Safety Regulation Group

Civil Aviation Authority

CAP 719

Fundamental Human Factors Concepts

(previously ICAO Digest No. 1)

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Important Note

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Foreword

1.1 Flight safety is the major objective of the International Civil Aviation Organization. Considerable progress has been made, but additional improvements are needed and can be achieved. It has long been known that some three out of four accidents result from less than optimum human performance, indicating that any advance in this field can be expected to have a significant impact on the improvement of flight safety.

1.2 This was recognized by the ICAO Assembly, which in 1986 adopted Resolution A26-9 on Flight Safety and Human Factors. As a follow-up to the Assembly Resolution, the Air Navigation Commission formulated the following objective for the task:

> "To improve safety in aviation by making States more aware and responsive to the importance of human factors in civil aviation operations through the provision of practical human factors material and measures developed on the basis of experience in States."

1.3 One of the methods chosen to implement Assembly Resolution A26-9 is the publication of a series of digests which will address various aspects of Human Factors and their impact on flight safety. These digests are intended primarily for use by States, to increase the awareness of their personnel of the influence of human performance on safety. The ICAO Secretariat will endeavour to assist States requesting additional information on the documentation available from various sources, on research undertaken by other States and on any assistance available from institutions or individuals.

1.4 The digests are aimed at the managers of both civil aviation administrations and the airline industry, including airline operational and training managers. Regulatory bodies, safety and investigation agencies and training establishments should also find them useful, as will senior and middle non-operational airline management, in their quest for effectiveness.

Introduction

1.1 Human behaviour and performance are cited as causal factors in the majority of aircraft accidents. If the accident rate is to be decreased, Human Factors must be better understood and the knowledge more broadly applied. The expansion of Human Factors awareness presents the international aviation community with the single most significant opportunity to make aviation both safer and more efficient. The purpose of this digest is to present an overview of the various components which constitute Human Factors and to clarify its meaning.

1.2 Ever since humans began to make tools, thousands of years ago, the application of elementary ergonomics has improved work efficiency. But it is only during the last hundred years that the modern evolution of ergonomics or Human Factors has begun.

1.3 The need during the First World War to optimize factory production and to assign thousands of recruits more effectively to military duties, and the fact that during the Second World War sophisticated equipment was surpassing human capability to operate it with maximum effectiveness provided further stimulus to Human Factors progress. Selection and training of staff, too, began to be approached more scientifically.

1.4 The institutionalization of Human Factors, or ergonomics, occurred with the founding of several organizations such as the Ergonomics Research Society in 1949, the Human Factors Society in 1957 and the International Ergonomics Association (IEA) in 1959.

1.5 The recognition that basic Human Factors education was needed throughout the industry led to various approaches to formal training in different countries. This recognition was tragically emphasized when, at Tenerife in 1977, two aircraft collided, with a loss of 583 lives, a disaster resulting almost entirely from a series of deficiencies in the application of Human Factors.

1.6 The 1976 agreement between the United States Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) to establish a voluntary, non- punitive, confidential Aviation Safety Reporting System (ASRS) constituted official recognition that adequate information for analysis of human behaviour and errors in human performance is best obtained by eliminating the threat of punitive action against the person making the report. By 1989, over 110 000 reports had been received by ASRS, the system had issued nearly 1 000 alert bulletins and over 1 500 special studies had been made. Similar schemes were later set up in the United Kingdom (CHIRP), Canada (CASRP) and Australia (CAIR).

1.7 It is not the purpose of this digest to determine if Human Factors was adequately applied in aviation in the past, but rather to present what can usefully be done to ensure adequate progress in the future. Nor is it intended that the digest be used as a substitute for properly constructed courses or books based on years of experience. Instead, the purpose of the digest is to provide an introduction to the subject and to encourage the use of available sources of education and training.

1.8 The scope of this digest includes:

a) the meaning and definition of Human Factors, a conceptual model of it, and clarification of common misconceptions;

b) the industry need for Human Factors;

c) the application of Human Factors in flight operations; and

d) the levels of expertise required and the formal approaches to education.

1.9 This digest was produced with the assistance of the ICAO Flight Safety and Human Factors (HF) Study Group. The major references used in its preparation are the book *Human Factors in Flight,* by Frank Hawkins, 1987, while parts of the conceptual approach, especially in Chapter 1, are based upon the ideas of Professor Elwyn Edwards as most recently published in the book *Human Factors in Aviation,* by Wiener and Nagel.

