.

In preparation for interviews, investigators must remember that every witness deals with the occurrence from a different perspective. Consider the cabin crew members who survived a crash and may be suffering guilt at the fact that they survived while others died; they may be struggling with their role in the crash sequence, tormenting themselves with “What if” questions. The situation might involve flight crew members experiencing a myriad of emotions: grief where deaths are involved; pressure from company management or union representative; stress over whether their livelihood is at stake; anxiety over regulatory action; confusion about what happened, etc. Company management concerns may focus on regulatory action and litigation, and responses may be tailored accordingly.

Next of kin interviews are always difficult — imagine the emotional roller coaster experienced by the next of kin: grief and anger at the loss of a loved one; perhaps guilt; anxiety over financial concerns; confusion caused by media accounts, etc. Further consideration will have to be given to the witness who is under medication for shock or physical pain as a result of injury; such a situation will have some bearing on how extensive the interview will be and on its validity.

The investigator has to be a chameleon, capable of adapting to various scenarios. An effective interviewer remains objective and avoids making evaluations early in the interview. Even when faced with conflicting evidence, the investigator should listen to what a witness has to relate and should suspend judgement of that information until all facts have been gathered and an assessment can be made: the pilot who has been fired may be a disgruntled employee with a desire to sully the company’s reputation or he may be a credible witness with very real truths to relate.

The investigator must give special consideration to grieving next of kin, projecting the right amount of empathy without becoming sympathetic. The interview is a dynamic situation, and, to take advantage, the investigator has to be adaptable, knowing when to focus and when to back off. Before conducting an interview, the investigator should try to obtain as much information about factors such as the crash sequence (walking the site may be helpful), applicable procedures that were in effect (allows comparison to what was done in actuality), the crew (scanning pilot records will tell, for example, whether the pilot was required to wear glasses, and, during subsequent interviews, the investigator can attempt to establish if the pilot wore glasses during the flight), etc. By knowing as much as possible before the interview, the investigator has room to manoeuvre and is saved having to re-interview.

Success of the interview

Good interviews are the result of effective planning. There are a number of preparatory issues that need to be considered before an interview is conducted:

Timing of interviews

Interviews should be conducted as soon as possible after the occurrence to prevent loss of perishable information as a result of fading memory or rationalization. Passage of time also permits contamination of information, which occurs when witnesses confer with one another or listen to or read media accounts. If it is necessary to delay interviews, statements should be requested. These serve the dual purpose of capturing facts before natural decay, in addition to assisting the investigator in the preparation of the subsequent interview.

Location

Witnesses should be made to feel at ease, and to this end the investigator should choose a location that is quiet, reasonably comfortable, and free from interruption. If a witness wishes to smoke, the investigator should accommodate this wish. Next of kin will probably prefer to be interviewed in their own home.

Approach

Because Human Factors permeate all aspects of an accident, it is often advantageous for the investigator to conduct interviews in conjunction with investigators from other groups. This approach recognizes the requirement for cross-fertilization within an investigation and, in doing so, becomes an effective tool in gathering information. The team approach may eliminate the need to re-interview a witness and is thus a more efficient use of resources. Further, as team members, the investigators are able to later corroborate the information given. In deciding whether to use the team approach, the witness's personality and the sensitivity of information sought must be considered. In some circumstances, a private one-on-one interview will illicit much more information.

During interviews, investigators should minimize their input and instead concentrate on active listening — an investigator who is talking isn't listening. Certainly, the investigator must direct the interview and keep it moving, but, generally, the less active the interviewer, the more productive the result. By listening to what is being said, the investigator will be able to reformulate questions appropriate to the situation, note discrepancies and sudden changes in conversation, perceive innuendoes and observe a witness's gestures and behaviour.

Silence can be an effective tool during the interviewing process, and the investigator should avoid trying to fill in pauses in conversation too quickly. More often than not, people want to talk about the occurrence, about the friend, husband or wife they lost, about the wrongs they believe should be righted, etc., and they will often fill in the pauses themselves.

