MINISTRY OF TRANSPORT AND COMMUNICATIONS

REPUBLIC OF THE UNION OF MYANMAR

AIRCRAFT ACCIDENT INVESTIGATION BUREAU

OPERATIONAL, HUMAN FACTOR AND ORGANIZATIONAL ASPECTS MANUAL

Effective Date- 7th August 2020 First Edition

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SECTION 0	: MANUAL ADMINISTRATION
CHAPTER 1	**: FOREWORD**

1. This Operational, Human Factor and Organization Manual is an internal document of the Aircraft Accident Investigation Bureau (AAIB) of Myanmar. It contains guidance material relating to the operational ,human factor and organizational aspects for conducting accident investigation.

2. Except for material which has been approved for public distribution, the contents of this Manual are not intended to be communicated to persons outside the AAIB without the consent of the AAIB.

3. This Manual is not regulatory in nature and is not a binding statement of policy, and is not all inclusive. Deviation from the guidance offered in this Manual may at times be necessary to meet the specific needs of an investigation.

4. The Manual will be revised when necessary. The Investigators of Accidents and AAIB officers are encouraged to contribute ideas for improving the contents of this Manual.

Aung Maw
Deputy Director
Aircraft Accident Investigation Bureau
Ministry of Transport and Communications

SECTION 0	**: MANUAL ADMINISTRATION**
CHAPTER 2	**: CONTENTS**

Sections/ Chapters		Page
SECTION 0	**MANUAL ADMINISTRATION**	
Chapter 1	Foreword	0-1-1
Chapter 2	Contents	0-2-1
Chapter 3	List of effectivity pages	0-3-1
Chapter 4	Amendment record	0-4-1
SECTION 1	**THE INVESTIGATION MANAGEMENT SYSTEM**	
Chapter 1	Foreword	1-1-1
SECTION 2	**ERGONOMICS**	
Chapter 1	Introduction	2-1-1
Chapter 2	Basic Facts about Ergonomics	2-2-1
Chapter 3	A Systems Approach to Safety	2-3-1
Chapter 4	Control of Human Error	2-4-1
SECTION 3	**HUMAN CAPABILITIES**	
Chapter 1	The Visual System	3-1-1
Chapter 2	The Vocal and Auditory Systems	3-2-1
Chapter 3	Human Information Processing	3-3-1
Chapter 4	Human Dimensions	3-4-1
SECTION 4	**DISPLAYS, CONTROLS AND FLIGHT DECK DESIGN**	
Chapter 1	Introduction	4-1-1
Chapter 2	Displays	4-2-1
	Appendix 1: Advisory, Caution and Warning (ACW) Systems	4-2-1A-1
Chapter 3	Controls	4-3-1

SECTION 5 THE ENVIRONMENT

Chapter 1	Stress	5-1-1
Chapter 2	Noise	5-2-1
Chapter 3	Temperature	5-3-1
Chapter 4	Humidity	5-4-1
Chapter 5	Pressure	5-5-1
Chapter 6	Illumination	5-6-1
Chapter 7	Vibration	5-7-1

SECTION 6 HUMAN FACTORS TRAINING FOR SAFETY INVESTIGATORS

Chapter 1	Introduction	6-1-1

SECTION 7 NEED FOR AND PURPOSE OFHUMAN FACTORS INVESTIGATION

Chapter 1	Background	7-1-1
Chapter 2	The Nature of Accidents and Incidents	7-2-1
Chapter 3	Definition of an Accident and an Incident	7-3-1
Chapter 4	Systems Approach to the Investigation of Human Factors	7-4-1
Chapter 5	Accident Scenario	7-5-1
Chapter 6	Investigation of Incidents	7-6-1
Chapter 7	Conclusions	7-7-1

SECTION 8 CONDUCT OF THE INVESTIGATION

Chapter 1	General	8-1-1
Chapter 2	The Single Investigator	8-2-1
Chapter 3	The Human Factors Investigator	8-3-1
Chapter 4	The Human Factors Group	8-4-1
Chapter 5	The Shel Model	8-5-1
Chapter 6	Use of Checklists	8-6-1
Chapter 7	Information Sources	8-7-1
Chapter 8	Analysis of Data	8-8-1

SECTION 9 REPORTING AND PREVENTIVE ACTION

Chapter 1	General	9-1-1
Chapter 2	Structure of the Report	9-2-1
Chapter 3	Accident Prevention	9-3-1
Chapter 4	Data Base Requirements	9-4-1

Appendix 1 HUMAN FACTORS CHECKLISTS (Section 6 to 9) 6 to 9-1A

SECTION 10 ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION

Chapter 1	General	10-1-1
Chapter 2	The Investigation Management System	10-2-1
Chapter 3	Progress Meetings	10-3-1
Chapter 4	Cooperation with the Media	10-4-1
Chapter 5	Dealing with Families of Accident Victims	10-5-1
Chapter 6	Securing the Records, Samples and Recordings	10-6-1
Chapter 7	Removal of the Aircraft Wreckage	10-7-1
Chapter 8	Release of the Aircraft Wreckage	10-8-1

SECTION 11 REFERENCES

Chapter 1	Sources of Technical Information	11-1-1

SECTION 0	**: MANUAL ADMINISTRATION**
CHAPTER 3	**: LIST OF EFFECTIVITY PAGES**

Page	(to) Page	Rev No.	Rev Date	Page	(to) Page	Rev No.	Rev Date
0-1-1				7-3-1			
0-2-1	0-2-3			7-4-1	7-4-4		
0-3-1				7-5-1	7-5-4		
0-4-1				7-6-1	7-6-2		
1-1-1	1-1-2			7-7-1			
2-1-1	2-1-2			8-1-1	8-1-2		
2-2-1				8-2-1			
2-3-1	2-3-3			8-3-1			
2-4-1	2-4-2			8-4-1	8-4-2		
3-1-1	3-1-4			8-5-1	8-5-8		
3-2-1	3-2-3			8-6-1			
3-3-1	3-3-4			8-7-1	8-7-3		
3-4-1	3-4-2			8-8-1	8-8-4		
4-1-1				9-1-1	9-1-2		
4-2-1	4-2-4			9-2-1	9-2-6		
4-2-1A-1	4-2-1A-2			9-3-1	9-3-5		
4-3-1	4-3-13			9-4-1			
5-1-1				6 to 9-1A	6 to 9-15A		
5-2-1	5-2-2			10-1-1			
5-3-1	5-3-2			10-2-1	10-2-6		
5-4-1				10-3-1	10-3-2		
5-5-1				10-4-1	10-4-2		
5-6-1				10-5-1	10-5-2		
5-7-1				10-6-1			
6-1-1	6-1-2			10-7-1			
7-1-1	7-1-4			10-8-1	10-8-2		
7-2-1				11-1-1			

SECTION 0	**: MANUAL ADMINISTRATION**
CHAPTER 4	**: AMENDMENT RECORD**

Amendment No.	**Date of issue**	**Date entered**	**Entered by**

SECTION 1	: THE INVESTIGATION MANAGEMENT SYSTEM
CHAPTER 1	**: FOREWORD**

1. This section provides a synopsis of the Investigation Management System.

2. In the case of an accident investigation involving a large or complex aircraft, a large team of investigators is usually required to conduct the investigation in the most effective and expeditious way. The effective management of a major investigation requires a management system based on a comprehensive plan, checklists, and a method and flow charts to track the progress of the investigation. In effect, a major investigation is a project that must be managed. This section of the manual presents one such project management system, entitled the “Investigation Management System”. This system divides the investigation activities into functional events. Each event is numbered with a corresponding descriptive phrase. The list of Investigation Management System events is contained in Part II of Doc 9756.

3. To assist in the management of the investigation and the monitoring of the workload, each event should be assigned to a group within the investigation team. These assignments should be documented. An example of the investigation event task-assignment chart is contained in Part II of Doc 9756.

4. The Investigation Management System flow chart, which consists of a set of events, should be completed sequentially in the course of an investigation. The flow chart allows the investigators to ensure that the essential sequence of events is followed and, as well, provides an up-to-date picture of what has been completed to date. An example of the Investigation Management System event flow chart is contained in Part II of Doc 9756.

5. A checklist is provided for each Investigation Management System event. The checklists may differ somewhat from one State to another due to local conditions and procedures. The checklists should be reviewed to ensure that the tasks are appropriate to the organization and conduct of accident investigations and are in line with the procedures of the State. The breakdown of activities and tasks into checklists allows the investigator-in-charge to clearly indicate what is to be accomplished by the investigators and by the groups during an investigation.

6. Use of the task-assignment flow chart, the event flow chart and checklists also allows the investigator-in-charge to provide direction and guidance to persons who are participating in an investigation for the first time and who may require specific advice. The checklists, aside from being

part of the Investigation Management System, provide for some order in what is sometimes a confusing situation. The Investigations Management System event checklist is contained in Part II of Doc 9756.

7. The investigation team members should be familiar with the Investigation Management System. The group chairpersons must be knowledgeable about this system and the tasks that their groups will be required to carry out. Group chairpersons should be well aware that the tasks listed for each event may not be complete and that particular circumstances may require additional tasks. When using the checklists, it is desirable that the investigators make notes of the date of completion of each task. They should also make notes when further action is required and note things of significance associated with a particular task. Regardless of how much planning goes into the provision of this type of checklist, there will be cases in which the outlined tasks have to be adapted to the special circumstances of the investigation.

8. The event flow chart and the checklists provide tools for the group chairpersons to organize the work of their groups. The flow chart also provides the investigator-in-charge with a tool to monitor progress. At the daily progress meetings, the investigators should report the particular tasks in their checklists that have been completed since their last report, and the investigator-in-charge should note the progress on the event flow chart. Another advantage of using this chart is the ease with which progress of the investigation can be reported to the headquarters office from the investigation site.

9. The Investigation Management System is one of the tools that an investigator should be called upon to use. The effectiveness of the Investigation Management System is directly related to the adherence to the flow chart and the checklists. An investigator likely to be appointed investigator-in-charge or group chairperson in a major investigation should be familiar with this system prior to attempting to use it in the field.

SECTION 2	: ERGONOMICS
CHAPTER 1	: INTRODUCTION

1. Ergonomics has been applied in the design of tools, even in an elementary way, since the beginning of civilization. In aviation, the focus in the early pioneering days — and for many years afterwards — was on advancing some general principles to guide the design of flight deck displays and controls. This later broadened into the experimental analysis of the design and layout of equipment, in close association with the analysis of the demands and workload that the equipment and tasks imposed upon the human operator. Today's approach to design takes the user's characteristics (capabilities, limitations, and needs) into consideration early on in the system development process, and subordinates engineering convenience to them. The terms "user-friendly" and "error tolerant", referring to modern equipment, reflect this intent.

2. It cannot be denied that technological progress has occurred, nor that such progress has enhanced flight safety, but operational experience indicates that human error is still induced to a significant extent by shortcomings in equipment design or in the procedures used to operate the equipment. Only by taking into account appropriate Human Factors considerations in system design can safety be further enhanced. It would be misleading, however, to propose that safety in the system can be achieved through design improvement alone: a systems approach to aviation safety is required.

3. This chapter addresses Human Factors issues relative to the interface between humans and machines in aviation. This interface has traditionally been viewed as presenting simple "knobs and dials" solutions to Human Factors problems. In some cases, these solutions could be found by looking at the appropriate table, but an understanding of how to solve Human Factors problems with respect to the human-machine interface within the aviation system is more than learning how to look at tables, especially since such simple solutions may not be valid for all situations.

4. The purpose of this chapter is to increase the awareness of the pervasiveness and influence of ergonomics in aviation safety. It is intended to provide basic knowledge — as well as a source of information — which will enable the reader to call upon the proper expertise when so required. It also intends to convey, in simple language, the current state-of-the-art information available from States, and to encourage the use of available education and training. This chapter:

- presents the basic facts about ergonomics, including the difference between ergonomics and Human Factors;

- discusses human capabilities that should be taken into account in equipment design;
- discusses the design of displays and controls, and how they are integrated into the flight deck;
- refers to environmental stresses of relevance to ergonomics.

SECTION 2	**: ERGONOMICS**
CHAPTER 2	**: BASIC FACTS ABOUT ERGONOMICS**

While in many countries the terms *ergonomics* and *Human Factors* are used interchangeably, there is a small difference in emphasis. Human Factors has acquired a wider meaning, including aspects of human performance and system interfaces which are not generally considered in the mainstream of ergonomics. The two terms may be considered synonymous, to preclude dwelling on academic or semantic considerations and to avoid confusion; however, it indicates that the term *ergonomics* is used in many States to refer strictly to the study of human-machine system design issues. From this perspective, ergonomics is the study of the principles of interaction between human and equipment, for the purpose of applying them in design and operations. Ergonomics studies human attributes, determining what requirements in hardware and software result from the characteristics of the activities involved. It attempts to solve the problem of adapting technology and working conditions to humans. Throughout this chapter, this latter concept of ergonomics has been adopted, and as such, it is clearly differentiated from Human Factors.

SECTION 2	: ERGONOMICS
CHAPTER 3	**: A SYSTEMS APPROACH TO SAFETY**

1. Safety in aviation through design can best be achieved following a system approach strategy. A system approach is a way of breaking down the “real world” into identifiable components, and looking at how these components interact and integrate. The Liveware-Hardware interface in the **SHEL** model can be seen as a *human-machine system*, comprising people and machines interacting in an environment in order to achieve a set of system goals. Ergonomics will try to optimize the interaction between people and machines in the system (the L-H interface), while taking into consideration the characteristics of all system components (e.g. the environment as well as the software).

2. A simplified representation of the person-machine system is shown in Figure 2-1. The *machine component* is displayed on the right. Displays (e.g. visual and auditory) inform the human about the status of the internal system or about conditions external to the system, while controls allow the human to effect changes in the system status. The *human component* of the system is shown on the left side of Figure 2-1. Information displayed must be perceived and processed by the human, and then conscious decisions may be made. Motor responses may be sent to effect changes in control settings. The line depicted in Figure 2-1 separating the machine and human represents the *human-machine interface*. Information travels through this interface in both directions; ergonomics is very much concerned with getting the information across this interface, and the ergonomist must ensure that displays and controls are compatible with human capabilities and task needs.

3. System goals must be defined before a person-machine system can be specified and designed. These goals, together with the identified operational constraints, spell out the conditions within which the person-machine system will function. Operation of the system outside this set of conditions may lead to unsafe conditions.

4. Another important task of the ergonomist is the allocation of functions and tasks to the human and machine components. The system design team (including the ergonomist) decides what functions should be given to the hardware and software and to the human, based on considerations such as human characteristics, task needs, workload, costs, training requirements, and technologies available. Functions allocated inappropriately may jeopardize system effectiveness and safety. The tendency to compare human and machine, in terms of the functions for which humans are superior to machines vis-à-vis those for which machines are superior to humans, should not be allowed to lead to a simplistic allocation of functions entirely to the human or the machine. Humans and machines should

be *complementary* in the accomplishment of tasks. Furthermore, this complementarity should be designed with adequate flexibility so that function allocation can be adapted to various operational situations (from routine flight to emergencies).

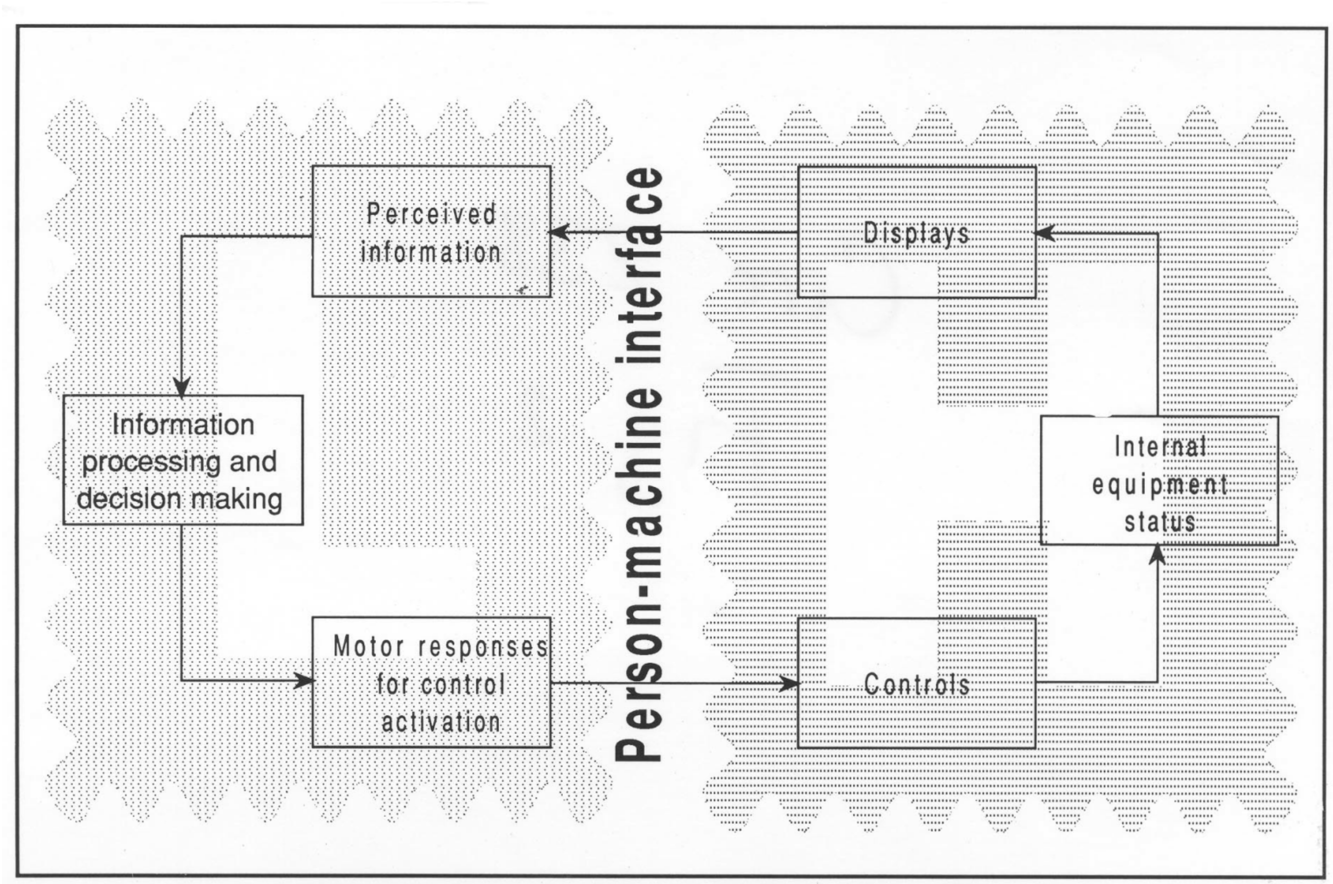


Figure 2-1. Representation of a person-system machine
(adapted from Meister, 1979)

5. The ergonomist must proceed systematically in order to achieve the desired system goals. The following set of example questions illustrates how an ergonomist may proceed when designing systems:

- What inputs and outputs must be provided to satisfy systems goals?
- What operations are required to produce system outputs?
- What functions should the person perform in the system?

- What are the training and skills requirements for the human operators?
- Are the tasks demanded by the system compatible with human capabilities?
- What equipment interfaces does the human need to perform the job?

A system designed without proper regard to these questions may end up like the one shown in Figure 2-2.