Chapter 1 The Meaning of Human Factors

1 Introduction

1.1 Human Factors as a term has to be clearly defined because when these words are used in the vernacular they are often applied to any factor related to humans. The human element is the most flexible, adaptable and valuable part of the aviation system, but it is also the most vulnerable to influences which can adversely affect its performance. Throughout the years, some three out of four accidents have resulted from less than optimum human performance. This has commonly been classified as "pilot error".

1.2 The term "pilot error" is of no help in accident prevention. In fact, it is often counter-productive because, although this term may indicate WHERE in the system a breakdown occurs, it provides no guidance as to WHY it occurs. An error attributed to humans in the system may have been design-induced or stimulated by inadequate training, badly designed procedures or the poor concept or layout of checklists or manuals. Further, the term "pilot error" allows concealment of the underlying factors which must be brought to the fore if accidents are to be prevented.

1.3 An understanding of the predictable human capabilities and limitations and the application of this understanding are the primary concerns of Human Factors. Human Factors has been progressively developed, refined and institutionalized since the end of the last century, and is now backed by a vast store of knowledge which can be used by those concerned with enhancing the safety of the complex system which is today's civil aircraft.

1.4 Throughout this digest capital initial letters are used for the term "Human Factors". The terms "human aspects" and "human elements" in common usage are helpful alternatives to avoid ambiguity and aid comprehension.

2 The disciplines of Human Factors

2.1 Many of the early concerns in aviation were related to the effects on people of noise, vibration, heat, cold and acceleration forces. Usually, the person nearest at hand with a knowledge of physiology was a physician; this may have generated one of the more persistent misconceptions about Human Factors, the belief that it is somehow a branch of medicine. Yet half a century ago work was expanding on the more cognitive aspects of the flying tasks and this trend has continued and is outside the scope of medicine. Optimizing the role of people in this complex working environment involves all aspects of human performance and behaviour: decision-making and other cognitive processes; the design of displays and controls and flight deck and cabin layout; communication and computer software; maps and charts; and the field of documentation such as aircraft operating manuals, checklists, etc. Human Factors knowledge is also increasingly used in staff selection, training and checking and in accident investigation.

2.2 Human Factors, like most coherent activities, is multidisciplinary in nature. For example, information is drawn from psychology to understand how people process information and make decisions. From psychology and physiology comes an understanding of sensory processes as the means of detecting and transmitting information on the world about us. The measures and movements of the body – essential in optimizing the design and layout of controls, and other workplace characteristics of the flight deck and cabin – call upon anthropometry and biomechanics. Biology and its increasingly important sub-discipline, chronobiology, are needed to understand the nature of the body's rhythms and sleep, and their effects in night flying and time-zone changes. Finally, no proper analysis or presentation of data from surveys or studies is possible without some basic understanding of statistics.

2.3 Professor E. Edwards has stated that while utilizing these academic sources of information, Human Factors is essentially concerned with solving practical problems in the real world. Human Factors is practical in nature; it is problem-oriented rather than discipline-centred. The relationship between Human Factors and the human sciences might be compared with that between engineering and the physical sciences.

3 Human Factors and Ergonomics

3.1 It has often been said that Human Factors is complex and diverse and that everyone has a different opinion about its meaning and scope. This is not true, as is very clear from the preceding paragraphs. Those professionally engaged in the research on and in the teaching and application of Human Factors know perfectly well what it is all about, and any diversity in approach is no more significant than in any dynamic technology in which new solutions and new truths are constantly sought.

3.2 Human Factors is about people in their living and working situations; about their relationship with machines, with procedures and with the environment about them; and also about their relationships with other people. In aviation, Human Factors involves a set of personal, medical and biological considerations for optimal aircraft and air traffic control operations.

3.3 One definition of Human Factors, as proposed by Professor Edwards, declares that "Human Factors is concerned to optimize the relationship between people and their activities, by the systematic application of human sciences, integrated within the framework of systems engineering". Its objectives can be seen as effectiveness of the system, which includes safety and efficiency, and the well-being of the individual. Professor Edwards further elaborates on his proposed definition, indicating that the word "people" includes both sexes, and that "activities" indicates an interest in communication between individuals and in the behaviour of individuals and groups. The human sciences study the structure and nature of human beings, their capabilities and limitations, and their behaviours both singly and in groups. The notion of integration within systems engineering refers to the Human Factors practitioner's attempts to understand the goals and methods as well as the difficulties and constraints under which people working in interrelated areas of engineering must make decisions. Human Factors uses this information based on its relevance to practical problems.