Co-operation

Co-operation, which is essential to the success of the interview, is often determined by the impression the investigator makes on the person being interviewed. A friendly approach that treats the witness as an equal and is as unobtrusive as possible is preferable to one that is effusive or bureaucratic. Simple things, such as assessing the audience and dressing accordingly, may make a difference in how forthcoming a witness is with information. Casual clothes instead of a suit may be more appropriate and less threatening in some environments. By developing a relationship of mutual confidence with a witness, the investigator is more assured of a free flow of information, ideas and opinions. According to the ICAO *Manual of Aircraft Accident Investigation*, "a philosophy of interview rather than interrogation is desirable in the questioning of witnesses by the investigator."

Control

It is imperative that the investigator control the interview. Under certain circumstances, a witness may wish to be accompanied by another person for support — a parent may wish to be present during the interview of a child, survivors may wish to have their spouse present, a crew member may want a lawyer or union representative in attendance — and this request should be accommodated. Control becomes a difficult task when third parties are present, but an early understanding of the ground rules as specified by the investigator should minimize disruptions. Before an interview begins, it should be clear to and agreed upon by all parties that the attendance of a third party, other than an expert assisting the investigator, will only be considered at the request of the witness; that the investigator is the only person to direct questions to the witness; that questions provided in writing by other parties in attendance may be given to the investigator and, if accepted, will be used at an appropriate time; and that the investigator maintains the right to prohibit certain individuals from attending when their attendance could inhibit an effective interview.

Tape recorder

A tape recorder is a valuable tool. It allows the investigator to focus full attention on what the witness has to say; it provides a complete and accurate record of what was said; and it allows the statement to be played back. The investigator should be prepared for witnesses who are reluctant to have their statements recorded. In such cases, it will be necessary to explain that the tape recorder is there to allow the interview to be conducted more quickly and to ensure accuracy; the fact that the tape recorder provides a good record and eliminates the need to possibly re-interview a witness may be used as an argument in defence of its use. Reluctance disappears quickly if the recorder is used unobtrusively. Where there is reason to believe that the reluctance will not dissipate, the investigator will have to use a different method, such as note-taking; those who subscribe to the team approach will be able to use this method best — one member asks questions and another takes notes.

Structure

Effective interviews are characterized by a logical structure designed to maximize the quality and quantity of relevant information. The interview comprises four basic parts — the plan, the opening, the main body, and the closing — each with a specific purpose. In cases where there are a large number of survivors, a list of questions to be asked of every survivor should be prepared so that a comparison for reliability can be made at a later date.

The plan

Prior to interviewing a witness, the investigator needs to define the general objectives of the interview, be aware of what some of the obstacles to achieving those objectives might be, and understand the expectations of the witness. The investigator should have some knowledge of the person being interviewed and should determine questions to be asked based on that knowledge. The sequencing of questions and the placement of the tougher questions can be considered at this step. Many witnesses, such as next-of-kin, have a legitimate requirement for information about the occurrence. The investigator should preplan the information which will be released to the witness at the appropriate moment in the interview.

Preparing a list of questions that has to be rigorously followed is not the purpose of the planning step; rather it is the time to ensure that all areas of concern will be addressed during the interview.

The opening

Most witnesses are probably being interviewed by an investigator for the first time. They will be apprehensive and may have misgivings about the interview and its end result. It is important, therefore, to eliminate as much of their uncertainty as possible. To do so, the investigator should give each witness a good explanation of the investigator's role, the witness's role and rights (including advising the witness who will have access to the transcript), the purpose of the interview, and the interview process. Witnesses should be made aware that their participation is important in the determination of cause and the prevention of a recurrence.

The main body

The right question asked in the right way at the right time is a powerful tool; it focuses on the important information; it terminates unproductive conversation; it helps people to concentrate their thoughts; and it allows the interview to flow smoothly.

Often the easiest and most effective way to begin an interview is with a free recall type question, wherein witnesses are allowed to tell their story without interruption. The investigator should be attentive to what is being said and should refrain from any gestures or mannerisms that may lead witnesses. This approach is non-threatening, it allows witnesses to believe that what they have to say is important, it begins to establish a rapport between the investigator and the witness, and it gives the investigator a baseline of uncontaminated information.

When it is apparent that a witness has nothing further to say, the investigator can begin to question in more detail. However, there is no need to change the approach — the investigator can begin the questioning for each specific topic with a general question, becoming more specific as the witness becomes more specific with the answers. By getting witnesses to co-operate in a general way, the investigator increases the likelihood that they will subsequently co-operate in more specific ways.