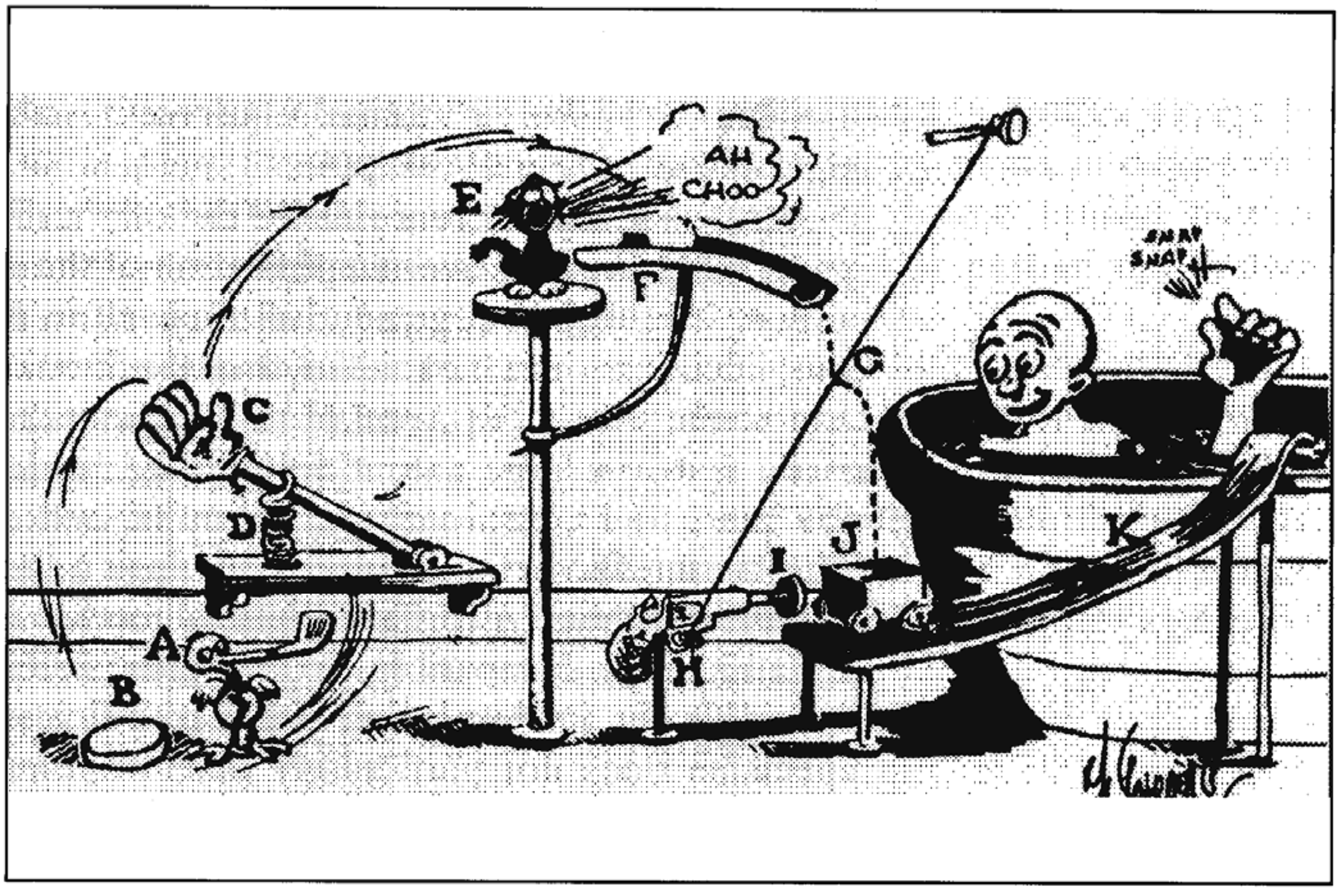


Figure 2-2. If the soap falls out of the bathtub, try this!
(adapted from *The Best of Rube Goldberg*, compiled by Charles Keller, Prentice-Hall, 1979)

SECTION 2	**: ERGONOMICS**
CHAPTER 4	**: CONTROL OF HUMAN ERROR**

1. Human error is a very complex issue. This term must be used judiciously, as it may be perceived as a loaded term implying blame. Moreover, the word "error" implies deviation from a definable correct or appropriate behaviour. In fact, appropriate behaviour is often difficult to define, and human error is increasingly being postulated as a symptom of deficiencies in equipment design or system performance rather than a cause in itself. Despite these cautions, human error continues to be an important concept in understanding the nature of and the factors affecting human behaviour, and various classifications of human errors have been proposed by different authors.

2. To minimize human error, one must first understand its nature. There are basic concepts associated with the nature of human error: *the origins and frequencies of errors can be fundamentally different*; and *the consequences of errors can also be significantly different*. While some errors may be due to carelessness, negligence or poor judgement, many are induced by poorly designed equipment or may result from the normal reaction of a person to a stressful situation. Errors due to poor equipment design or stressful situations are likely to be repeated and can be remedied through the practice of ergonomics.

3. Each of the interfaces in the **SHEL** model has a potential for error where there is a mismatch between its components. For example:

- The *Liveware-Hardware interface* is a frequent source of error: knobs and levers which are poorly locatedor improperly coded create mismatches at this interface.

- In the *Liveware-Software* interface, delays and errors may occur while seeking vital information from confusing, misleading or excessively cluttered documentation and charts. Problems can also be related to information presentation and computer software design.

- Errors associated with the *Liveware-Environment* interface are caused by environmental factors such as noise, heat, lighting, air quality and vibration and by the disturbance of biological rhythms.

- In the *Liveware-Liveware* interface, the focus is on the interaction between people because this process may affect crew and system effectiveness. This interaction also includes leadership and command, shortcomings in which may reduce operational efficiency and cause misunderstanding and errors. Considerations which prevent errors such as these are in the mainstream of ergonomics.

4. The control of human error requires two different approaches. First, it is desirable to *minimize the occurrence of errors* (total elimination of human error is not a realistic goal, since errors are a normal part of human behaviour). For example, errors may be reduced by ensuring a high level of staff competence; by designing controls and displays so that they match human characteristics; by providing proper checklists, procedures, manuals, maps and charts; by controlling noise, vibration, temperature extremes and other stressful conditions; and by providing training and awareness programmes aimed at increasing co-operation and communication among crew members. The second approach in the control of human error involves *minimizing the impact or consequences of errors* by providing safety buffers such as cross-monitoring, crew co-operation and fail-safe equipment design.

SECTION 3	: HUMAN CAPABILITIES
CHAPTER 1	**: THE VISUAL SYSTEM**

1. The visual system (i.e. the eyes and the associated parts of the nervous system) is generally considered to be the most important sensory system by which humans acquire information from external sources. No attempt will be made to discuss the anatomy of the visual system, since it is described in many standard texts. The emphasis is to highlight the visual system at work, what it does and does not do. Visual performance depends on several factors: some are internal to the visual system (i.e. visual acuity, accommodation and convergence, adaptation to light and darkness, perception of colours, etc.), while others are external and include variables such as task, target, and environmental characteristics (e.g. light intensity, contrast, size, location, movement and colour). All of these factors interact to determine the accuracy and speed of human visual performance. An understanding of these human and system factors will enable the ergonomist to predict and optimize system performance in a variety of operational conditions.

2. It is convenient to separate visual functions into its three component senses: light, form, and colour. The eye is capable of functioning over a wide range of light intensities, from faint starlight over full moon to bright sunshine. The eye requires time to adjust to varying levels of light intensity because the mechanism involved is a photochemical process. When adapting from dark to light the eye adjusts rapidly, whereas in adapting from light to dark the adjustment is slow. The adaptation involves three processes. First, the amount of light that can enter the eye (and thus reach the retina) is regulated by pupil size; pupil size increases when a person tries to see in the dark and decreases while in brighter light. Secondly, a photochemical process occurs when light intensity changes. Thirdly, two mechanisms function at different light intensity levels: rod vision, based on the function of the peripheral light perceptors in the retina, the rods, operates from the threshold up to moonlight level; here form acuity is poor and colours cannot be discriminated. From early morning light level, cone vision, based on the function of the central light perceptors in the retina, the cones, takes over and form acuity and colour perception become good. At the transitional stage, roughly corresponding to full moonlight, both rods and cones are functioning. Another important feature of rod and cone vision is their different spectral sensitivity, easily detected at dusk when red colours turn dark before other colours change, due to the relative insensitivity of the rods to red light. A result of this double mechanism for light appreciation is that, to detect dim lights, one must look off-centre. To endeavour to protect night vision by preserving rod adaptation (red cockpit lighting) is to a large extent illusory as very few flight tasks can be performed with rod vision.

> In November 1979, a DC-10 on a sightseeing flight over the Antarctic crashed into the side of a 12 000 ft volcano. The aircraft had descended below the overcast at 6 000 ft to provide the passengers with a view of the ice pack below. Incorrect navigation coordinates loaded into the Inertial Navigation System (INS) put the aircraft 25 miles off the correct track; however, the crew failed to spot the slopes of the volcano in a condition with 70 km visibility. Close examination of the effects of visible and invisible texture on visual perception, and the illusion caused by sector whiteout can offer an explanation regarding why the crew did not see the obstacle.
>
> *Source*: ICAO ADREP Summary 80/1.

3. Visual acuity is the ability of the visual system to resolve detail. It can be expressed in various notations, commonly, it is expressed in terms related to the smallest letter an individual can read from a Snellen chart at 20 feet compared with the distance at which a "normal" person can read the same letter. For example, 20/20 is normal vision, and 20/40 means that the individual can read at only 20 feet what a normal person would read at 40 feet. Absolute brightness, brightness contrast, time to view the object, movement and glare are among the factors which affect visual acuity.

4. To see an object sharply, the eye must focus on it. When focusing on objects between infinity and 5-6 metres, the normal eye does not change, but when focusing on objects at a shorter distance (less than c. 5 metres), two things happen: the eyes accommodate (i.e. they adjust their refractive state to correspond to the distance to the object), and the eyeballs turn inwards so that the visual axes of the two eyes converge on the object. When visual clues are weak or absent (e.g. empty space), the muscles controlling accommodation and convergence adjust by themselves to a distance of c. one metre ("empty space myopia"). This will significantly affect visual performance when a person is looking for distant objects and visual cues are weak, as is the case when trying to spot reported traffic from a flight deck.

5. Spatial orientation involves both the visual function and the vestibular apparatus ("balance organ") of the inner ear. Proprioception ("seat of the pants") plays a role too, but it is less important. It is also influenced by past experience. Figure 3-1 presents a simplified model of this activity.

In June 1988, an Airbus A320 crashed in Mulhouse-Habsheim, France, during a flight. The report of the Investigation Commission includes the following remarks on the subject of visual misjudgment: "Whereas he [the captain] was accustomed to using 2 000- to 3 000-m long runways with approximately 100-ft high control towers, he found himself on an 800-m long grass strip with a 40-ft high tower; the scale effect may have created a false impression." The report also mentions that the very high nose-up attitude, given the approaching maximum angle-of-attack, would have put the pilot's eye-level particularly high compared with the rest of the airplane. The first tree impact involved the rear fuselage.

Source: ICAO ADREP Summary 88/3.

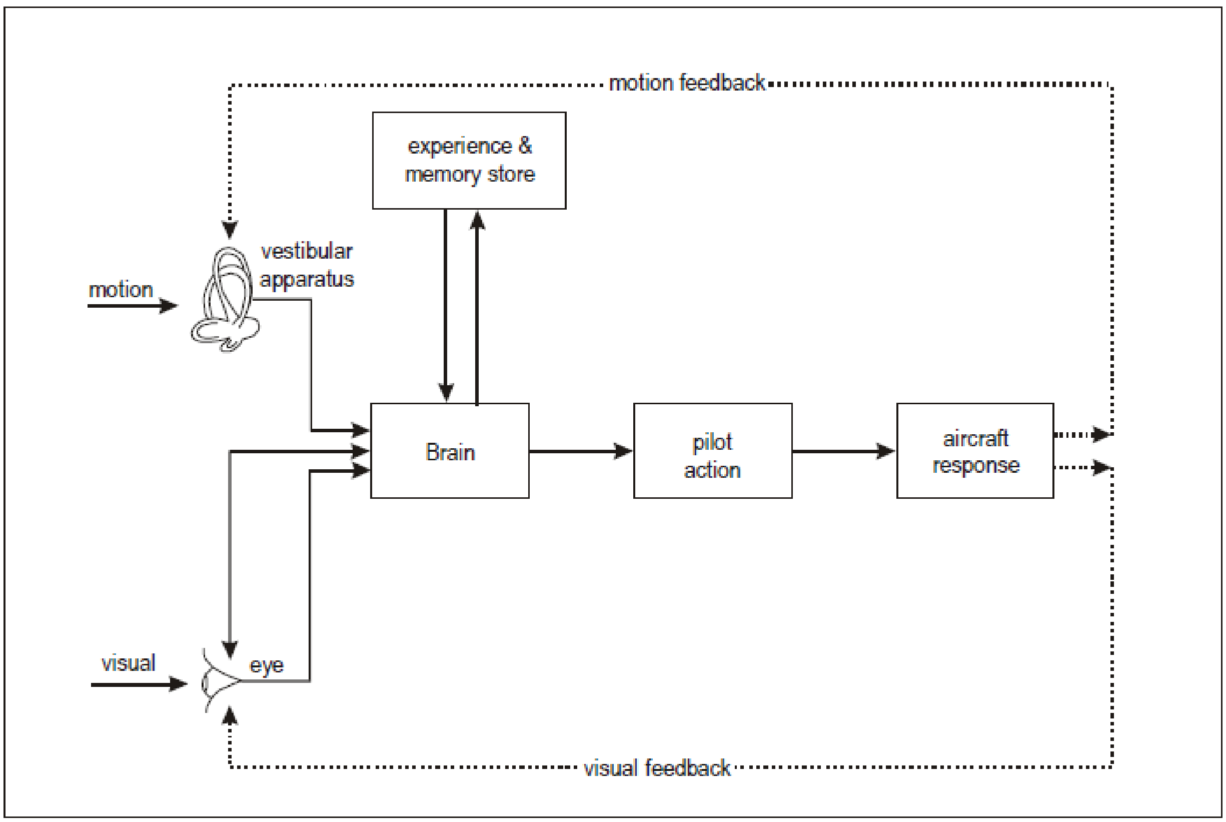


Figure 3-1. A simplified model illustrating some of the components involved in visual perception
(adapted from Hawkins, 1987)

6. The eye usually conveys the information sensed fairly faithfully. Ambiguity and uncertainty may occur, however, when this sensed information is processed by the brain and combined with emotional factors, past learning, experience or expectation. These factors are included in the mind set, which is well reflected in the popular saying that one sees what one expects to see. For example, a warning light indicating system failure may be correctly sensed, but a pilot's past experience with nuisance warnings may suggest that the warning is based on a faulty signal and can therefore be ignored.

7. The failure to respond to a visual stimulus even when clearly perceived may be due to fascination (i.e. conning of attention). In such a case, the pilot concentrates on one flight instrument — for example, the flight director — and disregards other important information to which the pilot should respond. Fascination occurs not only under conditions of high workload, but also when workload is low and tedium prevails.

> A de Havilland DHC6-300 Twin Otter, hauling a diamond drill and crew, was approaching to land onto a 700-ft long esker (an esker is a geological formation like a sand bar) near Concession Lake, Yellowknife, Canada. The aircraft touched down in a ravine, 65 ft short. The pilot had never landed in this particular esker before and he did not notice an 8-degree upslope, resulting in a flat approach.
>
> *Source:* ICAO ADREP Summary 89/381.

8. ***Visual illusions*** of one kind or another have been experienced by all flight deck crew members. For many years physiologists and psychologists have been proposing theories to explain them, and such studies and general information on visual illusions in aviation can be found elsewhere. For the purpose of this chapter, it is enough to emphasize human vulnerability to these phenomena.

> A Cessna Citation was descending from FL330 for a visual night landing at Stornoway, UK, in December 1983. The aircraft was observed on the radar display continuing a steady descent to sea level, where the radar trace disappeared, 10 mi from its destination. The night was very dark, and there was a layer of stratus clouds between 1 000 and 3 000 ft. Radar recordings indicate that at about 3 000 ft, the pilot reduced to approach speed, lowered the flaps and gear and descended very rapidly. All occupants died of drowning, indicating a non-violent impact with the sea. No evidence was found from the partially recovered wreckage indicating engine or airframe failure. The approach over the dark sea towards a lighted area fostered conditions conducive to visual illusions.
>
> *Source:* ICAO ADREP Summary 85/1.

SECTION 3	: HUMAN CAPABILITIES
CHAPTER 2	**: THE VOCAL AND AUDITORY SYSTEMS**

1. The ***vocal system*** generates speech, which is the result of the interaction of several of its components. Different voices utilize different ranges of pitch and frequency, and although there are many ways in which speech can be deformed, so long as the pattern of frequency remains intact, the speech will remain intelligible. The ***auditory system*** senses audio signals and speech, and conveys them to the brain for processing. The external ear comprises the pinna, auditory canal, and eardrum. The middle ear has three small bones called ossicles, which transmit sound from the outside to the inner ear. The middle ear is connected to the nose and throat; through swallowing, yawning or sneezing, pressure within the middle ear is equalized with that of the outside. The inner ear houses the vestibular apparatus which has functions such as maintaining balance and providing the brain with information related to acceleration and changes of position.

2. Impaired hearing may be a result of the connection between the middle ear and the mouth/nose being blocked (e.g. due to a common cold). It may also be caused by the deposit of new bone or calcium material in the ossicles or by infections in the middle ear causing accumulation of fluid which dampens the movement of sound transmitting components. Long-term exposure to loud noise (such as that from machinery or aircraft engines) may damage permanently nerves in the inner ear. Disease conditions such as brain tumours and strokes can interfere with the functioning of the brain region which is associated with hearing. Lastly, hearing ability generally deteriorates with age.

3. There are four primary characteristics of sound in speech: *intensity* (sound pressure level), which is measured in decibels (dB) and results in the subjective sensation of loudness; *frequency*, which is measured in hertz (Hz) or cycles per second and produces the sensation of pitch; *harmonic composition*, which refers to the quality of speech; and the *time factor*, which reflects the speed at which words are spoken, the length of the pauses, and the time spent on different sounds.

4. ***Noise*** is any unwanted sound or sound which has no relationship with the immediate task. It may interfere with speech communications, annoy the listener or affect task performance, and it may have health implications. The relationship between the loudness of the “wanted” sound and that of the background noise is called *signal-to-noise ratio*, which is more important factor than the absolute level of the signal or noise when determining intelligibility. Noise as an environmental stressor is further discussed later in this chapter.

"On arrival to work I climb into a helicopter (worth about three million pounds) and am subjected to appalling noise levels — even allowing for the use of a good headset AND earplugs, very aggravating levels of vibration, an excruciatingly uncomfortable seat, a cockpit heater that works flat out or not at all — etc., etc. The list goes on and on. Why has the situation been allowed to come about? How can this situation be resolved? …"

Source: CHIRP *Feedback* No. 10, April 1986 [*Feedback* is the periodic bulletin of the United Kingdom CAA Confidential Human Factors Incident Report (CHIRP)].

…Towards the end of this transmission (the ATC clearance), the CVR showed that the captain made the exclamation "Yes!". Some five seconds later, while the first officer was still reading back the ATC clearance, the captain said, "We go — check thrust ..." followed by the sounds of engine spin-up.

The CVR showed that the last portion of the first officer's readback became noticeably hurried and less clear. He ended his readback with the words, "We are now — uh — taking' off" or "We are now at take-off".

The controller then said, "Okay (pause) stand by for takeoff, I will call you". On the KLM CVR, the portion of this transmission following the word "okay" was overlaid by a high-pitched squeal, and the tone of the controller's voice was somewhat distorted, though understandable.

In Clipper 1736, upon hearing the KLM first officer advised that they were "taking off", and the controller's "okay" and pause, the Pan Am first officer transmitted: "and we are still taxiing down the runway — the Clipper one seven three six". It was this transmission which caused the squeal and the distortion in the KLM cockpit of the controller's transmission directing them to stand by for takeoff. The Pan Am transmission was itself totally blocked by the controller's transmission to KLM. Only the words "Clipper one seven three six" were heard in the tower. The controller then said, "Papa Alpha one seven three six, report runway clear", to which the Clipper replied, "Okay, we'll report when we are clear". During these transmissions, KLM 4805 continued to accelerate on its takeoff run.

Aboard the KLM aircraft, the flight engineer asked, "Is he not clear, then?" The captain said, "What did you say?" The flight engineer: "Is he not clear, that Pan American?" To this, both captain and first officer responded with a positive and almost simultaneous, "Yes".

About seven seconds later, the first officer called, "V one". Three seconds later, the Dutch crew saw directly in front of them the shape of Clipper 1736 turning to KLM's right in its attempt to clear the runway. At 1706:49 GMT, KLM 4805 collided with Clipper 1736.

Source: "Human Factors Report on the Tenerife Accident" U.S. ALPA.

5. *Redundancy* in spoken language helps to convey information even when the sound is distorted or surrounded by noise. One underlying danger in the case of distorted information is that gaps are filled in by the listener based on previous experience, learning and expectation, hence there is a risk of false hypothesis emerging. *Masking* is the consequence of one sound component (e.g. unwanted noise) reducing the ear's sensitivity to another component (e.g. an audio signal or speech). The more the speech content is lost — through distortion, noise, personal hearing deficiencies, etc. — the greater the risk of expectation playing a role in the interpretation of aural messages. The consequence of this may be disastrous.

6. Ergonomics attempts to mitigate the adverse effects of noise on hearing and speech intelligibility by attacking the problem at the source, transmission, and/or receiver end of the signal, speech, or noise.

SECTION 3	**: HUMAN CAPABILITIES**
CHAPTER 3	**: HUMAN INFORMATION PROCESSING**

1. Humans have a powerful and extensive system for sensing and processing information about the world around them. The information sensing and processing can be broken down into several stages as generalized in Figure 3-2. Information in the form of stimuli must be sensed before a person can react to them. There exists a potential for error, because the sensory systems function only within a narrow range. Once stimuli are sensed, they are conveyed to and processed by the brain. A conclusion is drawn about the nature and meaning of the message received. This interpretative activity involving high-level brain functions is called ***perception***, and is a breeding ground for errors. Expectation, experience, attitude, motivation, and arousal all influence perception and may cause errors.