3.4 The term ”ergonomics” derives from the Greek words ”ergon” (work) and ”nomos” (natural law). It is defined as ”the study of the efficiency of persons in their working environment”. In some States, the term ergonomics is used strictly to refer to the study of human-machine system design issues. In this digest, the term ergonomics is used in a broader context, synonymous with the term Human Factors, and, therefore, including human performance and behaviour.

4 A conceptual Model of Human Factors

4.1 It is helpful to use a model to aid in the understanding of Human Factors, as this allows a gradual approach to comprehension. One practical diagram to illustrate this conceptual model uses blocks to represent the different components of Human Factors. The model can then be built up one block at a time, with a pictorial impression being given of the need for matching the components. The SHEL concept (the name being derived from the initial letters of its components, Software, Hardware, Environment, Liveware) was first developed by Edwards in 1972, with a modified diagram to illustrate the model developed by Hawkins in 1975. For those familiar with the long-established concept of ”man-machine-environment” (now referred to as ”human-machine-environment”), the following interpretations are suggested: liveware (human), hardware (machine) and software (procedures, symbology, etc.), environment (the situation in which the L-H-S system must function). This building block diagram does not cover the interfaces which are outside Human Factors (hardware-hardware; hardware-environment; software-hardware) and is only intended as a basic aid to understanding Human Factors.

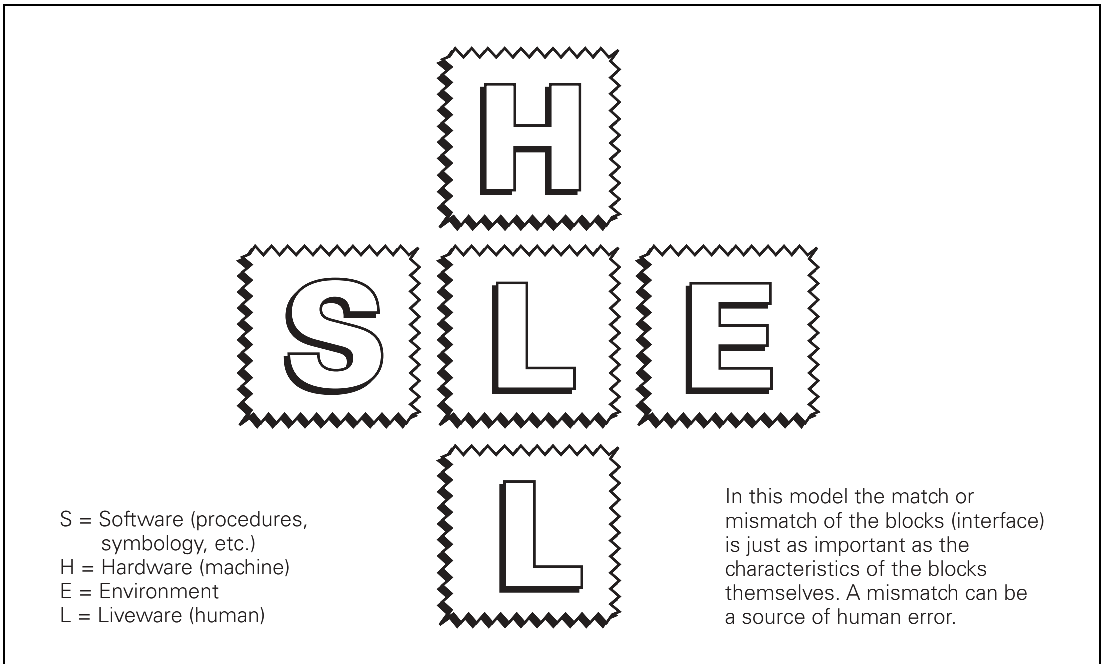


Figure 1 The SHEL model as modified by Hawkins

4.2 **Liveware**. In the centre of the model is a person, the most critical as well as the most flexible component in the system. Yet people are subject to considerable variations in performance and suffer many limitations, most of which are now predictable in general terms. The edges of this block are not simple and straight, and so the other components of the system must be carefully matched to them if stress in the system and eventual breakdown are to be avoided.