There are various types of questions, each of which will elicit a different type of response. The general or "open" question is the least leading and allows witnesses to answer in their own way and to formulate opinions as they see fit. With next of kin, a question such as "I didn't know your son; I wonder if you would tell me about him?" achieves the same result as a free recall question — witnesses begin to talk about something with which they are familiar and which is non-threatening. Often witnesses will begin to answer a question before it is fully asked; investigators can take advantage of this by using open-ended or trailing-off questions (e.g. "You said earlier that your training was …"), which can evoke rapid and accurate descriptions of the subject matter. They also lead to more witness participation.

The open question may not produce exactly the answer expected, and it may be appropriate for the investigator to redirect witnesses by means of a supplementary question which is more specific. There is a caution, however, that should be acknowledged when asking more specific questions — the more specific the question becomes the more likely it is to lead witnesses, possibly pressuring them to remember something that they do not know or did not observe. "Was the pilot fatigued?" is leading, in that it contains a possible answer and thus contaminates the information; it would be better to ask the witness to "describe the pilot's physical condition and mental outlook toward the job recently". "How proficient was the pilot at single-engine go-arounds?" uses a "marked" word (proficient) and effectively eliminates any neutrality that the investigator may be trying to achieve with the question. By using unmarked words and by setting the stage with a series of questions, the investigator can obtain the information without contaminating the response — "What is the policy for practising single-engine go-arounds?" followed by "When was the last time the pilot practised this procedure?" and ending with "Describe the procedure used by the pilot during the last practice session". This approach is neutral and does not lead the witness.

The "closed" question (one evoking a "yes" or "no" response), produces limited information and should be avoided, unless specifically intended. "Did your husband talk to you about the problems he was having with the chief-pilot?" "Was the co-pilot uncomfortable about flying into that airport because she had not flown that route before?" "Did the captain and first officer have problems in working together as a crew?" are all questions that can elicit a yes or no response, and the investigator will have to try another tactic to get more complete responses. The investigator may be more successful by phrasing the questions as follows — "How did your husband feel about flying with this company?" "You mentioned that the co-pilot was not comfortable about flying into that airport, why not?" "Describe the captain and co-pilot's working relationship".

Occasionally, the investigator will have to ask questions which are more personal in nature and thus require an indirect approach. For example, the investigator believes that the deceased pilot was under a great deal of domestic stress because of marital problems; asking the pilot's spouse "Was there anything that may have been upsetting your husband on the day of the accident?" or "Did you notice any change in your husband's behaviour in the recent past?" will increase the chance of getting closer to the truth of the matter. The indirect approach in delicate situations also eliminates the possibility of bringing the interview to an abrupt end as may be the case with a more direct question such as "Were you and your husband having marital problems"?

Questions should be brief, clear, and unambiguous. They should be relevant to the information required and be presented one at a time. Jargon and terminology that may confuse or intimidate witnesses should be avoided. Some witnesses who have had difficulty recalling events benefit from hearing the tape recording of their initial description of the occurrence. While listening to the account they suddenly recall forgotten information. Near the end of an interview, witnesses should be asked if they have any other information to add or if they have any questions.

The closing

The closing is the time to summarize the key points and to verify understanding of the information obtained; to assure the witness that the interview has been valuable; to establish the availability of the witness at a future date should that be necessary; and to indicate the availability of the investigator should the witness wish to provide additional information or enquire about the progress of the investigation.

Assessment

None of the information gained in an interview should be accepted at face value. Issues such as health can be verified against medical records; fatigue against work schedules; attitudes toward management, training and maintenance against interviews with family members, friends and colleagues, etc. By comparing the information gathered during interviews to information gleaned from other sources, the investigator will be able to piece together the puzzle more accurately and establish the credibility of various witnesses. Weight factoring of interview information and matrix evaluation of information obtained from several witnesses are effective methods of quantifying and qualifying that information.

In assessing the validity and significance of the information, the investigator should remember that witnesses' portrayals of facts are influenced by personal biases — so too are the investigator's. One example of bias is the "halo effect", which occurs when an investigator forms a global impression (either positive or negative) of a person, based on one characteristic that biases the interviewer's assessment of the other person's ideas. For example, a seemingly comfortable, self-assured person may given more credibility than is warranted.