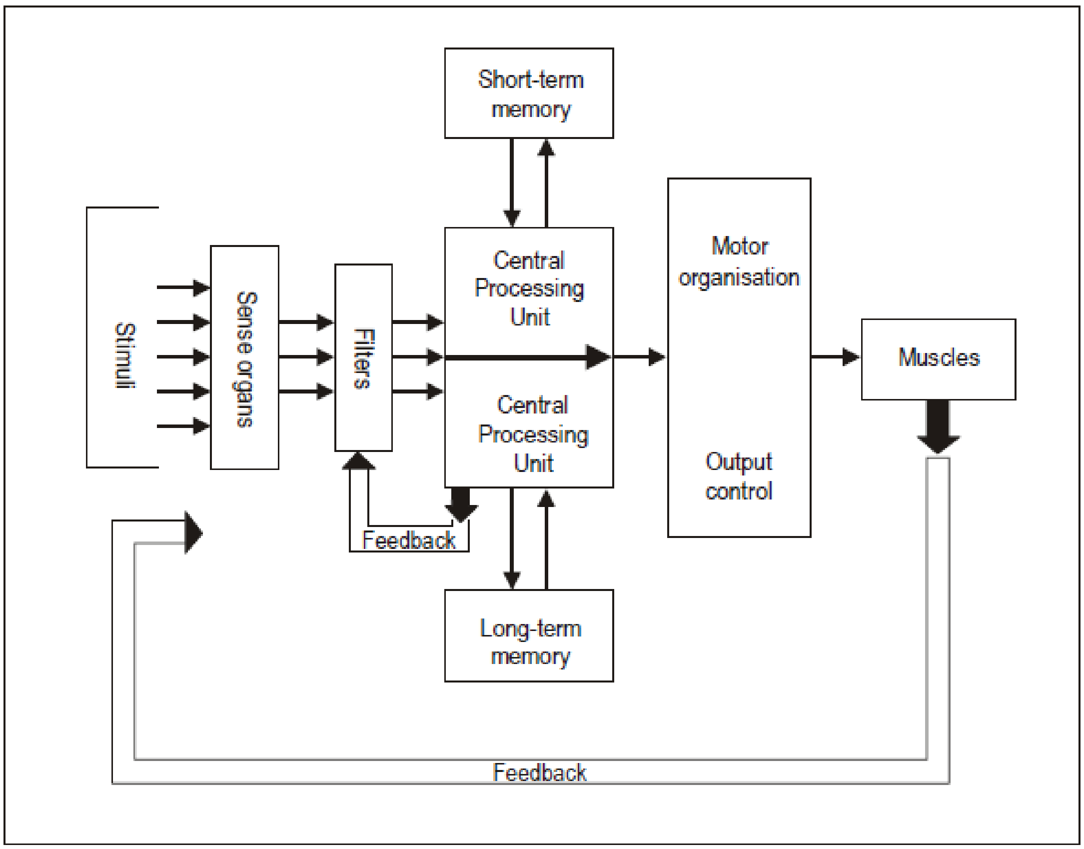


Figure 3-2. Model of the human information processing system
(adapted from Hawkins, 1987)

2. After conclusions have been formed about the meaning of stimuli, decision-making begins. Again, many factors may lead to erroneous decisions: inadequate/ inappropriate training or past

experience; emotional or commercial considerations; fatigue, medication, motivation and physical or psychological conditions. Action (or inaction) follows decision. Once action has been taken, a feedback mechanism may be available to inform the person how effective the action was. Potential for committing errors exist in these two last phases.

3. The ability to remember is essential to human information processing; even the simplest system cannot function without memory. Since human memory is a limited resource, the ergonomist must be careful to design systems that do not overload it. There is a distinction between long-term and short-term memory. Long-term memory is associated with the retention and retrieval of information over a long period of time. Instruction and training are effective means of enhancing those retention and retrieval capabilities. Short-term memory allows data retention and processing for current activities. The data readily fade away after the activities are completed.

4. The duration of information storage differentiates short-term from long-term memory. Short-term memory involves rapid, continuous changes in information, and allows short-term retention and processing of data. Long-term memory involves less frequently repeated sequences and is characterized by long-term storage of information. Repetition or rehearsal allows information to be stored in long-term memory.

5. Short-term memory has very limited capacity. It has generally been determined that it can accommodate a small amount of information at one time (seven plus or minus two elements). Elements (e.g. symbols) at the beginning and, especially, at the end of a series are retained better. Human ability to discriminate visual information is similarly limited. This fact should be considered when presenting information on the flight deck.

6. The above-mentioned limitation of seven data elements holds for items which, in the person's experience, appear unrelated. For example, the term LOW PRESSURE involves 11 unrelated letters, but they are really two groups or chunks for short-term memory. The individual items within each chunk have been blended as a single coherent unit. In any system in which strings of items need to be memorized, the ergonomist must try to capitalize on the chunking principle to enhance short-term memory.

> "Approaching from the west. Approach instructed "Report visual before joining. Expect clearance to joining downwind left-hand for Runway 31, QFE ...
>
> "Reported visual and told to call Tower. Tower instructed us to "Join downwind left-hand for runway 13, QFE ...". The other pilot and I both wrote this down independently, and read it back. In view of the previous message I wondered whether to query it, but this ATC is usually pretty good, so I decided I must have mis-heard the previous.
>
> "... Just about airport boundary we saw an aircraft on short finals for 31 ... Tower called back rather irately "You were cleared to join downwind left-hand for 31 ..."
>
> "... Another classic human error which has always existed with 13/31 runways since the advent of radio control. Transpositions or swaps of positions are one of the commonest types of error in short-term memory ..."
>
> *Source:* CHIRP *Feedback* No. 23, February 1991.

7. Attention, as a technical term, has two different meanings. It refers to the human ability to ignore extraneous events and to focus on the events of interest (selective attention). This is exemplified by a person's ability to maintain a conversation amid a noisy party. It is, in short, the ability to focus on a source of information embedded within several sources. On the other hand, divided attention is the human capability to attend to more than one thing at the same time. An example of this is talking to ATC and watching for outside traffic simultaneously.

8. There is no single definition for mental workload. Some relate it to information processing and attention, others to time available to perform a task, still others to stress and arousal. Subjective opinions on workload can be collected, using rating scales, questionnaires or interviews; these methods have been frequently used when attempting to define or measure workload under operational conditions. As technology advances in our society, mental workload will become more important than physical workload. With modern automated systems, operators sometimes have monotonous work which consists of unvarying physical or mental activity. Considerable effort has been directed, and will continue to be directed, to establishing methods for assessing mental workload, with the ultimate goal of describing or predicting how much mental workload is associated with a given task.

In May 1978, a Boeing 727 crashed into Escambia Bay while on a surveillance-radar approach to Pensacola Regional Airport. The crew was blamed for the unprofessional way in which they conducted the non-precision approach. However, ATC was also mentioned as a factor which accelerated the pace of flight deck activities after the final approach fix. NTSB found that the aircraft was positioned on the final approach course "… in a situation that would make it impossible for the captain to configure his aircraft in the manner specified in the flight manual". There was also confusion regarding the nature of the instrument approach available at Pensacola. These factors resulted in the crew's failure to extend the gear and flaps appropriately. Moreover, subsequent warning from the ground proximity warning system went unheeded, and it was turned off seconds before the impact. The NTSB concluded, "… these [events] increased the captain's workload, and contributed to producing the major causal area of the accident - a lack of altitude awareness".

Source: ICAO ADREP Summary 78/6.

SECTION 3	: HUMAN CAPABILITIES
CHAPTER 4	: HUMAN DIMENSIONS

1. One of the primary objectives of ergonomics is to match working (and living) areas and stations with human characteristics. Some of the basic characteristics of humans are those associated with the size and shape of the various parts of the body and with their movements. Figure 3-3 illustrates the importance of considering human dimensions in equipment design. The controls of some lathes in current use are so placed that the ideal operator should be four-and-a-half feet tall, be two feet across the shoulders, and have a four-foot arm span — it is probably easier to change the machine than the people who must operate it! Anthropometry is concerned with human dimensions such as weight, stature, limb size and other specific measures such as seated eye height and reach when seated with and without restraining devices (such as a shoulder harness). With this information it is possible to estimate the optimum height for work surface and location of controls, the height and depth of stowage areas, minimum knee room between seat rows, width of seats, length of armrests, height of headrest, life-raft and seat cushion design, and reach requirements. Biomechanics specializes in the application of the science of mechanics in the study of living organisms (the human being in this case). The discipline studies areas such as the movements of body parts and the forces they can apply. For example, it is necessary not only to know that a certain force will move a control, but also where the control is located relative to the body and the direction of control movement.

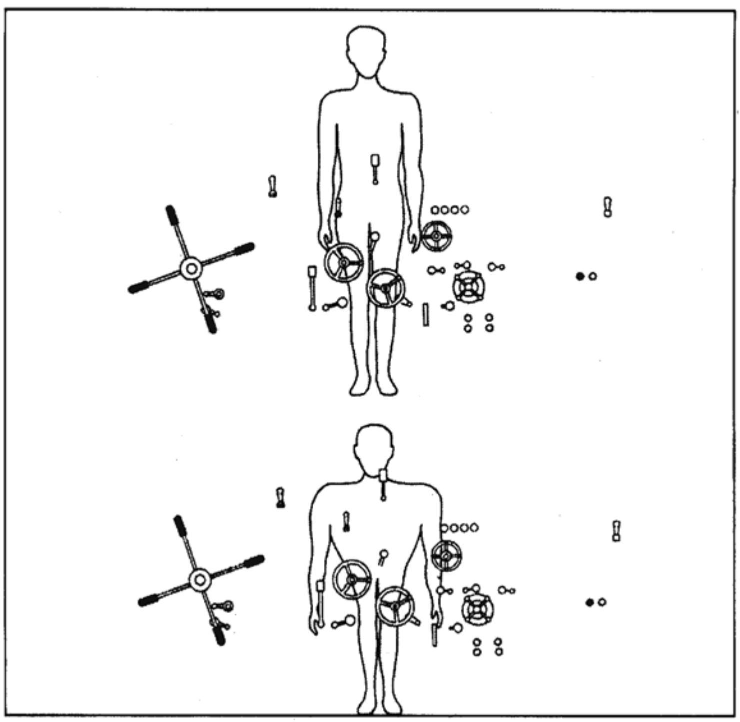


Figure 3-3. The controls of a lathe in current use are not within easy reach of the "average" person (from *Applied Ergonomics*, IPC; 1969; Vol. 1)

2. Data collection is an important step. Data must be collected from a representative and sufficiently large sample of the people who will use the equipment. When using these data, one must take into account the date of data collection, since human physical dimensions may change from generation to generation. For example, it is known that people in some developed countries have generally become taller during the past 50 years. An ergonomist must determine when and how such changes will become a factor in design considerations.

3. The ergonomist should take into account the concept of designing for human differences. Not only are there differences in physical dimensions among ethnic groups, but there are also differences between men and women within one ethnic group (for instance, control force requirements which can be met by males may be too high for females). Many aviation hardware pieces have for some time been manufactured according to Caucasian male dimensions, even though in many cases they are equally used by Asians, Africans, and others. The ergonomist will identify the target user group and design equipment accordingly. If a single design solution to accommodate all user differences is not possible, a range of adjustments is provided, so that most users are accommodated — rudder pedal and seat adjustments on the flight deck are among the examples.

SECTION 4	: DISPLAYS, CONTROLS AND FLIGHT DECK DESIGN
CHAPTER 1	**: INTRODUCTION**

1. Displays and controls are at the heart of ergonomics. If we refer to the **SHEL** model, they are mostly part of the Liveware-Hardware and Liveware-Software interfaces. In the case of displays, the transfer of information goes from the Equipment to the Liveware. Controls are used to transfer information and commands in the other direction, from the Liveware to the Equipment. There is usually an information loop involved in this process, and ergonomists have the mission of optimizing the flow within this loop. The following paragraphs present some of the considerations in the design of displays and controls and their integration into the workplace of the flight deck.

2. This chapter does not discuss the issues associated with the introduction of automation on the flight deck.

SECTION 4	: DISPLAYS, CONTROLS AND FLIGHT DECK DESIGN
CHAPTER 2	**: DISPLAYS**

1. The function of a display is to convey information (about the status of the flight for example) accurately and rapidly from its source to the operator. Human capabilities and limitations in information processing discussed before should be considered in the design of displays. Timely, appropriate, accurate, and adequate amount of information must be presented to the operator according to task requirements. It would be detrimental to task performance to present more information than required, especially when the operator is overloaded, fatigued or under stress.

2. Visual displays may be *dynamic* (e.g. altimeters and attitude indicators) or *static* (e.g. placards, signs, and charts) They present quantitative (e.g. altitude and heading) or qualitative (e.g. landing gear status) information. They may warn (e.g. ENGINE FIRE) or caution (e.g. oil pressure indicator or light).

3. Displays may also be *tactile/ kinaesthetic* (tactile means related to the sense of touch, kinaesthetic related to the sense of motion) or *auditory*. Especially when the visual system is (or is expected to be) heavily loaded, these displays may be used to communicate information to the human operator. Tactile/kinaesthetic information transfer may also be applied under degraded visual conditions. (A stall warning using the stick-shaker method is a good example). The auditory canal is particularly suited for alerts such as warnings. For this reason, there is a tendency to apply such aural displays heavily, sometimes indiscriminately, on the flight deck. Indiscriminate use of aural alerts on the flight deck has been known to cause annoyance and confusion or to affect task performance negatively. In such cases, one cannot over-emphasize the importance of taking proper Human Factors considerations into account in the design of these displays.

4. There are basic issues which must be resolved before a display can be properly designed and located. Both design and location of displays can greatly influence the effectiveness of the dialogue between human and machine. The following are some example considerations:

- How, by whom, and in what circumstances will the display be used?
- Auditory displays are generally omnidirectional, while visual displays are not. Will more than one person be required to see the display?
- How will ambient illumination influence the effectiveness of the visual display?

- Should the information be presented in the analogue or digital format? Digital displays provide greater accuracy for recording or systems monitoring (e.g. for engine instruments), while analogue instruments are preferable when the numeric values are changing frequently or rapidly (e.g. with altimeter and rate of climb indicators).

- What is the angle at which the display will be viewed?

- Will there be parallax problems?

- What will be the viewing distance? Will character and symbol sizes need to be increased to afford readability at a distance?

- Displays which are in a standby or inactive mode should clearly enunciate that fact. Ambiguity will likely increase mental workload and induce errors.

- Information which is suspect should not continue to be displayed to the operator.

- Consider display factors such as brightness, colour, contrast and flicker.

5. The display of letters and numbers (known as alphanumerics) has been the subject of much research. Mechanical, electro-mechanical and electronic displays present various ergonomic problems which deserve attention. Information presented must be legible, so that characters can be easily differentiated or identifiable. In addition, the information must be readable, which means that total words or groups of letters and numerals are comprehensible. Readability is generally a function of factors such as character style, type form (e.g. uppercase or italics), size, contrast and spacing. 4.6.8 Dial markings and shapes are two additional aspects considered by the ergonomist. Examples of the basic types of displays used in presenting quantitative information are shown in Figure 4-1. Scale progressions should have fixed and regular graduation markings, and should be presented in single units. Steps of 10 or 5 are good, and steps of 2 are acceptable. Decimal points should be avoided, and if used, the 0 ahead of the decimal point should not be included. Full readings should be displayed as opposed to truncated versions (e.g. 15 for 150). Care should be taken in the design of pointers when the instrument also contains a digital read-out which can be obscured by the pointer. The tip of the pointer should touch the end of the graduation scale but should not overlap it. The distance between the pointer and the surface of the scale may result in parallax which should be eliminated or minimized. There will be no such problem if the scale is displayed on an electronic display. In general, the size of the displayed information (e.g. scales and icons) must be positively related to the viewing distance (i.e. the longer the viewing distance, the larger the scale or icon size). This design consideration must allow for environmental correction factors like lighting, vibration and non-optimum viewing angles.

The drum-pointer altimeter display has a history of being misread in studies and real-life occurrences dating back to 1959. This particular instrument is susceptible to the thousand-foot misreads, especially when the indication is near zero. The results of a study undertaken by NASA indicated that the problem is because humans cannot efficiently read both the drum and pointer at the same time. They also showed that the number of times when the altitude window on the drum-pointer altimeter is read is very small. The time necessary to read the window is almost twice as long as text reading. This instrument is believed to have been misread, and considered a contributing factor, in at least the following accidents:

a. American Airlines B727, Constance, Kentucky (USA), November 1965;
b. Northeast Airlines DC9, Martha's Vineyard, Massachussets (USA), June 1971;
c. Eastern Airlines DC9, Charlotte, North Carolina (USA), September 1974;
d. National Airlines B727, Pensacola, Florida (USA), May 1978;
e. Alitalia DC9, Palermo, Italy, December 1978; and
f. Iberia B727, Bilbao, Spain, February 1985.

Source: "The Killer Instrument — The Drum Pointer Altimeter" (1990) Harold F. Marthinsen, Director of US ALPA's Accident Investigation Department.

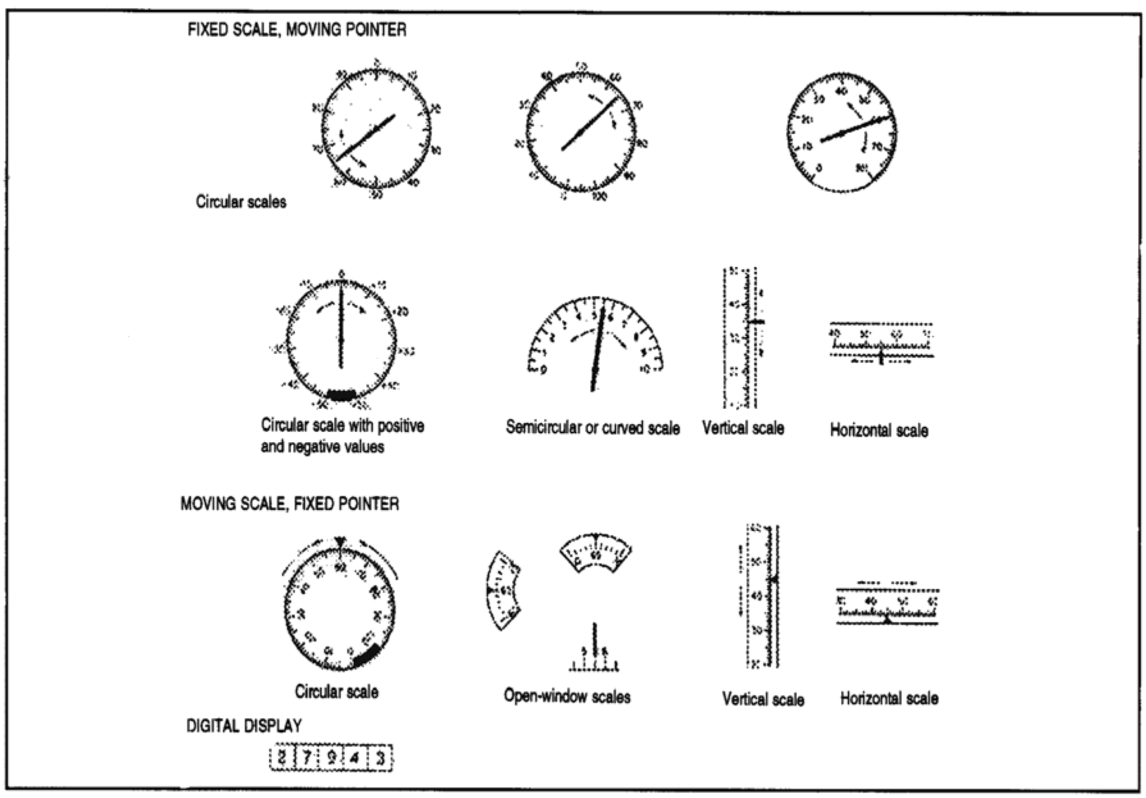


Figure 4-1. Example displays used in presenting quantitative information
(adapted from McCormich *et al.*, 1983)

> Shortly after a night takeoff from Bombay, at an altitude just under 1500 ft, the Boeing 747 with 210 persons on board rolled a 14-degree bank to the right. Over the next 13 seconds, the aircraft gradually returned to wings-level. Then it continued to roll into a 9-degree left bank. At this point, an abrupt left-aileron input was made, it was momentarily reversed, and then went to hard-over left. The pilot held hard left rudder and ailerons until impact with the sea 30 seconds later, with the aircraft in a 108-degree bank and at more than 300 knots. Incorrect information presented to the crew, through a failure (horizon control reversal) in the flight director, contributed to the accident.
>
> *Source:* ICAO ADREP Summary 78/5.

6. The introduction of electronic (e.g. cathode-ray tube) displays provided the opportunity to overcome many of the earlier constraints of electro-mechanical displays, permitted integration of displays, and afforded greater flexibility and a more effective use of panel space. Electronic displays generally have three applications on the flight deck: for flight instruments, systems information (e.g. engine data as well as data on other systems, including warning systems), and flight management systems (FMS). Electronic displays present a variety of ergonomics concerns, including: brightness and brightness contrast; the use of colours for different pieces of information; the fatiguing effect of extended periods of screen monitoring; the symbology utilized; what information should appear, and where, on the screen; and the fact — for reasons not yet very clear — that reading text from a screen is slower than from printed paper. On the other hand, electronic displays are generally cost-effective and versatile, and offer the user a reasonable amount of control over certain important display properties such as brightness and brightness contrast.

7. Many operators have introduced heads-up displays (HUDs) as an additional tool to allow for operations in lower weather minima. The symbology utilized by these devices must be common to the symbology utilized in screens.

SECTION 4	: DISPLAYS, CONTROLS AND FLIGHT DECK DESIGN
CHAPTER 2 APPENDIX 1	**: ADVISORY, CAUTION AND WARNING (ACW) SYSTEMS**

1. Warnings signify a condition requiring an immediate crew action for maintaining the safety of the system, and their colour coding is normally RED. Cautions imply a condition which may become an emergency if allowed to progress or deteriorate. These usually require the appropriate, but not immediate attention, and their coding is AMBER. Advisories are generally for information only, and may or may not require crew action. Their coding may be BLUE, WHITE, or GREEN. Three basic principles apply to the design of flight deck warning systems:

- they should ***alert*** the crew and draw their attention;
- they should ***report*** the nature of the condition; and
- preferably they should ***provide guidance*** regarding the appropriate action required.