4.3 In order to achieve this matching, an understanding of the characteristics of this central component is essential. Some of the more important characteristics are the following:

a) **Physical size and shape**. In the design of any workplace and most equipment, a vital role is played by body measurements and movements, which will vary according to age and ethnic and gender groups. Decisions must be made at an early stage in the design process, and the data for these decisions are available from anthropometry and biomechanics.

b) **Physical needs**. People's requirements for food, water and oxygen are available from physiology and biology.

c) **Input characteristics**. Humans have been provided with a sensory system for collecting information from the world around them, enabling them to enable him to respond to external events and to carry out the required task. But all senses are subject to degradation for one reason or another, and the sources of knowledge here are physiology, sensory psychology and biology.

d) **Information processing**. These human capabilities have severe limitations. Poor instrument and warning system design has frequently resulted from a failure to take into account the capabilities and limitations of the human information processing system. Short- and long-term memory are involved, as well as motivation and stress. Psychology is the source of background knowledge here.

e) **Output characteristics**. Once information is sensed and processed, messages are sent to the muscles to initiate the desired response, whether it be a physical control movement or the initiation of some form of communication. Acceptable control forces and direction of movement have to be known, and biomechanics, physiology and psychology provide such knowledge.

f) **Environmental tolerances**. Temperature, pressure, humidity, noise, time of day, light and darkness can all be reflected in performance and also in well-being. Heights, enclosed spaces and a boring or stressful working environment can also be expected to influence behaviour and performance. Information is provided here by physiology, biology and psychology.

4.4 The Liveware is the hub of the SHEL model of Human Factors. The remaining components must be adapted and matched to this central component.

4.5 **Liveware-Hardware**. This interface is the one most commonly considered when speaking of human-machine systems: design of seats to fit the sitting characteristics of the human body, of displays to match the sensory and information processing characteristics of the user, of controls with proper movement, coding and location. The user may never be aware of an L-H deficiency, even where it finally leads to disaster, because the natural human characteristic of adapting to L-H mismatches will mask such a deficiency, but will not remove its existence. This constitutes a potential hazard to which designers should be alert.

4.6 **Liveware-Software**. This encompasses humans and the non-physical aspects of the system such as procedures, manual and checklist layout, symbology and computer programmes. The problems are often less tangible in this interface and are consequently more difficult to resolve (for example, misinterpretation of checklists or symbology).

4.7 **Liveware-Environment**. The human-environment interface was one of the earliest recognized in flying. Initially, the measures taken all aimed at adapting the human to the environment (helmets, flying suits, oxygen masks, anti-G suits). Later, the trend was to reverse this process by adapting the environment to match human requirements (pressurization and air-conditioning systems, soundproofing). Today, new challenges have arisen, notably ozone concentrations and radiation hazards at high flight levels and the problems associated with disturbed biological rhythms and related sleep disturbance and deprivation as a consequence of the increased speed of transmeridian travel. Since illusions and disorientation are at the root of many aviation accidents the L-E interface must consider perceptual errors induced by environmental conditions, for example, illusions during approach and landing phases. The aviation system operates within the context of broad political and economical constraints, and those aspects of the environment will interact in this interface. Although the possibility of modifying these influences is beyond Human Factors practitioners, their incidence is central and should be properly considered and addressed by those in management with the possibility to do so.

4.8 **Liveware-Liveware**. This is the interface between people. Aircrew training and proficiency testing have traditionally been done on an individual basis. If each individual crew member was proficient, then it was assumed that the team consisting of these individuals would also be proficient and effective. This is not always the case, however, and for many years attention has increasingly turned to the breakdown of teamwork. Flight crews function as groups and group influences play a role in determining behaviour and performance. In this interface, we are concerned with leadership, crew co-operation, teamwork and personality interactions. CAP 720 (previously Human Factors ICAO Digest No. 2) describes current industry approaches to deal with this interface, and concerns cockpit resource management (CRM) and line-oriented flight training (LOFT) programmes. Staff/management relationships are also within the scope of this interface, as corporate climate and company operating pressures can significantly affect human performance. CAP 720 also demonstrates the important role of management in accident prevention.

Chapter 2 The Industry Need for Human Factors

1 Overview

1.1 Admiral Donald Engen, the former Administrator of the United States Federal Aviation Administration, has been quoted as saying (1986): "We spent over fifty years on the hardware, which is now pretty reliable. Now it's time to work with people." This declaration somehow sets the foundation upon which the industry need for Human Factors can be assessed. Curiously enough, we retain a lawyer for advice about a legal problem, or hire an architect to build a house, or consult a physician when trying to establish the diagnosis of a medical problem, but when it comes to solving Human Factors problems, we have adopted an intuitive and in many cases perfunctory approach, even though many lives may depend on the outcome. A background of many years of industry experience or thousands of flying hours may have little or no significance when looking for the resolution of problems which only a thorough understanding of Human Factors can provide.