In summary, an interview is a dynamic event conducted in real time; planning, experience and responsiveness on the part of the interviewee are all keys to a successful outcome. While re-interviews are possible, there is no substitute for the effective first interview.

Appendix 3

EXPLANATORY HUMAN FACTORS

THE INDIVIDUAL

Physical — characteristics of the individual

	Explanatory factors
Physical characteristics	Size
	Weight
	Strength
	Age
Sensory limitations	Sensory threshold (vision/visual)
	Hearing
	Vestibular (inner ear)
	Proprioception (sense receptors — muscles/joints)
	Smell
	Touch
	Kinaesthetic (muscle movement)
	“G” tolerance
Other physical limitations	

Physiological — the person’s well-being

	Explanatory factors
Health/lifestyle	Disease
	Fitness
	Diet
	Obesity
	Age
	Stress
	Smoker (heavy)
	Pregnancy
	Blood donation
	Other predisposing condition
Fatigue	Fatigue — acute
	Fatigue — chronic
	Fatigue — skill
	Fatigue — other
	Crew rest
	Sleep deficit/disruption
	Other sleep disorder
	Circadian dysrhythmia (jet lag)
Drugs	Medication —over-the-counter
	Medication — prescription
	Drugs — illicit
	Other stimulants (coffee, cigarettes)
Alcohol	Alcohol— impairment
	Alcohol — hangover
	Alcohol — addiction
Incapacitation	Carbon monoxide poisoning
	Hypoxia/anoxia
	Hyperventilation
	Loss of consciousness
	Motion sickness
	Nauseating fumes
	Toxic fumes
	Other medical
Decompression/diving	Decompression
	Trapped gas effects
	Underwater diving
Other physiological limitations	

Psychological — the person’s mental well-being

	Explanatory factors
Perceptions/illusions	Situational awareness
	Disorientation — spatial
	Disorientation — visual
	Disorientation — temporal
	Disorientation — geographic (lost)
	Disorientation — other
	Vertigo
	Illusion — visual
	Illusion — vestibular
Attention	Attention span
	Inattention
	Distraction
	Channelized attention
	Fascination
	Vigilance
	Attention — other
Attitudes	Motivation
	Attitude
	Habituation
	Boredom/monotony
	Complacency
	Mind set/expectancy
	False hypothesis
	Get-home-itis
	Confidence — in A/C
	Confidence — in equipment
	Confidence — self
	Attitudes — other
Information processing	Mental capacity
	Decision-making
	Judgement
	Memory
	Forgetting
	Co-ordination/timing
	Information processing — other
Experience/recency	Experience — in position
	Experience — on instruments
	Experience — on A/C type
	Experience — total A/C
	Experience — other
	Recency — in position
	Recency — on instruments
	Recency — on A/C type
	Recency — on aerodrome/route
	Recency — other
Knowledge	Competence
	Skill/technique
	Airmanship
Training	Training — initial
	Training — on-the-job
	Training — ground
	Training — flight
	Training — recurrent
Planning	Planning — pre-flight
	Planning — in-flight
Mental state	Emotional state
	Anxiety
	Apprehension
	Panic
	Arousal level/reactions
	Mental pressure — self stress
Personality	Type — aggressive
	Type — assertive
	Type — non-assertive
	Type — other
Workload	Task saturation
	Underload
	Situational awareness
	Prioritization
Other psychological limitations	

Psychosocial — the person's interaction with the non-work community

Off-duty problems	Mental pressure
	Interpersonal conflict
	Personal loss
	Financial problems
	Significant lifestyle changes
	Culture
	Family pressure
Other psychosocial limitations	

THE INTERFACES BETWEEN INDIVIDUALS AND THEIR WORK

Between people — the interaction of the person with other persons in the workplace

Oral communication	Misinterpretation
	Phraseology
	Language barrier
	Readback/hearback
	Other communications
Visual signals	Signage
	Ground/hand signals
	Body language
	Data link
Crew interactions	Crew supervision
	Crew briefing
	Crew co-ordination
	Crew compatibility
	Crew resource management
	Crew task assignment
	Crew — other behaviour
Controllers	Controller supervision
	Controller briefing
	Controller co-ordination
	Controller — other
Passengers	Passenger behaviour
Other interaction	