2. Several considerations can be given to the last item. A good indication is provided by the number of aircraft which were involved in an accident because the crew shut down the wrong engine after an engine failure. Considerations in the design of the ACW systems include, first, system reliability, since confidence in a system will be lost if it is plagued by spurious warnings. Secondly, excessive appearance of an ACW signal will reduce response to it and become a nuisance. Lastly, auditory multi-warnings (i.e. the same sound being used to alert to more than one condition) require special considerations. They are effective in attracting attention, but may breed error or delay in corrective response. Voice messages may be added to enhance identification and interpretation.

3. Advisories, cautions, and warnings on the flight deck can be grouped into four broad categories:

- those which inform about performance, or departures from operational envelopes or safe flight profiles (e.g. for stall, overspeed and ground proximity); they are usually of high urgency;
- those which inform about aircraft configuration (e.g. landing gear and flap positions);
- those which inform about the status of aircraft systems; these include limiting bands and flags on instruments; and
- those related to communications (e.g. SELCAL and interphone).

> In December 1974, a Boeing 727 crashed 12 minutes after departure from JFK airport. The airspeed and altitude values recorded in the FDR are consistent with the predicted climb performance until the aircraft reached 16,000 ft, when icing was encountered. The airspeed when the stick-shaker was activated was estimated to be 165 kt, compared to the 412 kt recorded by the FDR. The pitch attitude would have been 30 degrees nose-up.
>
> The crew had not activated the pitot-heaters, and ice accumulated and blocked the pitot heads, producing erroneous airspeed and Mach warnings. They incorrectly diagnosed the stall warnings as Mach buffet and pulled the aircraft nose-up, which resulted in a stall and spin.
>
> *Source:* NTSB AAR 75-13.

4. The following important principle must be reiterated: in the case of a failure, the user of a display should not be presented with unreliable information. The failure should be annunciated on the display itself, rather than on an indicator. It is very likely that, as long as the unreliable information is shown, sooner or later it will be used.

SECTION 4	**: DISPLAYS, CONTROLS AND FLIGHT DECK DESIGN**
CHAPTER 3	**: CONTROLS**

1. Controls are means for the human operator to transmit messages or command inputs to the machine. The message should be transmitted within a specified accuracy and time period. Different types of controls perform different functions: they may be used to transmit discrete information (e.g. selecting a transponder code) or continuous information (e.g. cabin temperature selector). They may send a control signal to a system (e.g. the flap lever) or control a display directly (e.g. an altimeter setting knob). As is the case with displays, the characteristics of the user population must be taken into account by the designer.

2. The functional requirements, as well as the manipulation force required, will determine the type and design of control to be adopted. An example checklist on how to select controls based on their functions is provided below.

Function/force	*Type of control*
Discrete functions and/or forces low	push buttons, toggle switches and rotary switches
Continuous function and/or forces low	rotary knobs, thumb wheels, small levers or cranks
High control forces	handwheels and large levers, large cranks and foot pedals

> In December 1972, a Lockheed L-1011 crashed in the Everglades swamps near Miami. While the crew was attempting to replace a faulty nose gear indicator light bulb, the autopilot was inadvertently disconnected, and the aircraft descended to crash into the swamps. The nose gear light fixture had not been provided with a shadow divider between the two light bulbs, as is the usual design practice. The shadow divider allows the pilots to see that one-half of the fixture is dark when the first light bulb fails. The second bulb, while working, confirm to the crew that the gear is safely locked. This particular aircraft had been probably flying for several trips with an undetected failed light bulb in the nose gear fixture. The second light bulb failed when the aircraft was approaching Miami. This resulted in the highly improbable situation in which both light bulbs were inoperative simultaneously. The absence of the shadow divider was thus one of the factors which had contributed to the chain of events leading to an accident.
>
> *Source:* ICAO ADREP Summary 72/557.

> "… in cruise, first officer selected LP cock instead of adjacent fuel pumps during fuel balancing. No. 1 engine flamed out - instantly relit …"
>
> *Source: Feedback* No.1, March 1983.
>
> "… taxying out of dispersal we had reached the point in the checklist for 'flap selection'. The captain confirmed flaps to go to take off so I put my left hand down, grasped the knob and pushed downwards. Its travel felt remarkably smooth, so I looked down to find I had actually closed down the No. 2 HP cock shutting the starboard engine down. The top of the flap lever and the HP cock are immediately next to each other …"
>
> *Source: Feedback* No. 2, July 1983.
>
> "… some readers may remember that we have published several reports about pilots who switched off the fuel cocks on BAC 1-11s by accident. BAe took the reports very seriously and put out a world-wide British Aerospace Policy Letter alerting all the operators to the possible problem. Not, perhaps, a cure - but certainly a step in the right direction."
>
> *Source: Feedback* No. 3, December 1983.

3. Another basic requirement for controls, from the ergonomics point of view, is their location within the work area. However, it must be remembered that the optimal location for a display may not be optimal for reach.

4. Other design considerations include: control-display ratio, which is the ratio between the amount of change in a display in response to a control input and the amount of change in the control effected by the operator; and the direction of movement of display element (e.g. a pointer) relative to the direction of control movement. As shown in Figure 4-2, a rotary knob located on the right side of a longitudinal display should go clockwise to move the arrow indicator up. Control resistance affects the speed and precision of control operation, control "feel", smoothness of control movement and susceptibility of control to inadvertent operation. Control coding (i.e. shape, size, colour, labelling and location) aims to improve identification, and reduce errors and time taken in selection (see Figure 4-3). The last of the example principles in control design involves protection against inadvertent actuation.
This can be achieved by methods such as gating, locking and interlocking (e.g. by interconnecting controls to guarantee that reverse thrust levers cannot be operated until thrust levers are in idle). In

some cases, an action which is incompatible with existing conditions may trigger a visual or aural warning (e.g. closing the thrust levers when the landing gear is retracted will turn on an aural warning).

In one particular family of twin-jet transport aircraft, the engine fire switch is a powerful control with which one action shuts off the ignition, the fuel, the hydraulic fluid supply, and the pneumatic duct to the affected engine. Recognizing the consequences of improper actuation of this control, the designers went to great lengths to reduce the probability of this specific error. The fire switch has been given a unique shape and feel, and is located where it can easily be seen. The switch requires a long stroke, pull action unlike operating any other control on the flight deck. A light on the handle of the switch shows which engine is on fire. Finally, the handle is locked in the normal position unless a fire is sensed for that engine (although a manual override switch is also provided). It is located so that an additional discrete action is required for an operator to accomplish the procedure. This system has worked well for the management of engine fires since it was introduced 25 years ago.

Source: "Error Tolerant Avionics and Displays", Delmar M. Fadden. Human Error Avoidance Techniques: Proceedings of the Second Conference. SAE P-229.

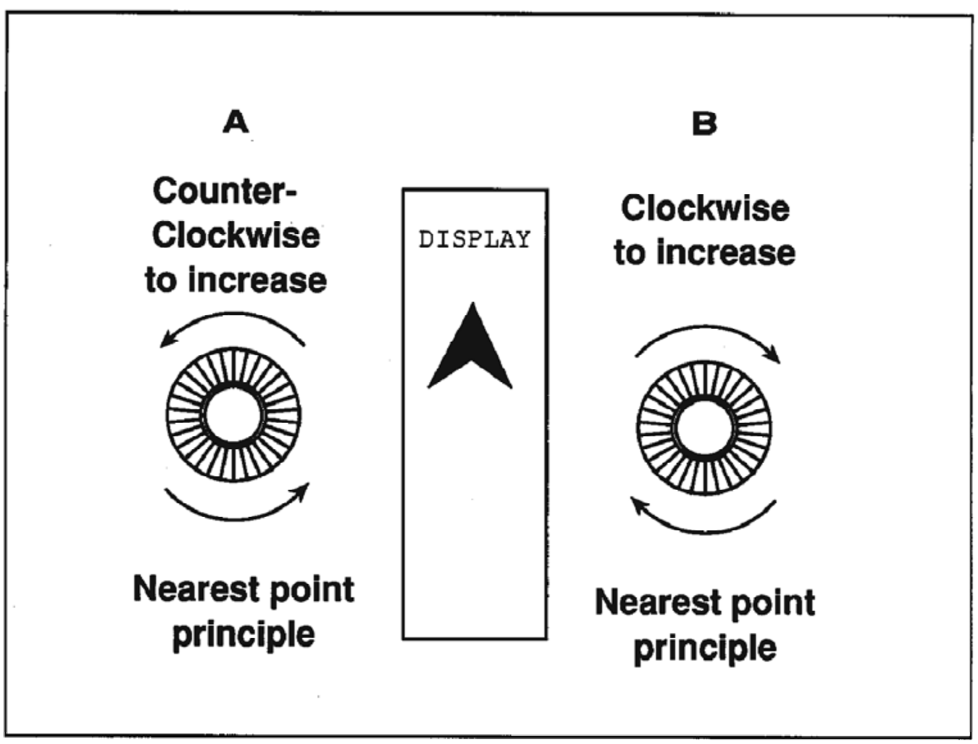


Figure 4-2. Two population stereotypes associated with this control-display relationship

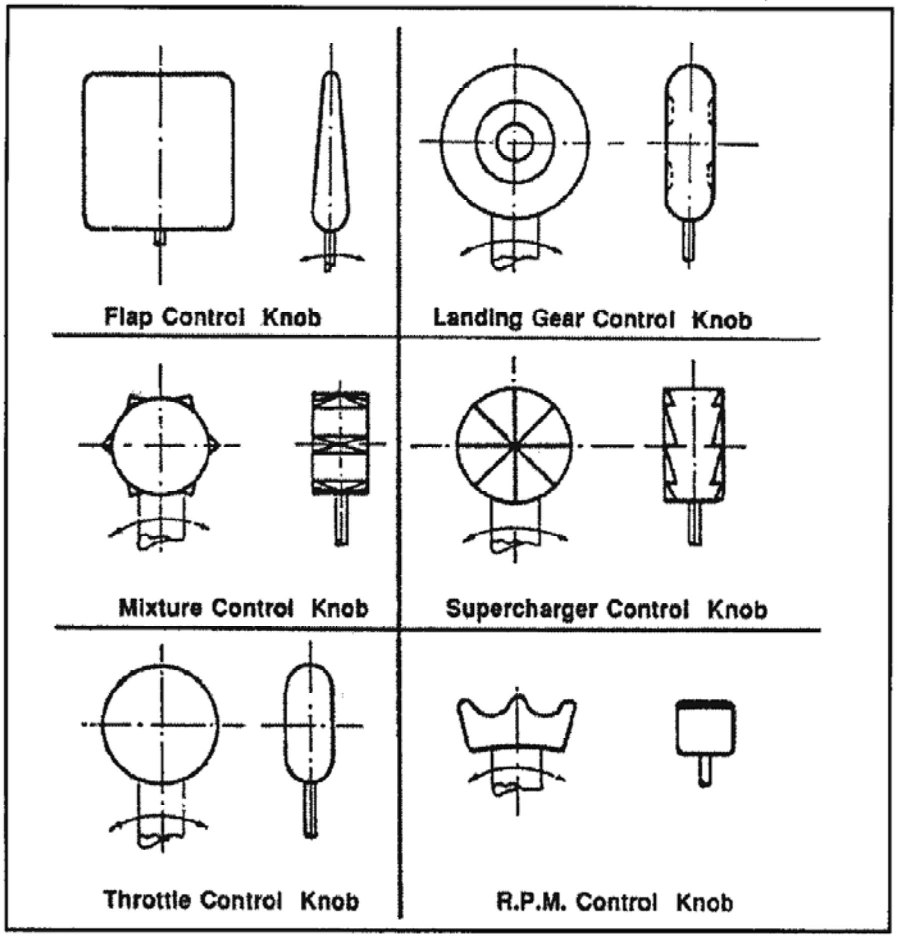


Figure 4-3. FAA requirements for cockpit control knobs
(adapted from 14CFR. Ch. 1, Section 25.781)

5. The use of keyboards on the flight deck has increased steadily over the years, as a consequence of the advent of computerization and modern avionics systems. An experienced typist can make one uncorrected error per 2 000 to 4 000 kestrokes. Flight deck crew members are generally considered to be unskilled typists. In addition, they may use the keyboard under adverse environmental conditions (e.g. under poor lighting and in turbulence). For on-board applications, accuracy and error detection are far more important than speed of entry. Key size, barriers between keys to prevent inadvertent operation and adequate handrests against vibration are some of the considerations in keyboard design. The traditional typewriter keyboard layout is named after the six initial letters of the top letter row (for example, QWERTY in English and AZERTY in French). DVORAK is an alternative layout, named after its originator, August Dvorak (see Figure 4-4). However, all of these configurations are generally unsuitable for flight deck applications because of space limitations and the need for single-handed operation. Figure 4-5 shows an example keyboard which has been adopted for many airborne navigational systems.

In July 1987, a Lockheed L-1011 flew within 100 ft of a Boeing 747 over the North Atlantic. It was later determined that the incident was due to a data input error made by the L-1011 crew. The crew allegedly had followed established data entry procedures by ensuring data entered was verified by another crew member; however, the input error still occurred. Subsequently, the crew did not follow established cross-check procedures, thus allowing the error to go unnoticed until the near collision occurred.

Source: ICAO ADREP Summary 87/331.

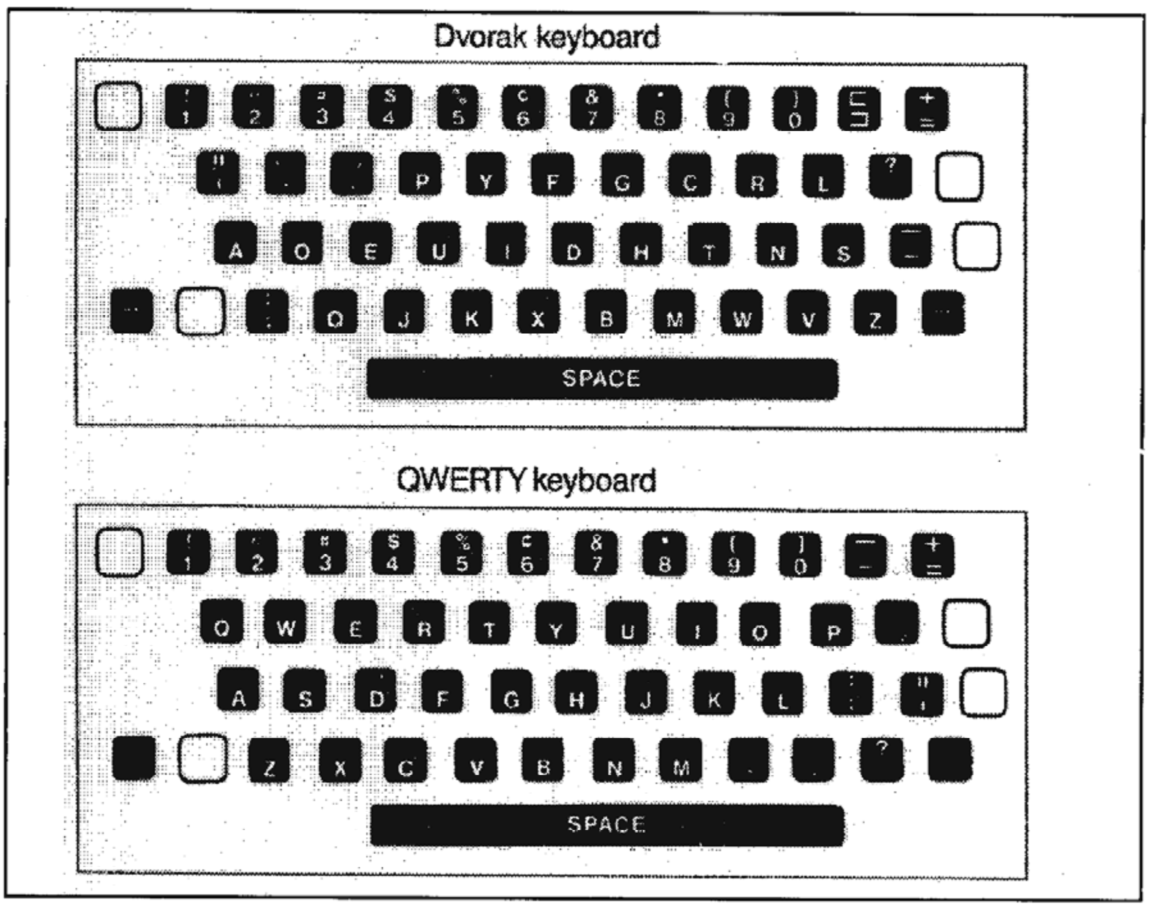


Figure 4-4. The traditional QWERTY keyboard and the more efficient Dvorak version

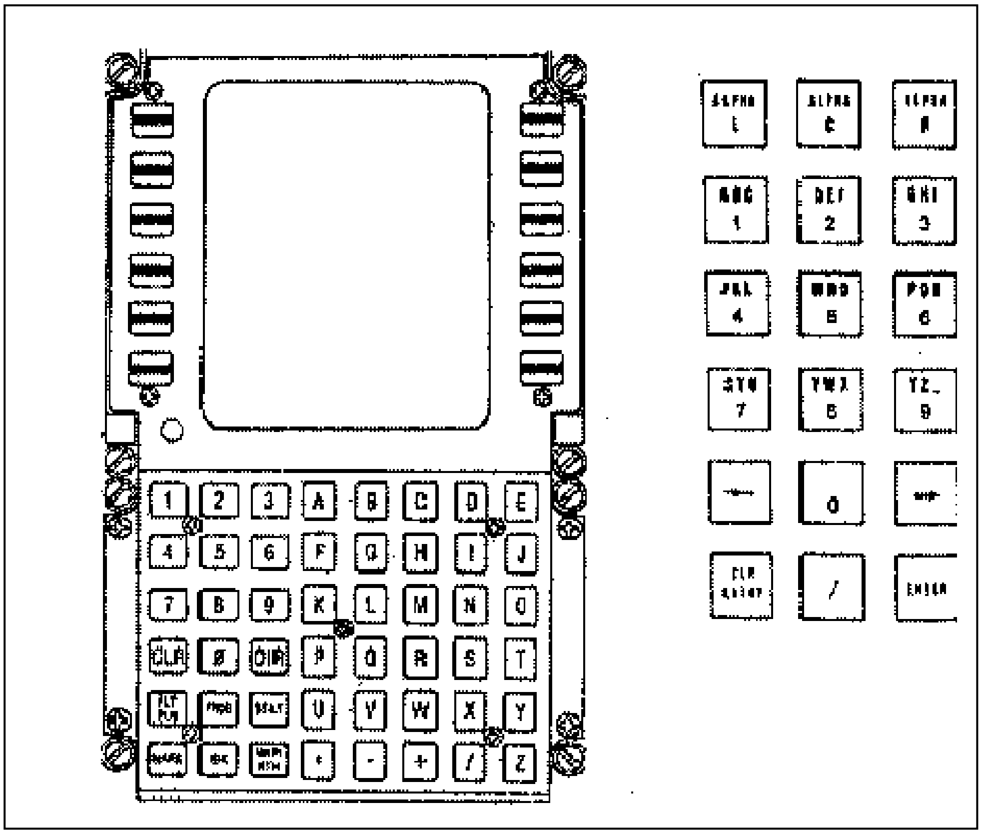


Figure 4-5. An example of a keyboard for a management or navigation system (left) and a suggested layout

(adapted from *Human Factors*, L.C. Butterbaugh and T.H. Rockwell, 1982)

6. For many years, the flight deck was viewed as a common place where numerous otherwise unrelated systems, such as hydraulics, electrics, pneumatics and pressurization, converged. Each system was designed by a different group of specialists, and its associated controls and displays were largely driven by the particular functional specifications of the relevant system. The flight crew was thus presented with an assortment of displays, knobs, switches and controls of various sizes, shapes and markings, which were usually selected from different manufacturers' catalogues. The designer's main task was to make sure that all the equipment pieces were installed within the allocated space. This design approach has generally failed to place emphasis on how to enable the crew to perform their tasks in the most efficient and effective manner.

7. In recent years, joint efforts by various civil and military industry groups, including manufacturers, airlines, pilots and authorities have led to the development of the concept of crew-system design. This concept emphasizes the functional integration of all system elements, taking into consideration the crew's requirements (e.g. for controls and displays). Factors integrated in the system

design concept also include geometry of the flight deck, furnishings (e.g. seats, windows and glareshield), environmental variables (e.g. noise, vibration, light, temperature and weather), and miscellaneous fixtures (e.g. coffee cup holders, eating facilities, foot rests and baggage holders). They also include the characteristics of people who will operate and maintain all components of the system.

8. This systems approach to flight deck design is made possible by an activity known as systems engineering. The purpose of this activity is to develop relationships among system components, evaluate the effects of individual components on each other, and ultimately integrate all system components into one effective functional entity. Human operators, maintenance personnel and trainers are viewed as components of a system; thus, this approach considers the final product as a human-machine complex. The flight deck is therefore seen as a system, with the components of Liveware, Hardware, Software and Environment.

9. For effective design, contemporary systems engineering approaches incorporate ergonomics inputs, which in turn treat the flight deck as a workplace and take proper consideration of the capabilities and limitations of the users. Ergonomists aim to recognize and resolve potential Human Factors problems early in the design phase before any equipment is produced.

10. The ergonomics approach starts with an appraisal of task requirements and user characteristics which will affect design decisions such as those specifying the layout and makeup of the flight deck. In addition, the designer must take into account constraints which can limit design options. Such constraints include the aerodynamic characteristics of the aircraft, which are related to the cross-section of the fuselage and the shape of the nose. For example, the Concorde flight deck width of 148 cm, which is dictated by aerodynamic requirements, represents a relatively cramped environment when compared with a Boeing 747 which has a deck width of 191 cm.