1.2 This is of special significance because, as already mentioned, it has long been known that some three out of four accidents result from performance errors made by healthy and properly certificated individuals. The sources of some of these errors may be traced to poor equipment or procedure design or to inadequate training or operating instructions. But whatever the origin, the question of human performance capabilities and limitations and human behaviour is central to the technology of Human Factors. The cost, both in human and financial terms, of less than optimum human performance has become so great that a makeshift or intuitive approach to Human Factors is no longer appropriate. Safety being the ultimate objective of all those involved in aviation, its logical follow up is to ensure a proper level of Human Factors knowledge throughout the industry.

1.3 The industry need for Human Factors is based on its impact on two broad areas, which interrelate so closely that in many cases their influences overlap and factors affecting one may also affect the other. These areas are:

- Effectiveness of the system
    - safety
    - efficiency
- Well-being of crew members.

2 Effectiveness of the System

2.1 Safety

The best way to illustrate the effect on safety of a lack of proper application of Human Factors is through the example of accidents. A few accidents in which aspects of Human Factors are relevant are described here as examples.

a) In the same month – December 1972 – an L1011 crashed in the Florida Everglades (NTSB/AAR 73-14) and a B-737 crashed at Midway Airport in Chicago (NTSB/AAR 73-16). In the first case, duties were not properly allocated and the whole flight crew became preoccupied with a landing gear indicator light bulb. In the second case, the captain – as a leader – did not properly manage the resources which were available to him.

b) In 1974, a B-707 crashed during approach at Pago-Pago in Samoa, with a loss of 96 lives. A visual illusion related to the black-hole phenomenon was a cause factor (NTSB/AAR 74-15).

c) In 1974, a DC-10 crashed after take-off because a cargo door failed (it opened and blew out). The force applied by a cargo handler to close the cargo door, the door design and an incomplete application of a service bulletin were cited as factors (ICAO Circular 132-AN/93).

d) In 1974, a B-727 approaching Dulles Airport in Washington crashed into Mount Weather, with a loss of 92 lives. Lack of clarity and inadequacies in air traffic control procedures and regulations led to the accident. The absence of timely action of the regulatory body to resolve a known problem in air traffic terminology was also listed as a factor (NTSB/AAR 75-16).

e) In 1977, two B-747s collided while on the runway at Tenerife, with a loss of 583 lives. A breakdown in normal communication procedures and misinterpretation of verbal messages were considered factors (ICAO Circular 153-AN/98).

f) In 1977, a DC-8 crashed after take-off in Alaska. The influence of alcohol on pilot performance was cited as a factor (NTSB/AAR 78-07).

g) In 1979, a DC-10 crashed into Mount Erebus in Antartica. Information transfer and data entry errors played a role in the accident (Accident Report No. 79/139, New Zealand).

h) In 1982, a B-737 crashed after take-off in icing conditions in Washington. Erroneous engine thrust readings (higher than actual), and the co-pilot’s lack of assertiveness in communicating his concern and comments about aircraft performance during the take-off run were among the factors cited (NTSB/AAR 82-08).

i) The report of a 1983 A300 accident in Kuala Lumpur suggests that variations in panel layout amongst the aircraft in the fleet had adversely affected crew performance. (The aircraft was on a dry lease.) (Accident Report No. 2/83, Malaysia).

j) In 1984, a DC-10 overran the runway at John F. Kennedy Airport in New York. Excessive reliance on automation was noted in the accident report (NTSB/AAR 84-15). Excessive reliance on automation was also listed as a factor in a loss of control incident in 1985, in which a B-747 lost 20,000 feet in less than two minutes and sustained structural damage (NTSB/AAR 86-03).

k) In 1987 an MD-80 crashed on take-off in Detroit. The pilots had not set the flaps, thus violating standard operating procedures. Also, the take-off configuration warning did not sound, for undetermined reasons (NTSB/AAR 88-05).

2.2 Efficiency

2.2.1 The need for application of Human Factors is not limited to flight safety. Efficiency is also radically influenced by the application of, or the lack of, Human Factors knowledge. For instance, neglect of Human Factors in flight operations can be expected to cause less than optimum performance of tasks. The following paragraphs are intended as an overview of particular applications of Human Factors knowledge which relate to efficiency.

2.2.2 Motivation can be explained as reflecting the difference between what a person can and actually will do; motivated individuals perform with greater effectiveness than unmotivated individuals. Human error and its consequences in aviation can be controlled by Human Factors technology, thus improving effectiveness.