Human-machine — the interaction of the person with the equipment at the workstation

Equipment	Instrument/controls design
	Instrument/controls location
	Workspace layout
	Workspace standardization
	Personal comfort
	Motor workload
	Information displays
	Obstacles to vision
	Alerting and warnings
	Eye reference position
Other interaction	

Human-system support — the interaction of the person with the supporting systems for the workplace

Written information	Manuals
	Checklists
	Publications
	Regulations
	Maps and charts
	NOTAMs
	Standard operating procedures
Computers	Computer software
	User-friendliness
Automation	Operator workload
	Monitoring task
	Task saturation
	Situational awareness
	Skill maintenance
Other human-software interaction	

Human-environment (internal) — the interaction of the person with the environment in the immediate work area

Environment	Heat
	Cold
	Ambient pressure
	Illumination
	Glare
	Acceleration
	Effect of noise
	Noise interference
	Vibration
	Air quality
	Humidity
	Pollution/fumes
	Ozone
	Radiation
	Other physical working conditions

Human-environment (external) — the interaction of the person with the weather and the environment outside the immediate work area

Weather/geography	Weather visibility
	Turbulence
	Infrastructure
	Time of day
	Lighting/glare
	Other air traffic
	Windblast
Illusion	Somatogravic
	Somatogyral
	The leans
	Coriolis
	Empty field myopia
	White-out
	Flicker vertigo
	Aerodrome — landing illusions
	Illusions — other

Worker-management — the interaction of the worker with the management

Personnel	Personnel recruitment
	Personnel staffing
	Personnel training
	Personnel policies
	Remuneration/incentives
	Personnel requirements
	Personnel scheduling
	Crew pairing
	Seniority
	Resource allocation
	Operational support
	Operational control
	Instructions/directions/orders
	Managerial operating pressure
Supervision	Operational supervision
	Quality control standards
Regulatory requirements	Qualification — in position
	Qualification — on type
	Certification
	Medical certificate
	Licence/rating
	Non-compliance
	Infraction history
	Other regulatory factors
Labour relations	Employee/management relations
	Industrial action
	Union/professional group
Pressures	Mental pressure — operational
	Morale
	Peer pressure
Other human-environment interaction	

Appendix 4
AVIATION ACCIDENT/INCIDENT DATA BASES

The most useful sources of supporting factual information come from reference and data bases directly related to the aviation operational environment, because these can be most easily generalized to the factual data pertaining to an aviation accident. The data from these data bases can be used (with some caution) to answer the question “What are the frequencies of such occurrences or behaviours?” (i.e. how many accidents or incidents have involved the same performance shortcomings?). Of course, specific information about the sample characteristics of the data bases being examined, and about the exposure rates of aircraft or pilots in similar situations is necessary in order to reach any conclusions about probabilities of similar accidents or incidents occurring again. Some examples of such data sources follow.

Investigation authority accident/incident data bases

ICAO maintains the ADREP system described in Document 9156. In addition, several ICAO States maintain their own accident/incident data bases. Each follows a different format, and human performance data is accessed in each case by different methods. Since there is not yet a standard vocabulary for Human Factors in aviation accidents, or a standard taxonomy for human error causation, there is no single set of key words that one can use to find common Human Factors causes across all data bases.

Several accident data bases contain valuable information, and they are well worth studying as long as the investigator is aware of the meaning of the retrieved data. All States do not use the same criteria for selecting accidents for inclusion in their data bases, so statistical analyses which involve combining data from more than one data base are risky. Even more important, data base codes (i.e. Human Factors key words) mean different things to different people. It is strongly recommended that the investigator accessing data from these data bases get assistance from the data base administrator. It is also wise for the investigator to question field investigators and coders who are responsible for coding the raw information for input into the data base. These people will be the only ones who will be able to explain, for example, what criteria have been used when coding “mental performance overload” or “self-induced pressure” as an underlying cause factor in an accident.

Manufacturer accident/incident data bases

Several aircraft manufacturers maintain their own accident/incident data bases for their own use and for that of their customers. Some of these data bases are available to the public. One example of manufacturer accident/incident data bases which may be of interest to the investigator follows.