11. Downward visibility during approach is a requirement which influences the design of the windshield and the location of the design eye position (see Figure 4-6). The design eye position is an important reference point which helps to determine placement of equipment such as displays.

12. The distance between pilots' seats is a factor when cross-monitoring is required or when the same displays or controls are used by both pilots. Difficulties in access to pilots' seats may result in the decision to move the seats slightly outwards; however, proper consideration must be given to this misalignment of pilot and control so that it does not lead to hazardous conditions during operations.

13. Viewing distances for displays is another important aspect dictated by flight deck geometry. For large aircraft, typical viewing distances from the pilot's eyes are 71-78 cm for the main panel,

20 cm for the overhead panel, and 2 m for the lateral systems panel (see Figure 4-7). Size of display details (e.g. alphanumerics) are determined by display location and distance from the eyes of the prospective user. Viewing distance issues are particularly applicable to persons wearing glasses. Viewing distances are also particularly relevant to "glass cockpits".

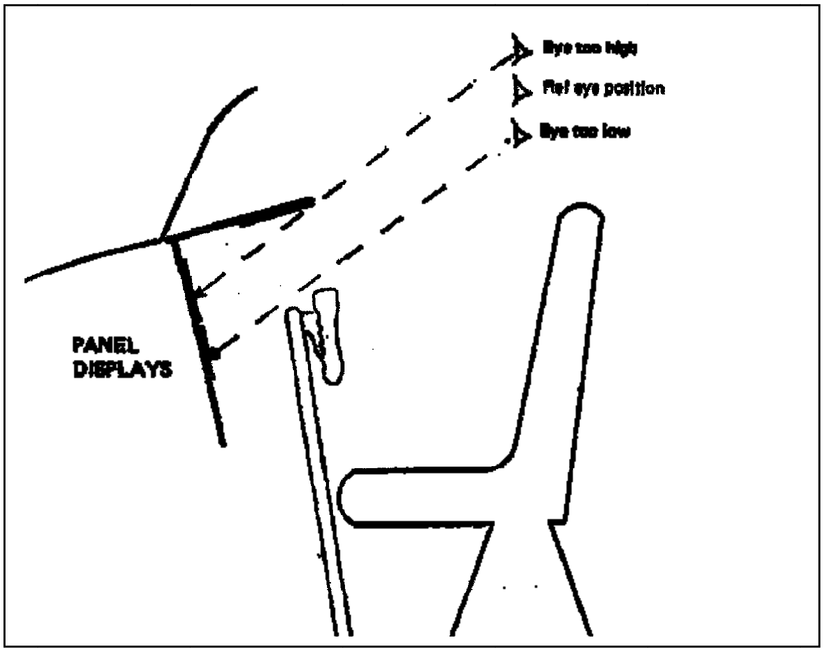


Figure 4-6. Reference eye position

(adapted from *Human Factors in Flight*, F.H. Hawkins, 1987)

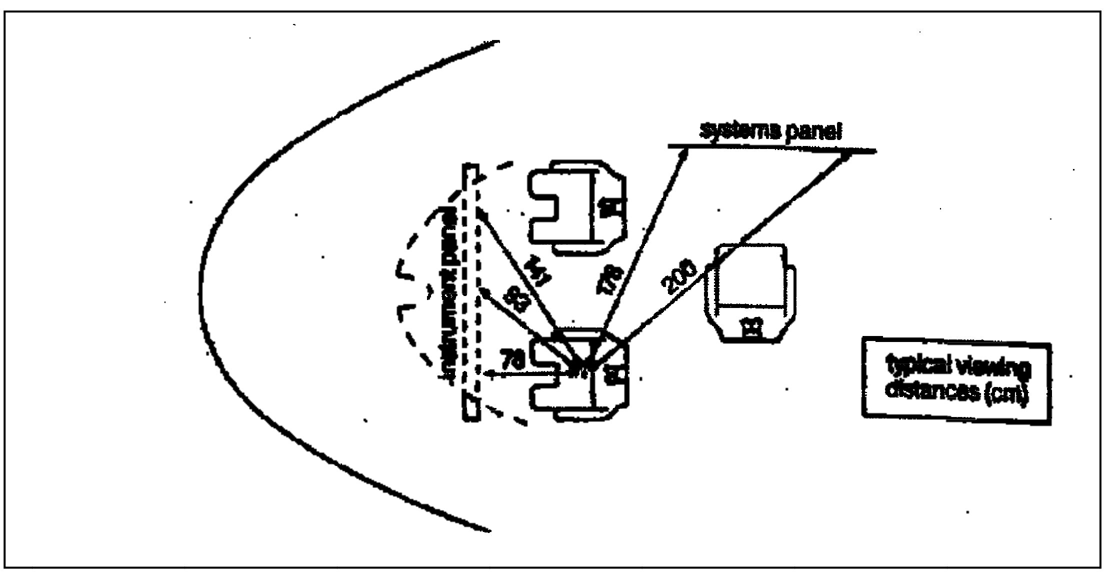


Figure 4-7. Typical viewing distances from the pilot's eye design eye position to various panels on the flight deck of a large jet

(adapted from *Human Factors in Flight*, F.H. Hawkins, 1987)

14. The panel containing flight instruments has received much attention from designers. The basic "T" layout which exists in most aircraft today is the result of the need for fast and accurate scanning of four basic parameters — speed, attitude, altitude and heading — with priority given to attitude (see Figure 4-8). Instrument panels which display system quantitative information (e.g. engine instrument panel) are arranged as a block or bank of instruments. A disturbance in the symmetrical pattern of that block as the result of a deviated indication on one of the instruments will be quickly detected by the crew. Synoptic panels (e.g. for the fuel, electrical, pneumatic and hydraulic systems) display the system in a schematic form with controls and displays appropriately placed. Flight guidance panels are generally mounted on the glareshield.

> In January 1989, a Boeing 737-400 crashed short of the runway at East Midlands airport, near Kegworth, Leicestershire, UK. During climb to cruising altitude, a series of compressor stalls occurred in the No. 1 engine. The stalls were caused by a structural failure, giving rise to airframe shuddering, producing smoke and fumes on the flight deck, as well as generating fluctuations of the No. 1 engine parameters. Believing that the No. 2 engine had suffered damage, the crew throttled the engine back. The shuddering caused by the surging of engine No. 1 ceased when engine No. 2 was throttled back. This persuaded the crew that they had dealt correctly with the emergency. They then shut engine No. 2 down and diverted the plane to land. At 2.4 miles from the runway, there was an abrupt reduction of power and a fire warning from engine No. 1, then the aircraft crashed.
>
> *Source:* ICAO ADREP Summary 89/1.
>
> In its report, the British AAIB recommends evaluating the information presentation on new instruments and their effectiveness in transmitting the associated information to the flight crew. It also recommends that engine instrument systems be modified to include an attention getting mechanism which will alert the crew of system abnormalities. Figure 4-9 illustrates the proposed rearrangement.

This allows both pilots to reach them without having to lean over the control column, and improves instrument scanning. Figure 4-10 presents an example checklist for the evaluation of a typical flight guidance panel. Other panels which require proper ergonomics design include those for radio and interphone controls, circuit breakers, galley equipment, and door operation.

15. Toggle switches can follow either the "forward-on" (push switch forward to turn on) or "sweep-on" (see Figure 4-11) concepts. The forward-on concept presents a problem of ambiguity with panels mounted vertically or close to the vertical. It also lacks flexibility when modules have to be relocated, and the new switch positions no longer follow the forward-on concept. The sweep-on concept solves these difficulties. In multi-type fleets within a company, both concepts might be found. This lack of standardization has been known to cause confusion and errors on the part of the crew.

16. Requirements for crew complement is another factor to consider in flight deck design and layout. On aircraft operated by three crew members, the third crew member may be sitting in front of a separate panel, facing it laterally, or may sit between the pilots, facing forward. Manufacturers have alternated between the two designs over the years. As a general rule, when systems complexity increases to the point of requiring extensive instrumentation, a separate station is required. On aircraft operated by two crew members, a large overhead panel is installed to accommodate controls which would otherwise be placed on the lateral panel. In general, overhead panels should have the most frequently used items located in the forward section, and the less frequently used items in the rear section, because the rear section is relatively inconvenient to reach.

17. The two- versus three-person crew issue has design implications which go beyond the basic process of relocating controls and displays. For instance, emergency response on two- person aircraft involving first stage failure of equipment with stand-by redundant module should require minimal crew intervention. Switching to the stand-by back-up module upon failure of the primary equipment should be automatic, obviating the need for manual input by a third crew member. However, the crew must still be informed of what has happened and provided with any other options required for further emergency action. In addition, activities and procedures which require prolonged headsdown time should be avoided to maximize opportunities for visual look-out.

In December 1983, an Airbus A300B4 crashed short of the runway at Kuala Lumpur during an approach under Instrument Meteorological Conditions (IMC). Among the contributory factors, it was indicated that the aircraft was on lease from another company, and its controls differed in some respects from the other A300's owned by the lessee company. The manual provided with the accident aircraft did not include details of some modifications which were made to the original instruments before the aircraft was transferred.

Source: ICAO ADREP Summary 84/6.

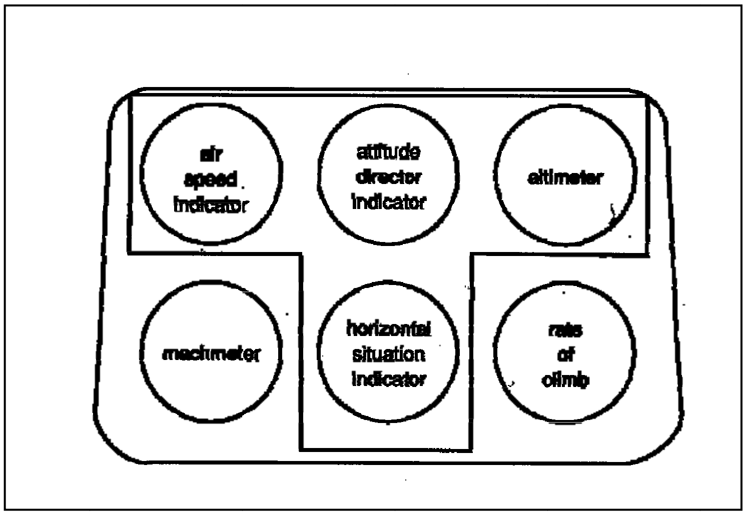


Figure 4-8. The "basic T panel"which forms the core of modern flight instrument panel layouts

(adapted from *Human Factors in Flight*, F.H. Hawkins, 1987)

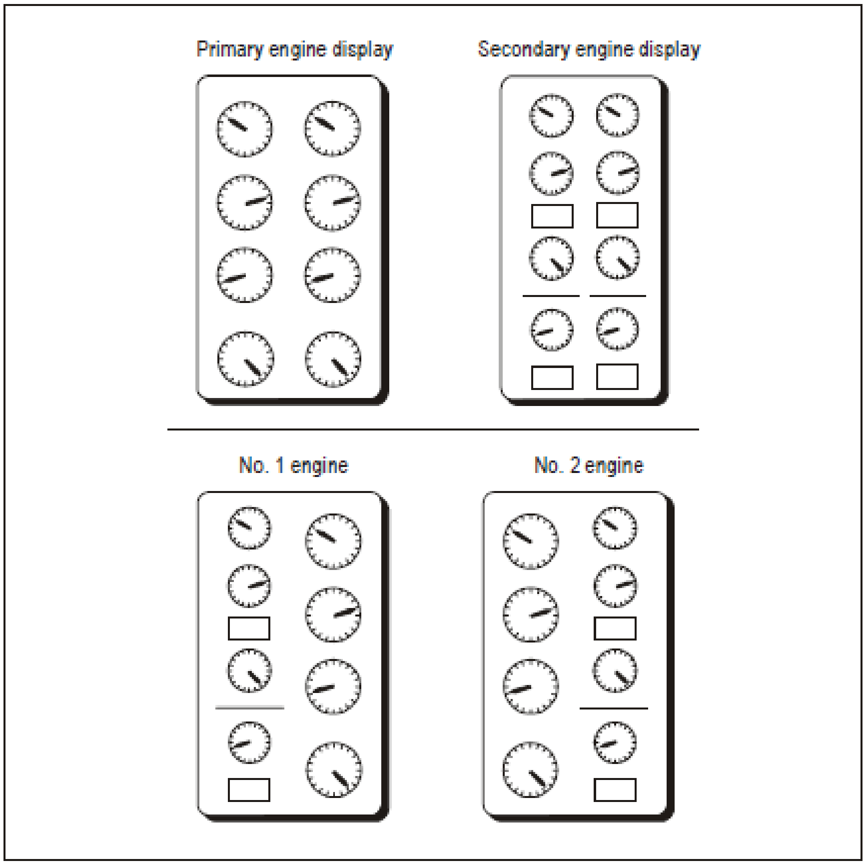
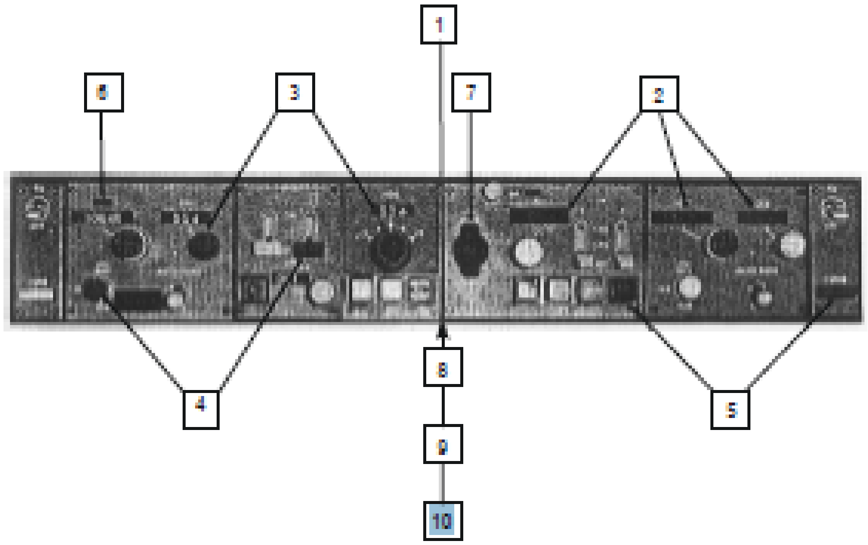


Figure 4-9. Proposed engine instrument system



1 Installation
- Use by which crew members: what priorities
- What location: sight and reach
- Vertical or horizontal mounting
- Operational function
- Vulnerability to reflections: direct sunlight
- Standard dimensions

2 Readouts
- Size of alphanumerics
- Letter/numeral type
- Visibility from pilots' reference position: parallax
- Counter, direction of movement
- Counter, movement characteristics (analog/digital)
- Glass cover anti-reflective coating
- Low reflectivity paint
- Use of colour
- White on black or black on white; contrast

3 Knobs
- Coding; shape, texture, colour
- Size
- Finger interference
- Turning ratio, fast slewing requirement
- Positive detenting
- Unambiguous position markings; visibility from pilots' reference eye position
- Operating force
- Direction of movement
- Finger friction, grip

4 Switches (toggle)
- Direction of movement
- Interference, inadvertent operation; guarding; lever-locking, ganging
- Coding, shape, texture, colour
- Type and size
- Position marking: visibility from pilots' reference eye position
- Actuation force

5 Switches (push-button)
- Size and shape
- Separation, fencing, inadvertent operation
- Vertical/horizontal installation: use in turbulence
- Function annunciation, day/night
- On/off indication, day/night
- Actuation pressure and travel

6 Panel nomenclature
- Lettering type and size
- Redundant nomenclature (clutter)
- Standard abbreviations
- Location
- Visibility obstructions

7 Controls
- Direction/ratio of movement
- Finger friction, grip
- Coding; shape, color
- Functional interrelation
- Finger interference, inadvertent operation
- "Blind" operational requirement
- Operating force
- Detent characteristic

8 General characteristics
- Colour finish
- Low reflectivity paint for panel, fasteners, counters, etc.
- Lightplate edge radius (damage potential)
- Delethalisation
- Compatibility with other cockpit panels
- Relative location of panel components/modules

9 Panel lighting
- Brightness vs voltage
- Balance, compatibility with other panels
- Even brightness, even illumination of readouts
- Colour temperature
- Use of colour/brightness coding of push-button switches, etc.
- Glare, high spots, leaks (note also lightplate edge radius)
- Controls, continuous/step, integration with cockpit system, location
- Light reflection potential, screening
- Location of switches/controls by light
- Lighting of knob/control positions
- Push-button switch lighting on and off position

10 Maintenance
- Ease of removal and installation
- Vulnerability to handling damage

Figure 4-10. Checklist for evaluation of a typical cockpit panel

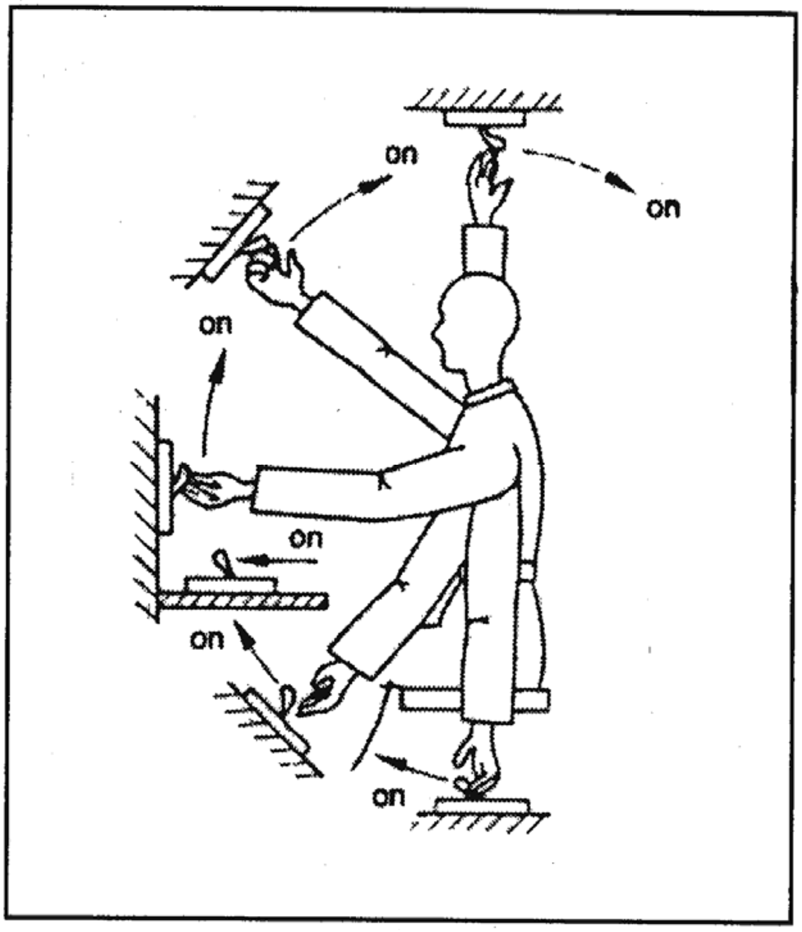


Figure 4-11. The "sweep-on"switch position concept which is slowly replacing the earlier "forward-on"arrangement

(adapted from *Human Factors in Flight*, F.H. Hawkins, 1987)

18. General principles in seat design are equally applicable to flight deck and passenger seats. Some of those principles include distributing the body weight throughout the buttock region around the sitting bones, and providing a proper seat height to avoid excessive pressure on the back of the thighs. The spinal column should be kept in balance and maintain its relatively natural curvature by proper lumbosacral support and seat design. Armrests should provide the proper arm support while allowing free mobility of shoulders, arms and torso. In addition, consideration must be given to factors such as durability and weight of the material, flammability, structural integrity, reliability, space available, certification requirements and cost. Proper attention must also be directed to seat controls, restraint systems and footrests.

19. Pilots are required to remain strapped to their seats for many hours, and the effects of seat characteristics go beyond the medical problems (e.g. back ailments) which may appear. Back pain or discomfort is distressing and can affect motivation, behaviour and performance.

SECTION 5	**: THE ENVIRONMENT**
CHAPTER 1	**: STRESS**

1. Stress was defined by Hans Selye as a nonspecific response of the body to any demand made upon it.1 This concept assumes that some “normal” or “optimal” state of bodily functions exists and that stressors (i.e. stimuli or situations that stress the person) cause a deviation from this normal state. Stress generally represents an attempt by the body to adapt to or cope with situational demands and to return to the normal state as soon as possible. It can be differentiated into life stress, environmental stress and cognitive stress. ***Life stress*** is produced by adverse occurrences in a person’s life (e.g. divorce, family bereavement). Environmental and cognitive stress are more closely related to the specific activities which humans undertake. ***Environmental stress*** includes the effects of factors such as temperature, humidity, noise, pressure, illumination and vibration. ***Cognitive stress*** refers to the cognitive (or mental) demands of the task itself. Countermeasures to minimize the potential untoward effects of environmental and cognitive stress are within the purview of ergonomics.