2.2.3 The proper layout of displays and controls in the flight deck promotes and enhances effectiveness. Properly trained and supervised crew members are likely to perform more efficiently. From the perspective of efficiency, standard operating procedures (SOPs), which are developed to provide the most effective methods of operations, should be regarded as a means of measuring the performance of crew members.

2.2.4 Application of group interaction principles enhances the managerial position of the captain, whose leadership role is essential to the integration of a team and thus to more effective performance. The relationship between cabin attendants and passengers is also important. Cabin crew members should have an understanding of passenger behaviour and the emotions they can expect to encounter on board, as well as how to manage emotional situations.

3 Well-being of Crew Members

Three of the many factors which may influence the well-being of crew members are fatigue, body rhythm disturbance, and sleep deprivation or disturbance. These will be briefly explained below. Other factors affecting physiological or psychological well-being include temperature, noise, humidity, light, vibration, workstation design and seat comfort.

3.1 Fatigue

Fatigue may be considered to be a condition reflecting inadequate rest, as well as a collection of symptoms associated with displaced or disturbed biological rhythms. Acute fatigue is induced by long duty periods or by a string of particularly demanding tasks performed in a short term. Chronic fatigue is induced by the cumulative effects of fatigue over the longer term. Mental fatigue may result from emotional stress, even with normal physical rest. Like the disturbance of body rhythms, fatigue may lead to potentially unsafe situations and a deterioration in efficiency and well-being. Hypoxia and noise are contributing factors.

3.2 Body rhythm disturbance

3.2.1 The most commonly recognized of the body’s rhythms is the circadian, or 24-hour rhythm, which is related to the earth’s rotation time. This cycle is maintained by several agents: the most powerful are light and darkness, but meals and physical and social activities also have an influence on the body’s systems. Safety, efficiency and well-being are affected by the disturbed pattern of biological rhythms typical of today’s long-range flights. The impact of circadian dysrhythmia is relevant not only to long-distance transmeridian flying – short-haul operators (couriers and freight carriers, for instance) flying on irregular or night schedules can suffer from reduced performance produced by circadian dysrhythmia. Air traffic controllers with frequently changing shift schedules can suffer a similar deterioration in their performance.

3.2.2 Jet lag is the common term for disturbance or desynchronization of body rhythms, and refers to the lack of well-being experienced after long-distance transmeridian air travel. Symptoms include sleep disturbance and disruption of eating and elimination habits, as well as lassitude, anxiety, irritability and depression. Objective evidence shows slowed reaction and decision-making times, loss of or inaccurate memory of recent events, errors in computation and a tendency to accept lower standards of operational performance.

3.3 Sleep

3.3.1 The most common physical symptoms associated with long-range flying result from disturbance of the normal sleep pattern, which may in some cases involve an over-all sleep deprivation. Adults usually take sleep in one long period each day; where this pattern has been established it becomes a natural rhythm of the brain, even when prolonged waking is imposed. Wide differences are found amongst individuals in their ability to sleep out of phase with their biological rhythms. Tolerance to sleep disturbance varies between crew members and is mainly related to body chemistry and, in some cases, to emotional stress factors.

3.3.2 Insomnia defines a condition where a person has difficulty sleeping. When occurring under normal conditions and in phase with the body rhythms, it is called clinical insomnia. Situational insomnia refers to difficulty in sleeping in particular situations where biological rhythms are disturbed, and is the one we are concerned about in long-range flying.

3.3.3 The use of drugs or tranquilizers to induce sleep is usually inappropriate, as they have an adverse effect on performance for a certain period after ingestion. Alcohol is a depressant of the nervous system. It has a soporific effect, but it disturbs normal sleep patterns, and the effects persist after it has disappeared from the blood. Caffeine in coffee, tea and various soft drinks increases alertness and normally reduces reaction times, but it is also likely to disturb sleep. Amphetamines, when used to maintain the level of performance during sleep deprivation, only postpone the effects of sleep loss. Some loss of efficiency is to be expected.

3.3.4 Sleep has a restorative function, and is essential for mental performance. Sleep deprivation and disturbance can reduce motivation. When this phenomenon is recognized, motivation can at least be partly restored by the application of extra effort. The relevance of this phenomenon to safety is obvious.

3.3.5 The resolution of the problem of sleep disturbance or deprivation includes:

- scheduling crews with due consideration to circadian rhythms and fatigue resulting from sleep deprivation and disturbance;
- adapting the diet, understanding the importance of meal times, and adopting other measures in relation to light/darkness, rest/activity schedules and social interaction;
- recognizing the adverse long-term effect of drugs (including caffeine and alcohol);
- optimizing the sleeping environment; and
- learning relaxation techniques.