- Boeing Commercial Airplane Company’s Product Safety Organization publishes a yearly statistical summary of commercial jet aircraft accidents, and manages both a computer-based and a hard copy data base of all commercial jet aircraft accidents (excluding Russian manufactured or operated aircraft and military operators of commercial-type aircraft). Accident data are obtained from government accident reports, operators, manufacturers, and various government and private information services. Accident selection essentially corresponds to the U.S. National Transportation Safety Board's (NTSB) accident definition. Variables of interest in this data base are phase of flight (workload considerations), aircraft type (design) cause factors (including primary flight crew).

Accident/incident voluntary reporting systems

Much valuable Human Factors information is available from largely confidential reporting systems used by several States to collect accident and incident information from involved pilots, controllers and other aviation personnel. These reporting systems are voluntary (the person experiencing, or with knowledge of, the incident is under no obligation to make a report), and usually some amount of protection is granted to the reporter, who in most cases has committed an unintentional error while flying or controlling an aircraft. The reporter may be guaranteed some degree of immunity from legal action (e.g. suspension or revocation of pilot licence) in exchange for which the agency collecting the reports is afforded an insightful look at the conditions underlying the incident. This kind of information is nearly impossible to obtain after an accident or incident using normal investigative methods, either because the pilot is deceased or because the reporter (pilot, controller or other) is not forthcoming for fear of reprisals from the government licensing agency, police or employer.

In general, reports from involved personnel, whether gathered by an investigator post-incident or reported by the involved person to a confidential reporting system, are vulnerable to untruths and inconsistencies and should be considered by the investigator as just another piece of information to be weighed and validated. Confidential reporting systems are susceptible to misinterpretation if the investigator attempts to make statistical inferences about the data, incorrectly assuming the sample in this type of data base is comparable to the sample in a State investigative accident data base such as the ICAO ADREP data base or the NTSB data base in the United States.

Confidential reporting systems contain only information voluntarily reported. Depending upon the level of immunity accorded and upon the types of errors for which such immunity is granted, levels of reports for certain types of errors may be inflated. For example, in the United States' Aviation Safety Reporting System (ASRS), which is jointly run by the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA), a large percentage of reports involve deviations from assigned altitudes, because pilots who report these deviations to ASRS are protected from suspensions of their licences (the common punishment for such a deviation).

Therefore, the investigator who chooses to use data from confidential reporting systems should consult administrators of these data bases to understand the significance of the data. As with the accident/incident data bases, these data can be very helpful as long as the investigator understands the scope and limitations of the data base.

Among the confidential reporting system data bases are:

Australia
The Manager, CAIRS
P.O. Box 600
Civic Square
ACT 2608

Canada
CASRP
P.O. Box 1996
Station B
Hull, P.Q.
J8X 9Z9

New Zealand
Confidential Safety Feedback System
Independent Safety Assurance Team
P.O. Box 12051
Auckland

United Kingdom
CHIRP
Freepost
RAF IAM
Farnborough, Hants.
GU14 6BR

United States
ASRS Office
625 Ellis Street, Suite 305
Mountain View, CA
94043

Appendix 5
HUMAN PERFORMANCE INVESTIGATION TRAINING

Notwithstanding the fact that human performance investigators need not be specialists in human performance, generalist investigators must possess an over-all awareness and understanding of human performance concepts and principles, and their application to aviation, if they are to be successful human performance investigators. To this end, it is essential that they all receive a minimal level of relevant training. Given the requisite training, the experience accident investigator should be able to conduct all but the most specialized aspects of the human performance investigation.

Human performance investigation training should include guidance on the interdisciplinary nature of the human performance investigation, fundamental areas of examination, data that should be collected, data sources, data collection methods including interview techniques, and analytical techniques. Training should also include general guidance on recommended reference material and on the type of specialists that are available to assist in the investigation of human performance, where they can be found and when it would be appropriate to employ them.

Several sources of general education courses in human performance concepts exist. They include both educational institutions and private contractors. New programmes are being constantly developed and to the extent that ICAO is aware of new programmes, the Organization will provide information to those interested. A list of example courses and sources can be found in Human Factors Digest No. 1 — *Fundamental Human Factors Concepts*.

Courses which focus specifically on the investigation of human performance are less prevalent. Information on course availability should be sought from national accident investigation agencies.

Appendix 6
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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.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

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