2. Stress has traditionally been linked to arousal, which refers to nonspecific changes (e.g. hormonal and brain activities) in the body to external stimulation. In general, stress and arousal levels are positively related — that is to say, high stress is associated with high arousal level. The Yerkes-Dodson law depicted in Figure 5-1 relates performance and arousal. It shows that people’s performance levels increase according to the degree of arousal to a point beyond which any additional boost in arousal will generally be detrimental to task performance. The over-all shape of the relationship curve remains the same across different tasks, but the exact shape and location of each curve vary according to task complexity.

3. Stress is related to a person’s ability to pay attention to cues in the environment. In a simple situation with few cues, stress will improve performance by causing attention to be focused. In a complex situation with many cues, stress will decrease performance because many cues will go unheeded. This explains many accidents in which crew under stress “locked on” to some particular instrument which was defective (even if the instrument was of minor importance), failing to attend to other pieces of crucial information.

SECTION 5	: THE ENVIRONMENT
CHAPTER 2	**: NOISE**

1. Noise is defined as any unwanted sound. There are two important aspects of noise which must be considered: the sources of noise, and the physiological and psychological effects on the person exposed to it. Noise affects a person in many ways depending on whether it is expected, whether it makes a task more difficult, and whether the person is relaxed or alert.

2. Major sources of noise in fixed-wing aircraft include the engines, the air conditioning, pressurization and hydraulic systems, and boundary layer turbulence. Inside the aircraft, noise is louder near the sides of the fuselage than at the centre. Noise level in the cockpit is easily changed by the interaction of the airflow with the fuselage surface. Soundproofing will reduce noise, but it will increase aircraft weight as well. This has many undesirable effects such as increases in fuel cost. Design improvement to reduce noise at its source would be a better alternative. For example, removing the windshield wipers in one particular large jet transport reduced the flight deck noise level by 2 dB.

3. The most important pathogenic effect of noise, impaired hearing, has already been discussed in 4.2. Other physiological effects include changes in blood pressure and heart rate, headaches, tiredness and gastrointestinal problems such as ulcers. In the past, prolonged monitoring of high-frequency (HF) radio represented a significant exposure to noise. This has been alleviated by the introduction of selective calling (SELCAL). Technological progress in communications — as well as in other areas — will certainly provide new improvements in hearing protection. The fact remains, however, that crew members who are exposed to intense aircraft noise over a long period of time can be expected to suffer hearing loss in addition to the natural loss through ageing.

4. Noise affects performance by interfering with the detection and understanding of task-related signals or speech. It interferes with verbal communication by affecting the signal-to-noise ratio and by decreasing speech intelligibility. It further affects verbal communication by impairing hearing.

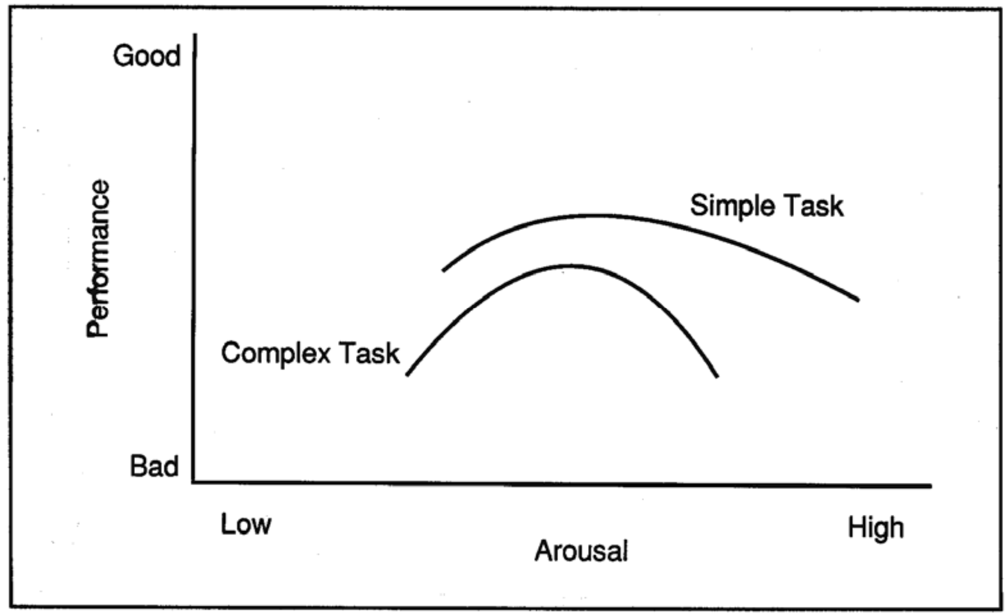


Figure 5-1. The Yerkes-Dodson law relating performance and arousal

> A twin-engine Beechcraft B-99 crashed during an instrument approach to the Shenandoah Valley Airport, Virginia, in September 1985. The NTSB concluded that among the factors which contributed to the flight crew's errors was "… intracockpit communications difficulties associated with high ambient noise levels in the airplane …"
>
> *Source:* ICAO ADREP Summary 88/4.

5. Because it is annoying for most people, noise can have an impact on psychological conditions. On the flight deck, this annoyance is compounded by the problems noise generates in communication. This may result in frustration and anxiety over the need to repeat messages or to understand them. This in turn may increase workload and fatigue. While it is the ergonomist's task to try to minimize noise through design and by providing hearing protection, crew members should be aware of the insidious effects of noise and the damage it can provoke, and of methods to reduce noise levels or to protect oneself from its detrimental effects.

SECTION 5	: THE ENVIRONMENT
CHAPTER 3	**: TEMPERATURE**

1. Temperature extremes are one of the most common environmental stressors. Since humans are comfortable only over a narrow band of temperatures, it is necessary to know how well they function at different temperature levels before remedial measures can be derived. Questions about air-conditioning requirements and human performance under heat or cold stress should be answered and taken into account during system design. Cabin environmental control systems are the principal means for controlling the internal aircraft environment.

2. Humans generate heat while performing mechanical work, and to a lesser extent, when resting. The excess heat is transferred to the environment, primarily by perspiration and sweating, in order to maintain a relatively constant body temperature of 37 degrees Celsius (C). The success of body temperature regulation depends on various factors: ambient temperature, humidity, and air velocity. If body temperature increases by more than 2 degrees C, physiological efficiency will be impaired.

> In February 1984, a Cessna T-303 crashed during landing at Hickory, North Carolina, U.S.A. The aircraft overran the runway and collided with a fence. The pilot was hampered by an inoperative heater and a dome light that could not be turned off.
>
> *Source:* ICAO ADREP Summary 86/5.

3. The physiological effects of ambient temperature extremes are well known, but the effects of heat stress on human performance are more complex. It is generally accepted that excessive heat will cause performance decrement, but there is little agreement regarding how much decrement will take place, or how long it will take to occur. People can withstand exposure to excessive temperatures for only a short period of time before measurable degradation sets in. Acclimatization prolongs this period. In non-acclimatized persons, degradation appears when the ambient temperature exceeds 30 degrees C, the relative humidity is high, and exposure exceeds three hours. Obviously, clothing and physical activity level play important roles, too.

4. When exposed to cold, the body attempts to maintain its core temperature by shivering and restricting blood flow to the body surface. Body temperatures below 35 degrees C are dangerous.

Consciousness becomes clouded at 34 degrees C, unconsciousness follows around 30 degrees C, cardiac irregularities are usual between 30 and 28 degrees C, and death is imminent. Although humidity is not a factor, air velocity is important; as a result, wind chill indices are increasingly being provided in weather reports. (Wind chill is not a psychological effect — it effectively lowers body temperature.) Cold increases both reaction and movement time, and manual dexterity begins to deteriorate when hand-skin temperature falls below 18 degrees C.

SECTION 5	: THE ENVIRONMENT
CHAPTER 4	**: HUMIDITY**

Humidity may become an issue with high-altitude jet transport aircraft because of the low relative humidity at their operational altitudes. The discomfort arising from low relative humidity may not imply physical indisposition. Over-all dehydration can be prevented with adequate fluid intake. Diuretics like coffee or tea should be avoided. The installation of humidifiers on aircraft could raise cabin/cockpit humidity, but there are potential problems such as weight penalty, condensation and mineral contaminations that the designer must consider.

SECTION 5	: THE ENVIRONMENT
CHAPTER 5	**: PRESSURE**

1. Cabin pressurization eliminates many problems associated with high altitude flying, but it introduces other potential problems, the most important being the risk of a rapid decompression. The time of useful consciousness (TUC) following a rapid decompression depends on aircraft altitude, the rate at which pressure falls, and the level of physical activity of the individual at the time of the event. At typical jet transport aircraft altitudes (35 000 feet) TUC will vary between 33 and 54 seconds. Those average values can be expected to drop by a half at 40 000 feet. This emphasizes the importance of immediate availability of supplemental oxygen to crew members.

2. The technical reliability of automatic delivery systems, as well as the design of certain types of flight crew quick-donning masks have sometimes been sub-optimal. It should be borne in mind that oxygen systems will be used in conditions accompanied by anxiety and other stressors, and simplicity of use and reliability are of utmost importance.

SECTION 5	: THE ENVIRONMENT
CHAPTER 6	**: ILLUMINATION**

1. The nature and quantity of cockpit illumination required for a certain task may vary considerably. Factors of importance are the speed and accuracy with which the displays must be read, the ambient illumination, other light sources (in particular, sunshine), and the presence of glare. Glare is defined as a condition of vision where there is discomfort or a reduction in the ability to see significant objects, or both, due to an unsuitable distribution or range of luminance (i.e. density of light, or light intensity per unit projected area) or to extreme contrasts in space or time.

2. Glare is an important aspect of the quality of the illuminated environment. It can be caused by bright light sources or light reflection off environmental surfaces. Glare may produce discomfort or annoyance, and may interfere with visual performance. The type of reflection off surfaces depends on the properties of the surface (e.g. whether it is polished, rough or matted). Some evidence suggests that there is an element of subjectivity in tolerance to glare. The most effective techniques for reducing glare include blocking the glare surface or placing supplementary lighting to offset the effects of glare.

SECTION 5	**: THE ENVIRONMENT**
CHAPTER 7	**: VIBRATION**

1. Vibration is any form of oscillating motion that changes its magnitude of displacement periodically with reference to a point, and it is a widespread physical phenomenon. The movement of pistons within the cylinders of engines or the disturbances generated in aircraft flying through turbulent air are forms of vibration which can be transmitted to humans. Vibration is generally transmitted through direct contact between the body and the vibrating structure, and it can have potentially harmful effects.

2. Vibration is of operational significance in aviation because it may impair visual acuity, interfere with neuromuscular control and lead to fatigue. Although better than before, high levels of vibration can still be encountered in helicopters as well as in fixed-wing aircraft during low-level flight.

3. Protection against vibration can be provided by attention to its source, by modification of the transmission pathway or by the alteration of the dynamic properties of the aircraft body. Reduction of vibration emanating from aircraft engines is a primary task for design and maintenance engineers. The installation of devices called dynamic vibration absorbers has reduced vibration levels on helicopters. Another ergonomic approach is by means of vibration isolation of the flight crew seats.

SECTION 6	: HUMAN FACTORS TRAINING FOR SAFETY INVESTIGATORS
CHAPTER 1	: INTRODUCTION

1. Human Factors issues are involved in most aviation occurrences. Thus, to advance aviation safety, we must improve our ability to identify the involvement of Human Factors issues 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 programmes.

2. This chapter presents information upon which the Human Factors training curricula for accident investigators can be developed. It has three purposes:

- to provide the basic contents which should be included in a Human Factors training course for accident investigators;
- 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. This chapter is intended to complement the ICAO *Manual of Aircraft Accident Investigation* (Doc 6920). (Further information applicable to the training of accident investigators can be found in Part 1, Chapters 1 and 2 of the manual.) The philosophical approach outlined in this chapter should be understood when applying the practical guidance provided in the investigation and prevention manuals. Human Factors also encompasses medical issues; however, the thrust of this chapter is on the non-medical aspects.

4. The primary focus of this chapter 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 chapter:

- 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;

- 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 analyze the information collected;

- 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;

- provides examples of Human Factors Checklists (see Appendix 1);

SECTION 7	**: NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION**
CHAPTER 1	**: BACKGROUND**

1. As evidenced by investigation records dating back to the 1940s, Human Factors issues 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*.

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.

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, unbeknown 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 chapter 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 manual and the series of ICAO Human Factors digests, it is anticipated that the most significant obstacles to the investigation of Human Factors will be eliminated. By applying the approach outlined in this chapter, investigators and their authorities should feel more confident in conducting these investigations.

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.

SECTION 7	**: NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION**
CHAPTER 2	**: THE NATURE OF ACCIDENTS AND INCIDENTS**

1. 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.

2. 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.

SECTION 7	**: NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION**
CHAPTER 3	**: DEFINITION OF AN ACCIDENT AND AN INCIDENT**

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".

SECTION 7	**: NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION**
CHAPTER 4	**: SYSTEMS APPROACH TO THE INVESTIGATION OF HUMAN FACTORS**

1. 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 Reason1 on accident causation and depicted graphically in Figures 7-1 and 7-2.

2. 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 uppermanagement 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.

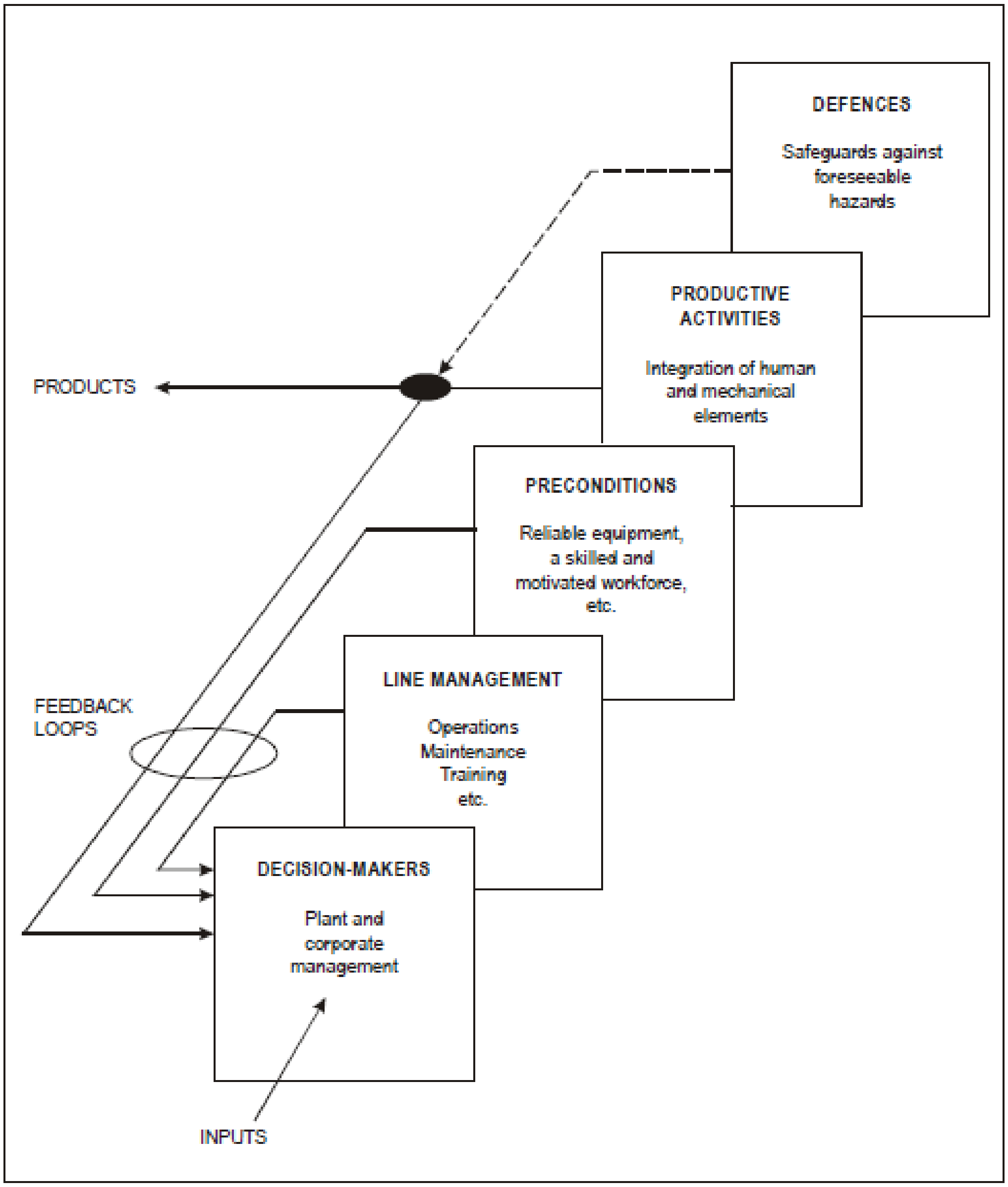


Figure 7-1. The basic components of any productive systems

(*Source*: James Reason, *Human Error*, 1990. United Kingdom: Cambridge University Press)

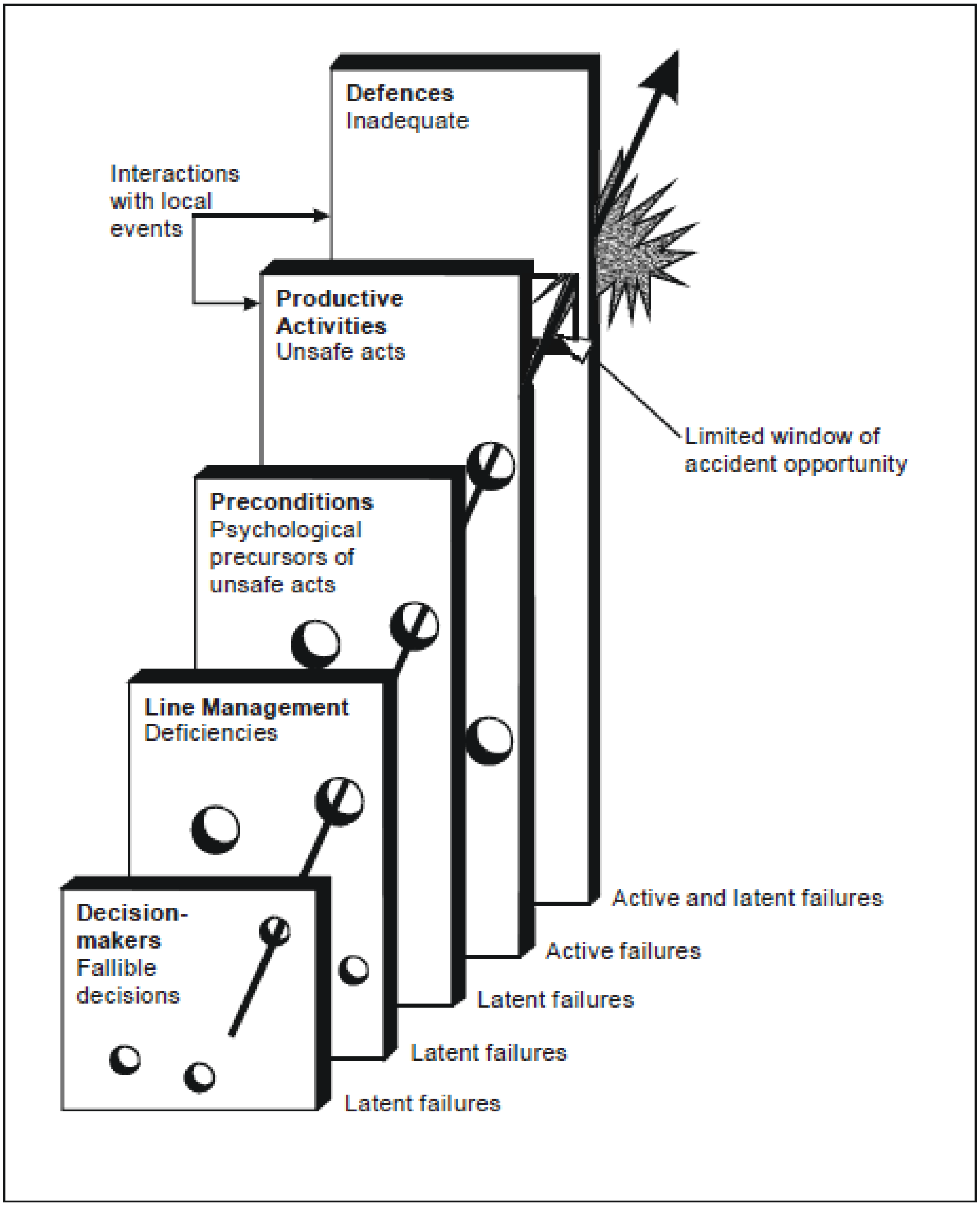


Figure 7-2. Modified version of James Reason's model of accident causation, showing the various human contributions to the breakdown of a complex system

(*Source*: James Reason, *Human Error*, 1990. United Kingdom: Cambridge University Press)

3. Illustrated in Figure 7-2 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.

4. 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.

5. 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.

SECTION 7	**: NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION**
CHAPTER 5	**: ACCIDENT SCENARIO**

1. 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.*

- *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.*

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. In Figure 7-3, 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.

10. 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.

SECTION 7	: NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION
CHAPTER 6	: INVESTIGATION OF INCIDENTS

1. 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 manner2. 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.