3.4 Health and performance

3.4.1 Certain pathological conditions – gastrointestinal disorders, heart attacks, etc. – have caused sudden pilot incapacitation and in rare cases have contributed to accidents. While total incapacitation is usually quickly detected by other crew members, a reduction in capacity or partial incapacitation – produced by fatigue, stress, sleep, rhythm disturbances, medication, certain mild pathological conditions such as hypoglycemia, etc. – may go undetected, even by the person affected.

3.4.2 Although no conclusive evidence is available, physical fitness may have a direct relationship to mental performance and health. Improved fitness reduces tension and anxiety and increases self-esteem. It has favourable effects on emotions, which affect motivation, and is believed to increase resistance to fatigue. Factors having a known influence on fitness include diet, exercise, stress levels and the use of tobacco, alcohol or drugs.

3.5 **Stress**

3.5.1 Stress can be found in many jobs, and the aviation environment is particularly rich in potential stressors. Of main interest is the effect of stress on performance. In the early days of aviation, stressors were created by the environment: noise, vibration, temperature, humidity, acceleration forces, etc., and were mainly physiological in nature. Today, some of these have been replaced by new sources of stress: irregular working and resting patterns and disturbed circadian rhythms associated with long-range, irregular or night-time flying.

3.5.2 Stress is also associated with life events, such as family separation, and with situations such as periodic medical and proficiency checks. Even positive life events, such as a wedding or the birth of a child, can induce stress in normal life. In situations where mental workload becomes very high, such as during take-off, landing or an in-flight emergency, cognitive stress may appear.

3.5.3 Individuals differ in their responses to stress. For example, flight in a thunderstorm area may be challenging for one individual but stressful for another. The same stressor (the thunderstorm) produces different responses in different individuals, and any resulting damage should be attributed to the response rather than to the stressor itself.

Chapter 3 Human Factors Applications in Flight Operations

1 Control of Human Error

To limit human error, one must first understand its nature. There are basic concepts associated with the nature of human error: the origins of errors can be fundamentally different; and the consequences of similar errors can also be significantly different. While some errors are due to carelessness, negligence or poor judgement, others may be induced by poorly designed equipment or may result from a normal reaction of a person to a particular situation. The latter kind of error is likely to be repeated and its occurrence can be anticipated.

1.1 Errors at the model interfaces

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

- The interface between Liveware and Hardware (human and machine) is a frequent source of error: knobs and levers which are poorly located or lack of proper coding 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.
- Errors associated with the Liveware-Environment interface are caused by environmental factors (noise, heat, lighting and vibration) and by the disturbance of biological rhythms in long-range flying resulting from irregular working/slee.ping patterns.
- In the Liveware-Liveware interface, the focus is on the interaction between people because this process affects crew effectiveness. This interaction also includes leadership and command, and shortcomings at this interface reduce operational efficiency and cause misunderstandings and errors.

1.2 Information processing

1.2.1 Before a person can react to information, it must first be sensed; there is a potential for error here, because the sensory systems function only within a narrow range. Once information is sensed, it makes its way to the brain, where it is processed, and a conclusion is drawn about the nature and meaning of the message received. This interpretative activity is called perception and is a breeding ground for errors. Expectation, experience, attitude, motivation and arousal all have a definite influence on perception and are possible sources of errors.

1.2.2 After conclusions have been formed about the meaning of a message, decision-making begins. Many factors may lead to erroneous decisions: training or past experience; emotional or commercial considerations; fatigue, medication, motivation and physical or psychological disorders. Action (or inaction) follows decision. This is another stage with potential for error, because if equipment is designed in such a way that it can be operated wrongly, sooner or later it will be. Once action has been taken, a feedback mechanism starts to work. Deficiencies in this mechanism may also generate errors.

Plain Talk

Because of the high cost of aviation gasoline, a private pilot once wrote to his aviation administration and asked if he could mix kerosene in his aircraft fuel. He received the following reply:

> "Utilization of kerosene involves major uncertainties/probabilities respecting shaft output and metal longevity where application pertains to aeronautical internal combustion power plants."

The pilot sent the following cable:

> "Thanks for the information. Will start using kerosene next week."

He then received the following urgent letter:

> "Regrettably decision involves uncertainties. Kerosene utilization consequences questionable, with respect to metalloferrous components and power production."

This prompted another cable from the pilot:

> "Thanks again. It will sure cut my fuel bill."