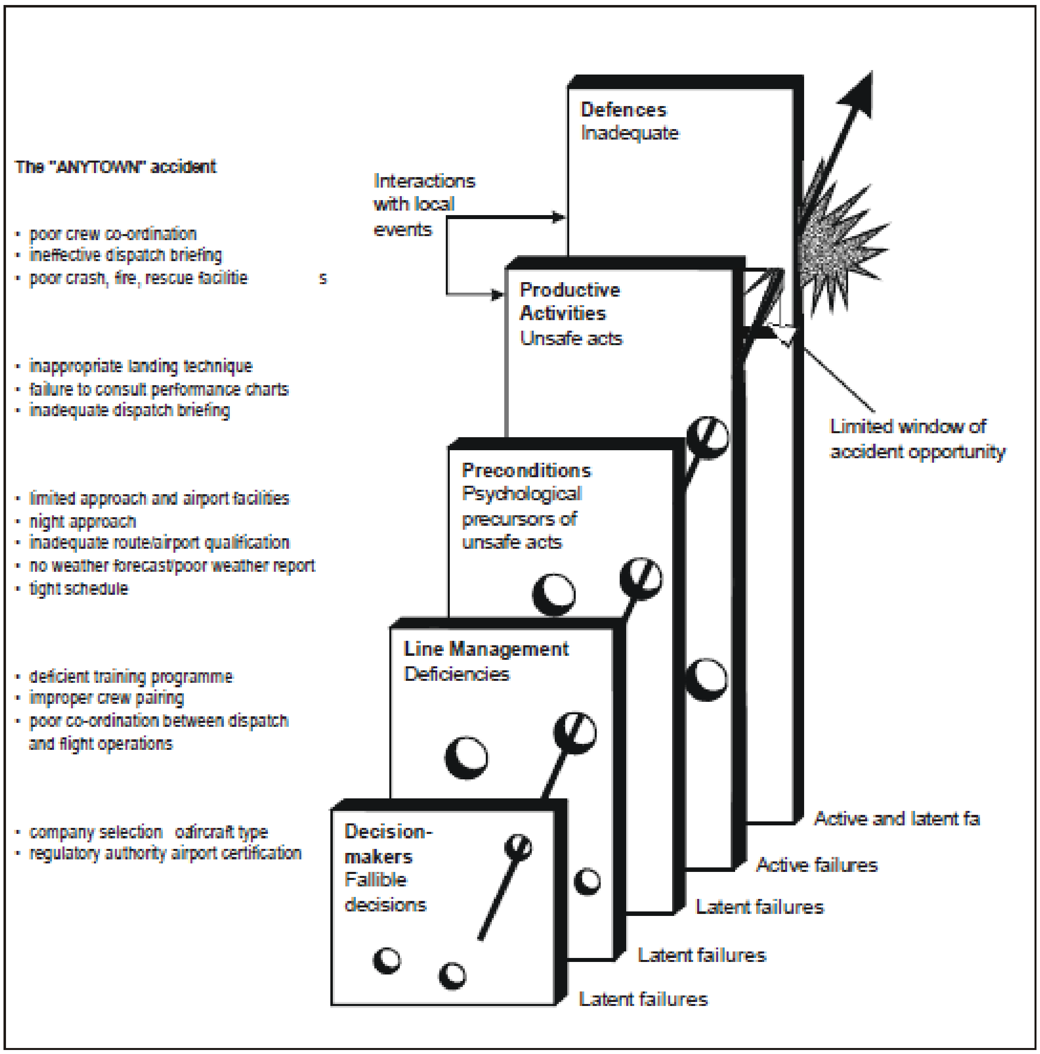


Figure 7-3. How the "Anytown"accident fits the modified version of James Reason's model of accident causation

2. 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.

3. 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.

4. 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.

SECTION 7	: NEED FOR AND PURPOSE OF HUMAN FACTORS INVESTIGATION
CHAPTER 7	: CONCLUSIONS

1. 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.

2. 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.

SECTION 8	: CONDUCT OF THE INVESTIGATION
CHAPTER 1	**: GENERAL**

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 chapter for investigators' Human Factors training 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. This section 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?

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.

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.

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.

SECTION 8	: CONDUCT OF THE INVESTIGATION
CHAPTER 2	: THE SINGLE INVESTIGATOR

1. 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. 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.

3. 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.

SECTION 8	: CONDUCT OF THE INVESTIGATION
CHAPTER 3	: THE HUMAN FACTORS INVESTIGATOR

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.

SECTION 8	**: CONDUCT OF THE INVESTIGATION**
CHAPTER 4	**: THE HUMAN FACTORS GROUP**

1. 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. 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.

3. 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?

4. 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 frontline operators were working.

5. 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.

6. 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.

SECTION 8	**: CONDUCT OF THE INVESTIGATION**
CHAPTER 5	**: THE SHEL MODEL**

1. 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 Figure 8-1 for a complete description of the SHEL model). 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.

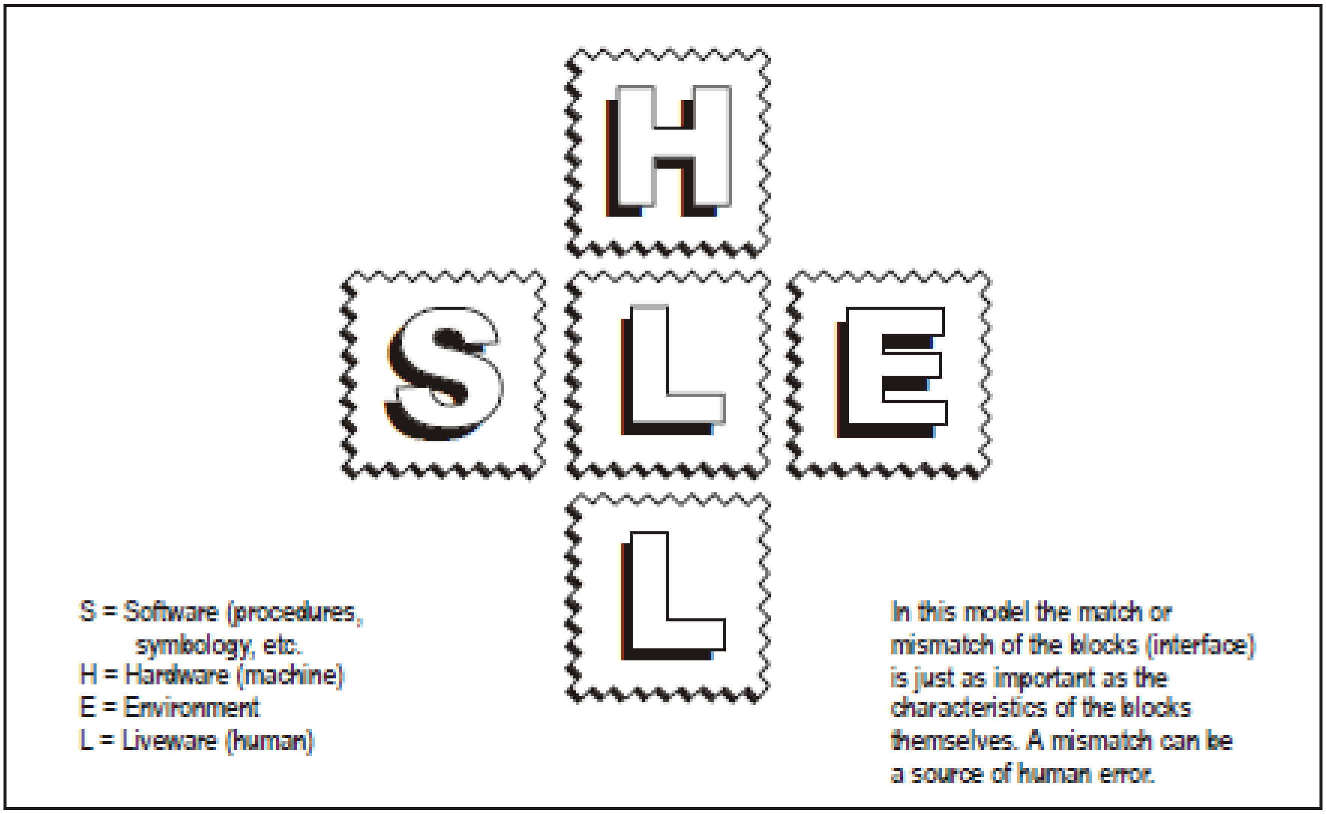


Figure 8-1. The SHEL model (adapted from Hawkins, 1975)

2. 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

3. 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

4. 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

5. 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

6. 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

7. 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?

8. 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?

9. 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.

10. 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."3 Although a standardized methodology has not been adopted, investigators have recognized the necessity for some form of ongoing reasoning process.

11. 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.

12. 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.

13. 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.

SECTION 8	: CONDUCT OF THE INVESTIGATION
CHAPTER 6	: USE OF CHECKLISTS

1. 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. 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.

SECTION 8	: CONDUCT OF THE INVESTIGATION
CHAPTER 7	: INFORMATION SOURCES

1. 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. 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.

3. 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).

4. 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.

5. 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 Doc 9683.

6. 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.

7. 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

8. 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.

9. 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, SECURITAS (Canada), ASRS (United States), CAIR (Australia), CHIRP (United Kingdom).

10. 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 Doc 9683 for a more detailed discussion of databases and their application to the investigation of Human Factors.

11. 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, a number of relevant reference documents are listed at the end of this manual. Some aviation research agencies will, on request, provide literature review services on selected topics. Additional references can be found in Part 1, Chapter 1 of Doc 9683.

12. 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.

SECTION 8	: CONDUCT OF THE INVESTIGATION
CHAPTER 8	**: ANALYSIS OF DATA**

1. 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. 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. 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.

3. 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.

4. 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.

5. Such straight-line cause and effect relationships may not 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.

6. 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 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.

7. 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.

8. 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

9. 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

10. 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 re-establish 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

11. 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.

12. 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.

SECTION 9	: REPORTING AND PREVENTIVE ACTION
CHAPTER 1	: GENERAL

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*.

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. 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.

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.

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."6 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*: 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.

SECTION 9	: REPORTING AND PREVENTIVE ACTION
CHAPTER 2	**: STRUCTURE OF THE REPORT**

1. 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.

2. 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. 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.

4. 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 subsection 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 subsection 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 subsection 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 subsections.

- pertinent information concerning the organizations and their management involved in influencing the operation of the aircraft, including organizational structure and functions, resources, economic status, management policies and practices and regulatory framework — *organizational and management information*.

- subsection 1.18 — *Additional Information* — provides a place to include information that cannot be readily included in any of the previous subsections. It is suggested that the investigator structure this section so that a subsection 1.18.1 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 subsection. 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 subsection 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 section 2 of this chapter, the investigator needs to present the empirical evidence to support the analysis of those Human Factors deemed influential in the occurrence. A subsection 1.18.2 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.

5. 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.

6. 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.

7. 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 Section 8 Chapter 8 para 9). 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.

8. 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 Section 8 Chapter 8 para 10). 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."

9. One way to present the analysis is to follow the order of the information presented in this chapter. 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.

10. Another effective way to present the analysis is through the use of Reason’s model as outlined in section 2 of Doc 9683. 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.

11. 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; and
- 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.

12. 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.

13. 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 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.

14. 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.

15. 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.

16. 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.

16. 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.

17. 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.

SECTION 9	**: REPORTING AND PREVENTIVE ACTION**
CHAPTER 3	**: ACCIDENT PREVENTION**

1. 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. ICAO Accident Prevention Manual Paragraph 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 shall recommend to the appropriate authorities, including those in other States, any preventive action which needs to be taken promptly to prevent similar occurrences.

2. 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. 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.

4. The Reason model, as illustrated in Figure 9-1, 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.

5. 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.

6. When companies, regulators, and accident investigators adopt a reform strategy, they turn their attention to loops 3 and 4 in Figure 9-1. 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.

7. 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.

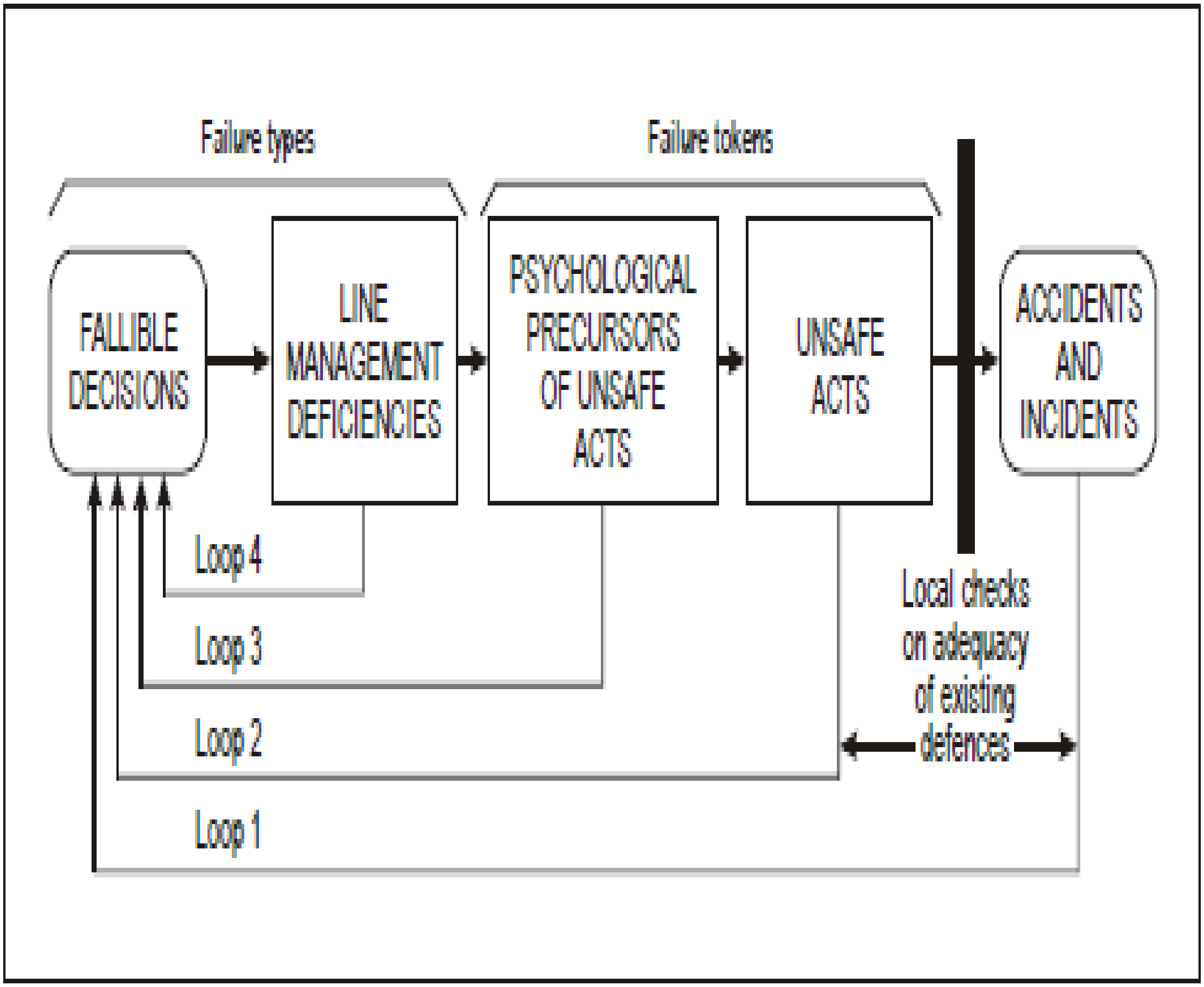


Figure 9-1. Preventive measures in accident occurrences can be parallelled to James Reason's approach to the role played by feedback loops in the control of safe operations

8. 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.

9. 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.

10. 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.

11. 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 manoeuvre. Richard H. Wood states it this way:

> "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.

12. 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. 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.

SECTION 9	**: REPORTING AND PREVENTIVE ACTION**
CHAPTER 4	**: DATA BASE REQUIREMENTS**

1. 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.

2. 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. Since human error or shortcomings in performance are usually factors in accidents, ADREP provides a sound framework for recording Human Factors data. Regarding incidents, however, ADREP contains only data from incidents which were investigated and reported to ICAO in accordance with Annex 13.

4. 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.

5. 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 of Section 6 to 9

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

Sr.	**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, excessivemotivation (“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
Sr.	**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)

Sr.	**MEDICAL FACTORS**
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)
Sr.	**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.)
Sr.	**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
Sr.	**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)

Sr.	**EQUIPMENT DESIGN FACTORS**
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.
Sr.	**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
Sr.	**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
Sr.	**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

Sr.	**Air Traffic Control**
F	Judgement
G	Training and currency
H	Co-ordination and back-ups
I	Supervisory presence
J	ATC policies and operating procedures
Sr.	**Vehicle Operators**
K	Selection and training
L	Working environment (noise, fatigue, visibility, etc.)
M	Command and control, supervision

Sr.	**Aircraft Line-Servicing Personnel**
N	Selection and training
O	Availability of relevant information
P	Operating pressures
Q	Supervision
Sr.	**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, co-ordination

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
* co-ordination

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?

SECTION 10	**: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION**
CHAPTER 1	**: GENERAL**

1. To achieve its purpose, an investigation must be properly planned and managed. The main parts of an investigation must be planned so that the members of an investigation team are aware of their various tasks and have the appropriate qualifications to perform them. The plan must also recognize that these tasks should be coordinated by the IIC, who is the leader of the team.

2. When a large aircraft is involved, a sizeable team of investigators, set up in specialized groups, is necessary to properly cover all aspects of the investigation. In some investigations, the areas on which the investigation should focus will become evident at an early stage, and the main investigation effort can then be effectively channeled into these relatively specialized areas. Nevertheless, it is still essential that investigators progress systematically through all aspects of the accident. Whether or not the causes of an accident are apparent, the investigation will determine any underlying systemic factors that may have contributed to the accident or its aftermath as well as any non-causal deficiencies that could contribute to future accidents or their aftermath.

3. In the case of accidents involving small aircraft, the investigation effort is proportionately smaller. The functions are still the same, but the work is undertaken by one or two investigators or, alternatively, by an investigator and a specialist qualified in a particular aspect that requires expert examination. Again, it is stressed that even when small aircraft are involved, pre-investigation planning and use of investigation checklists are essential.

SECTION 10	**: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION**
CHAPTER 2	**: THE INVESTIGATION MANAGEMENT SYSTEM**

1. An accident investigation involving a large or complex aircraft should require a large team of investigators in order to conduct the investigation in the most effective and expeditious way. The effective utilization of the available investigators in a major investigation can be achieved by using an “investigation management system” (reference to ICAO *Manual of Aircraft Accident and Incident Investigation* (Doc 9756, Part II, Chapter 4). The investigation management system divides the investigation activities into functional areas, each of which can be assigned to a group within the investigation team. Each investigation group should have as many members as are necessary to examine the particular circumstances of the accident.

2. After the initial visit and walk-through of the accident site, the first management action to be taken by the IIC is to convene an “organizational meeting”. At the organizational meeting, the IIC should identify all participants who should be assigned to the team and he or she should excuse others, such as news media, lawyers, insurers, who should not be permitted to be part of the team.

3. The primary purpose of the organizational meeting is to describe the rules, policies and procedures of the investigation and to organize the team into the specific groups responsible for various aspects of the investigation.

Note 1.— Attention must be paid to the need to facilitate entry of accredited representatives and advisers from other States involved in the investigation. To this end, the State of Occurrence of the accident must not require any other travel document than a passport of qualified personnel designated or appointed by other States to participate in the investigation. In this connection, reference is to be made to ICAO Annex 9 — Facilitation, *Chapter 8, Section B.*

Note 2.— Organizational meetings should be convened by the [Accident Investigation Authority] IIC for both large and small investigations as part of the investigation management system.

Note 3.— If properly planned and organized, the organizational meeting should take less than one hour so that the investigation groups can then begin their important work.

4. At the organizational meeting, the IIC should discuss the rights, obligations, and responsibilities of the investigators. The IIC should also discuss the policies and procedures contained in this manual and should make available a copy of this manual for review by all participants to ensure they understand their roles, tasks and duties. Then the IIC should organize the investigators into groups led by senior investigators.

5. An attendance roster should be circulated for all participants to sign. Signing the attendance roster confirms that the person signing has read, understood, and will comply with the *Aircraft Accident Investigation Bureau* legislation, regulations, policies and procedures during the course of the investigation. Administrative personnel should be assigned to ensure all participants sign the attendance roster for each team meeting.

Note.— Use of interpreters is important during team meetings, even if all participants appear to fully understand the language being used (most often English) during the meetings. Those persons for whom English is not their first language may have difficulty understanding complex issues discussed at the meetings.

6. Depending on the magnitude and circumstances of the accident, several groups may be formed for various technical investigation areas (see Figures 10-1, 10-2 and 10-3).

7. The investigation group chairpersons are senior investigators, each responsible for a specific group. The members of the investigation groups should include specialists from the *Aircraft Accident Investigation Bureau*, the airline, the *Department of Civil Aviation(DCA)*, the aircraft and engine manufacturers, the airport and employee unions, as appropriate. The groups also may include advisers assigned by the accredited representatives from other States. All members of the group should normally have access to all information uncovered in the course of the investigation and are required to participate in the investigation until the group report is completed.

8. The investigation groups that might be formed during a major investigation might include: Witnesses, Meteorology/Weather, Air Traffic Services, Aircraft Structures, Aircraft Systems, Powerplants, Maintenance Records, Survival Factors, Human Performance, Aircraft Performance, and Flight Recorders. Other special groups may be formed as the need arises, such as Fire and Explosion, Underwater Recovery, Mock-up, etc. The circumstances and complexity of the accident should determine the number and types of groups required (see Figure 10-3).

Note 1.— The ICAO Manual of Aircraft Accident and Incident Investigation *(Doc 9756), Part II, Chapter 3—* Investigation Responsibilities, *provides an overview of the typical responsibilities of* *investigation team members of a major investigation. In addition, Chapter 4 —* Major Accident Investigations, *includes information on the Major Accident Investigation Guide (MAIG), which provides the IIC, group chairpersons and other investigation team members with basic major investigation guidelines.*

Note 2.— The ICAO Manual of Aircraft Accident and Incident Investigation *(Doc 9756), Part III, contains detailed guidance on how to conduct specific areas of investigation.*

Note 3.— Each of the Aircraft Accident Investigation Bureau group chairpersons should provide a copy of the relevant guidance materials to his or her group members to review before beginning the investigation.

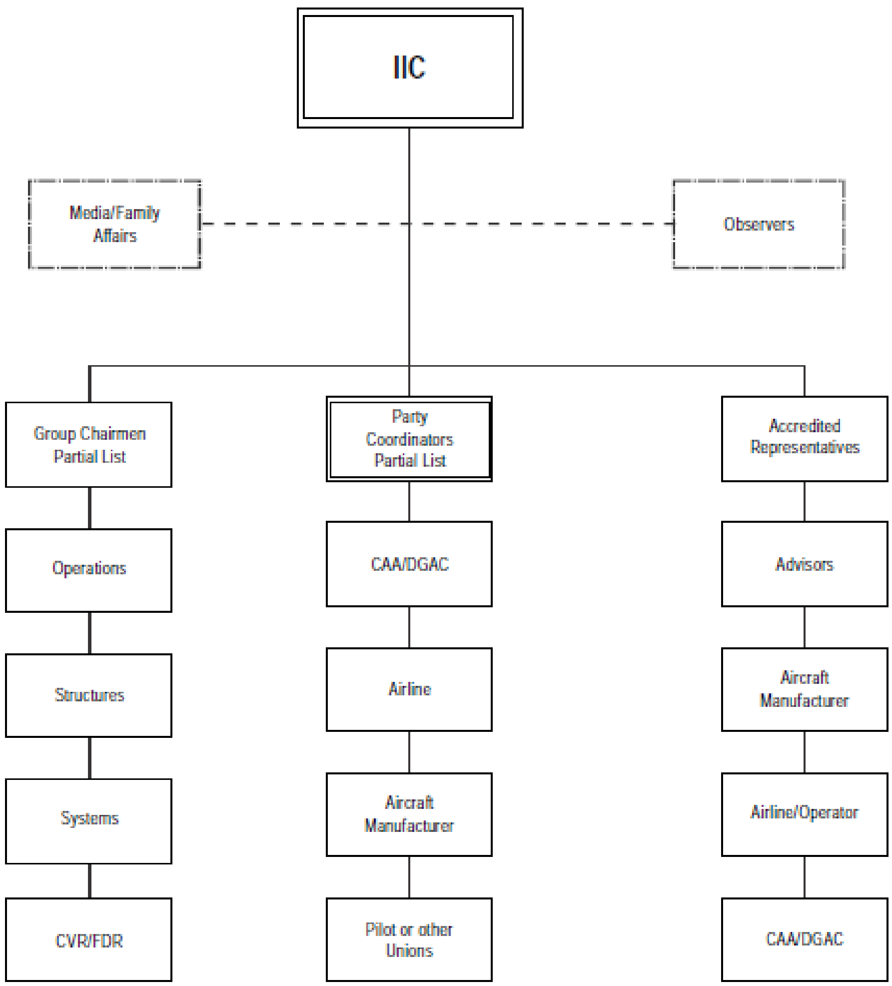


Figure 10-1. Example of how the investigation team may be organized, depending on the nature of the investigation

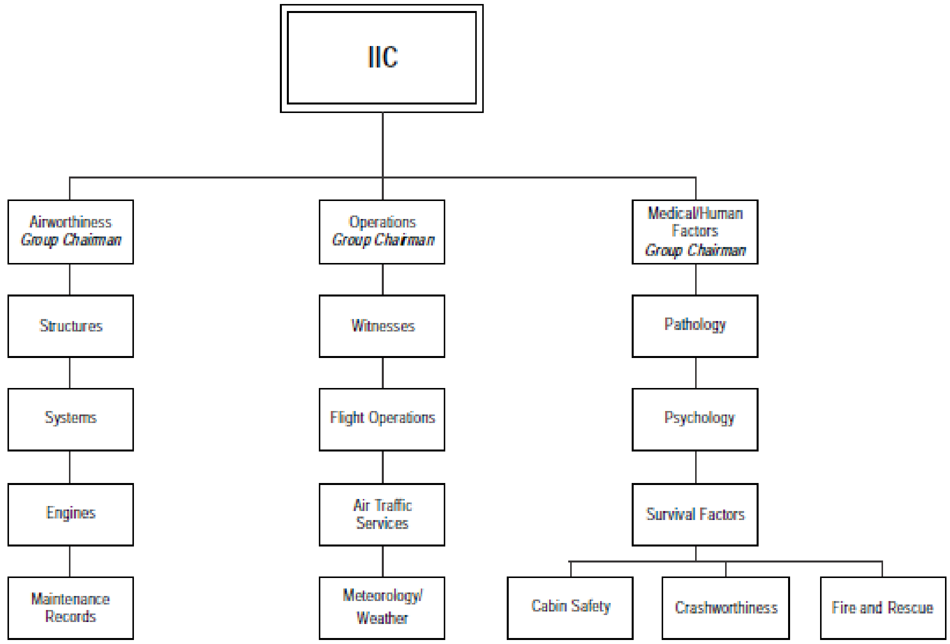


Figure 10-2. Investigation team — Example

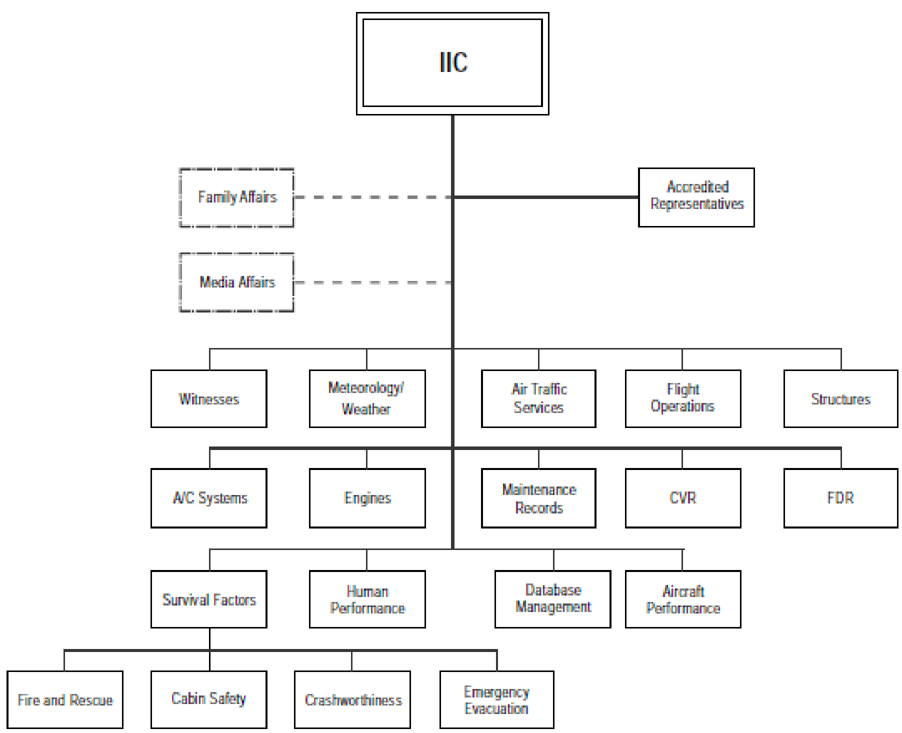


Figure 10-3. Investigation team — Example B

9. In all investigations, a coordinator (spokesperson/team leader) from each of the organizations involved (airline, regulator, manufacturer, etc.) is appointed for liaison duties with the IIC, and to oversee the work of the specialists from their organization. The IIC is the person responsible for communications with the accredited representatives (and their advisors) from other States participating in the investigation in accordance with ICAO Annex 13.

10. Accident investigation management can be greatly facilitated if the IIC uses a flow chart with a number of events. Each event has a corresponding descriptive phrase. The flow chart allows the investigators to ensure that the essential sequence of events is followed. The ICAO *Manual of Aircraft Accident and Incident Investigation* (Doc 9756), Part II, contains an “Event Checklist” specifically intended to aid accident investigation management by documenting the various stages of the investigation. This checklist should be used as a tool to manage the various investigation steps to be taken to complete the investigation. It is a tool only and must be supplemented by other materials.

11. Each event checklist should be used in conjunction with the Major Accident Investigation Guide contained in the ICAO *Manual of Aircraft Accident and Incident Investigation* (Doc 9756), Part II; and the specific investigation task materials (checklists) contained in Doc 9756, Part III, and tailored to the particular accident circumstances. Since the investigation tasks may differ due to the circumstances of the accident, the checklists should be reviewed to ensure that the tasks are appropriate to the organization and conduct of the accident investigation. Arranging the activities and tasks into checklists allows the IIC to clearly indicate what has been accomplished and what is to be accomplished by the investigators and the various groups during the investigation. It also makes it easier for the IIC to provide direction and guidance to those persons who are participating in an investigation for the first time and who may require specific advice. The checklists, aside from being part of the investigation management system, establish some order in what is often a confusing situation.

12. The group chairpersons are responsible for completing the investigation tasks using the relevant checklists to fulfil their various tasks. Therefore, the group chairpersons must be knowledgeable about the investigation management system and the tasks their groups are required to carry out. They should be well aware that the outlined tasks are not necessarily exhaustive and that particular circumstances may warrant revision of tasks. When using the checklists, it is desirable that the investigators take note of the completion date of each task, any further action required or anything of significance associated with a particular task. Regardless of how much planning goes into the

preparation of the checklists, there will inevitably be cases in which the outlined tasks will have to be adapted to the particular circumstances of the investigation.

13. The checklists help the group chairpersons organize the work of their groups, and provide the IIC with a tool to monitor progress. At the daily progress meetings, the investigators should report which tasks on their checklists have been completed since their last report, and the IIC should record that progress on the flow chart. The advantage of this system is the ease with which the progress of the investigation can be reported to headquarters from the accident site and the fact that the flow chart at headquarters can be updated to reflect the current status of the investigation.

14. The investigation management system is one of the fundamental tools to be used in a major investigation, and an investigator who is likely to be appointed IIC or group chairperson of a major investigation should be familiar with this system prior to attempting to use it in the field. The effectiveness of the system is directly related to how well each investigator adheres to the flow chart and the checklists.

15. It is the policy of the *Aircraft Accident Investigation Bureau* to use the investigation management system during the conduct of its investigations.

SECTION 10	: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION
CHAPTER 3	: PROGRESS MEETINGS

1. The investigation management system incorporates the use of a daily progress meeting of the investigation team. The primary purpose of progress meetings is for all team members to participate in the daily reports of the various groups and for all team members to be aware of findings of other groups and to plan future activities. It also builds the "team concept", which is essential for a major accident investigation to be successful. Further, the progress meetings provide the IIC the opportunity to oversee the progress and findings of the investigation and to provide leadership and guidance as necessary.

Note.— Progress meetings should be held even if the number of investigation team members is small (3 to 5 persons) and may be held in an informal setting, such as in a vehicle at the accident site or similar location. Large progress meetings (10 to 100 persons) should be held in a more formal setting, such as a large room at a hotel or similar location. Holding such meetings is part of the investigation management system.

2. The typical format for a progress meeting would be for the IIC to make a general opening statement and to bring the team up to date on developments outside of the team, such as review of maintenance records, reports from flight recorder read-outs, and other investigation activities being conducted away from the accident site. If new investigators join the team, they will be given the rules, policies, and procedures and assigned to the appropriate group.

3. Next, the IIC should request that each group chairperson give a brief report. The format of group chairperson reports should be:

- What we did today
- What we found today
- What we plan to do tomorrow
- Any questions, comments, or suggestions

4. Group reports should be short and concise. Relevant documents, such as weather reports or similar data, should be distributed to other participants and do not have to be read at the progress meeting. Reports and questions should be restricted to factual information. This is not the place to begin to speculate or analyse the causes of the accident. If the progress meeting is organized and managed properly, it should not take more than one hour.

Note.— When participants have different first languages, the use of interpreters is essential for all persons to gain the full benefit of the progress meeting reports, so they can understand the information to pass on to their superiors and to develop accident prevention measures. In some cases, it would be appropriate for the group chairpersons to provide advance hard copies of their briefing notes for participants to follow during those oral briefings.

5. Following the progress meeting, the IIC should report findings and progress to his or her superiors and should prepare for possible media and family briefings.

SECTION 10	**: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION**
CHAPTER 4	**: COOPERATION WITH THE MEDIA**

1. All major aircraft accidents and most small accidents generate a high degree of interest from the public and the media. A good rapport with the media is usually an asset to the investigation. It may be necessary to enlist the cooperation of the local media to withhold precise details of the location of an aircraft accident until adequate crowd control measures can be implemented. It may also be necessary to enlist the aid of the media in obtaining further information about the local area, the names of possible witnesses or when seeking the public's assistance in recovering missing pieces of the aircraft wreckage.

2. To promote dissemination of factual information and to minimize speculation and rumours about the accident, the *Aircraft Accident Investigation Bureau* should provide the media, on a regular basis, with details of the progress of the investigation and facts that can be released without prejudice to the investigation. For this reason, the IIC and the *Aircraft Accident Investigation Bureau* should establish a single point of contact for media inquiries. This contact is usually the IIC or a person designated by the *Aircraft Accident Investigation Bureau Head* or the IIC. The IIC, in consultation with the accredited representatives, should provide unprejudicial facts and circumstances to the media. Nevertheless, it is necessary to ensure that the needs of the media do not interfere with the proper conduct of the investigation. The media should be informed that a preliminary (factual) report will be released about 30 days after the accident.

3. Other agencies and organizations involved or affected by the accident (such as airlines, airport authorities, emergency services, and aircraft manufacturers) may also need to release information to the media about their involvement, and such efforts should be coordinated, to the extent possible, among the agencies and organizations involved. Nonetheless, the *Aircraft Accident Investigation Bureau* is the primary point of contact and the only organization permitted to release information on the progress and findings of the investigation.

4. For accident investigations outside *Myanmar* and conducted by other States, the *Aircraft Accident Investigation Bureau* -appointed accredited representative and the advisers participating in the investigation shall not give the media or the public access to any information or documents obtained during the investigation without the express consent of the State conducting the investigation.

The release of such information by the *Aircraft Accident Investigation Bureau* or other *Myanmar* officials, without the consent of the State conducting the investigation, would undermine the mutual confidence and cooperation among the States involved and must therefore be avoided.

SECTION 10	**: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION**
CHAPTER 5	**: DEALING WITH FAMILIES OF ACCIDENT VICTIMS**

1. The *ICAO Policy on Assistance to Aircraft Accident Victims and their Families* (Doc 9998) and the *Manual on Assistance to Aircraft Accident Victims and their Families* (Doc 9973) contain internationally accepted guidance and practices for States to follow when dealing with aircraft accident victims and their families.

2. Victims and their families are not permitted to participate in the investigation; however, ICAO Annex 13, paragraph 5.27, "States having suffered fatalities or serious injuries to their citizens", provides certain rights and entitlements to States having a special interest in an accident by virtue of fatalities or serious injuries to their citizens. Specifically, such States are permitted to appoint an "expert", who shall be entitled to:

a) visit the scene of an accident;

b) have access to the relevant factual information, which is approved for public release by the State conducting the investigation, and information on the progress of the investigation; and

c) receive a copy of the Final Report.

3. This should not preclude the State from also assisting in the identification of victims and in meeting with survivors from that State.

4. These provisions do not permit the appointed expert to actively participate in the investigation.

Note.— For accidents that occur outside Myanmar that involve Myanmar citizens, it may be necessary for Myanmar to send experts to assist the other State with the identification of victims. This task is not directly related to accident investigation and does not fall under the mandate of the Aircraft Accident Investigation Bureau. Although the Aircraft Accident Investigation Bureau may not be required to provide an expert(s) for this task, the Aircraft Accident Investigation Bureau should encourage the relevant Myanmar foreign affairs authorities and personnel to provide such assistance, normally through the Myanmar Embassy in the other State.

5. ICAO Annex 9 — *Facilitation*, Chapter 8, Section I - *Assistance to aircraft accident victims and their families*, contains SARPs related to States' obligations to facilitate entry into their territory, on a temporary basis, of family members of victims of aircraft accidents. *Myanmar* should extend all necessary assistance, such as issuing emergency travel documents, arranging transport, and clearing customs for families of aircraft accident victims.

[[Note.— Some States have legislation specifically dealing with the handling of families and aircraft accident victims. This section of the manual should be tailored to be consistent with such requirements. If there are no formal requirements in the State, the manual should address, in general, how the families and victims should be dealt with, in order to comply with ICAO requirements in this regard. Suggested text is provided below.]]

6. The general responsibilities for dealing with the families and aircraft accident victims lie with the airline, which should have in place a plan for dealing with families and victims of aircraft accidents. However, the State of Occurrence should provide oversight of such activities. Therefore, the *Aircraft Accident Investigation Bureau* should establish liaison with relevant family members or their representatives, to facilitate the provision of briefings on the progress of the investigation, and to facilitate the necessary access for other States' experts, in accordance with the provisions of ICAO Annex 13, paragraph 5.27, and the ICAO *Manual on Assistance to Aircraft Accident Victims and their Families* (Doc 9973).

SECTION 10	**: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION**
CHAPTER 6	**: SECURING THE RECORDS, SAMPLES AND RECORDINGS**

The *Aircraft Accident Investigation Bureau* procedures require that, in the event of an accident, all air traffic services communication recordings and documents deemed to be associated with the flight, and aviation meteorology data, be secured and placed in protective custody. The *Aircraft Accident Investigation Bureau* has agreements (MoUs) with the relevant organizations to fulfil this requirement. Further instructions are in place, which require that the aircraft operator's documentation associated with the aircraft, the flight crew and the flight operation is placed in safekeeping.

SECTION 10	**: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION**
CHAPTER 7	**: REMOVAL OF THE AIRCRAFT WRECKAGE**

Detailed information concerning planning, equipment and procedures for the removal of disabled aircraft at airports is contained in the *Airport Services Manual* (Doc 9137), Part 5 - *Removal of Disabled Aircraft*.

SECTION 10	: ORGANIZATION AND MANAGEMENT OF THE INVESTIGATION
CHAPTER 8	**: RELEASE OF THE AIRCRAFT WRECKAGE**

1. The aircraft wreckage should remain under the custody of the *Aircraft Accident Investigation Bureau* until such time as it should be released back to the owner of the aircraft, or the owner's representative (insurance company). In many cases, the aircraft wreckage should be released in increments, depending on the needs of the investigators for testing of selected components.

2. For accidents in Myanmar involving aircraft registered and operated by other States, the *Aircraft Accident Investigation Bureau* should facilitate the release from custody of the aircraft, its contents, or parts thereof, as soon as they are not required for the investigation, to person(s) duly designated by the State of Registry or State of the Operator. This provision is particularly important when occurrences involve minimal damage to an aircraft that needs to be repaired and returned to service.

3. Portions of the aircraft wreckage may be released, or the entire aircraft wreckage may be released, using the aircraft wreckage and parts release form (see Appendix A) that includes the name and organizational information of the IIC and the owner of the aircraft or the owner's authorized representative. The release form should include the identifying information on the accident and the aircraft.

4. If the entire aircraft wreckage is to be released, the IIC should sign the aircraft wreckage and parts release form and he or she should obtain a signature from the owner of the aircraft, or the owner's representative, who accepts the aircraft wreckage. If only portions of the aircraft wreckage are being released, the aircraft wreckage and parts release form should list the components being released and any components being retained for further examination, along with the appropriate signatures verifying the release and retention of parts. Each time a portion of the aircraft wreckage is released, an additional aircraft wreckage and parts release form should be completed to document the transfer.

Note.— The Aircraft Accident Investigation Bureau IIC should obtain full concurrence with all parties, including police involved in the investigation, about the decision to release aircraft wreckage before it is turned over to the owner of the aircraft or the owner's representative. The IIC should also coordinate his or her decision with the Aircraft Accident Investigation Bureau management personnel.

Appendix A

Wreckage and Parts Release Form

Aircraft Accident Investigation Bureau
Investigation Number

The *Aircraft Accident Investigation Bureau* is conducting an investigation into the following aviation safety matter.

Investigation title and/or other description — aircraft make, model, registration, date of occurrence, etc.

The items listed below are no longer required by the *Aircraft Accident Investigation Bureau* as part of its accident/incident investigation.

Note.— It is strongly recommended that components be inspected by authorized personnel where it is intended for them to be returned to operational service.

Item details (description and condition)	Date returned

Aircraft Accident Investigation Bureau **IIC or Delegate**

Signature of IIC/Delegate

Name of IIC/Delegate

Date

Phone
( )

Fax
( )

Email

Please return a signed copy of this form to the above person at the *Aircraft Accident Investigation Bureau.*

Owner or agent acknowledgement

I accept custody of the listed items.

Owner or Agent's name

Phone

Signature of Owner or Agent

Date

SECTION 11	: REFERENCES
CHAPTER 1	**: SOURCES OF TECHNICAL INFORMATION**

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