The same day he finally received a clear message:

> "DON'T USE KEROSENE. IT COULD KILL THE ENGINE – AND YOU TOO!"

1.3 Controlling human error

The control of human error requires two different approaches. First, it is necessary to minimize the occurrence of errors by: ensuring high levels of staff competence; designing controls so that they match human characteristics; providing proper checklists, procedures, manuals, maps, charts, SOPs, etc.; and reducing noise, vibration, temperature extremes and other stressful conditions. Training programmes aimed at increasing the co-operation and communication between crew members will reduce the number of errors (the total elimination of human error is an unrealistic goal, since errors are a normal part of human behaviour). The second avenue to the control of human error is to reduce the consequences of the remaining errors by cross-monitoring and crew co-operation. Equipment design which makes errors reversible and equipment which can monitor or supplant human performance also contribute to the limitation of errors or their consequences.

2 Training and Evaluation

2.1 The purpose of this section is to illustrate how Human Factors applies to the design of methods of operational training.

2.2 Education and training are seen here as two different aspects of the teaching process. Education encompasses a broad-based set of knowledge, values, attitudes and skills required as a background upon which more specific job abilities can be acquired later. Training is a process aimed at developing specific skills, knowledge or attitudes for a job or a task. Proper and effective training cannot take place unless the foundations for the development of those skills, knowledge or attitudes have been laid by previous education.

2.3 A skill is an organized and co-ordinated pattern of physical, psychomotor, social, linguistic and intellectual activity. Teaching is a skill in its own right, and the possession of a skill in a particular activity does not necessarily indicate skill in teaching that activity to others. This is an important consideration in the selection of flight instructors, check pilots, or anyone connected with a teaching activity.

2.4 Skills knowledge or attitudes gained in one situation can often be used in another. This is called positive transfer. Negative transfer occurs when previous learning interferes with new learning. It is important to identify the elements of training which can induce negative transfer since a return to earlier learned practices may occur in conditions of stress.

2.5 Learning is an internal process and training is the control of this process. The success or failure of training must be determined by the changes in performance or behaviour which the learning produces. Since learning is accomplished by the student and not by the teacher, the student must be an active rather than a passive participant. Memory is relevant to learning – short-term memory (STM) refers to the storage of information which will be stored and quickly forgotten, while long-term memory (LTM) allows the storage of information for extended periods of time. STM is limited to a few items of information during a few seconds. Through repetition, information is transferred into LTM. While there is a very large capacity in LTM and fewer storage problems, there are certainly retrieval problems, as exemplified by the problems of witness recollections of past events.

2.6 A number of factors can interfere with the success of a training programme - obvious ones like sickness, fatigue or discomfort as well as others like anxiety, low motivation, poor quality instruction, an unsuitable instructor, inadequate learning techniques or inadequate communication.

2.7 One approach to cost-effective training is called the systems approach. Its first step is to determine the training needs, possibly through job task analyses. The second step provides a clear job description and analysis. The objective of the training can then be formulated, and criteria can be established for the selection of the trainees. Next, the course content is determined, and the course implemented. Different methods include: lectures, lessons, discussions, tutorials, audio-visuals, programmed instruction, and computer-based training.

2.8 There are two major types of training devices: training aids (such as slides, video-graphs, blackboards, wall charts), which help the teacher present a subject and training equipment (such as the flight simulator), which provides for active participation and practice by the trainee. The development of simulators is based on the need to provide practical training in as realistic an environment as possible, at low cost and risk, and with a high degree of efficiency. To obtain approval from certifying authorities, the simulator's fidelity must be high enough to develop the proficiency and performance which are expected in real life situations.

2.9 It is often assumed that to achieve the best training results it is necessary to incorporate the highest degree of fidelity in the training situation. Fidelity is expensive, however, and it must be cost-effective. Motion, control loading, sound and visual systems, and specific equipment simulation (radar – built-in test equipment – flight management computers, etc.) involve considerable expenditure. At the upper limits of simulation, a very small increase in fidelity becomes very expensive – this is especially relevant since available evidence supports the fact that a good return of training transfer is often obtained from moderate levels of fidelity. It is the specialist's task to determine the degree of fidelity needed to meet specific training requirements for a particular situation. High fidelity is required in a training device when the student must learn to make discriminations when selecting switches or controls and where the responses required are difficult to make or critical to the operation. Low fidelity in the equipment is acceptable when procedures are first being learned, in order to avoid confusion and not overload the beginner. As the training progresses, increased fidelity is generally required for user acceptance.

3 Human Factors Training

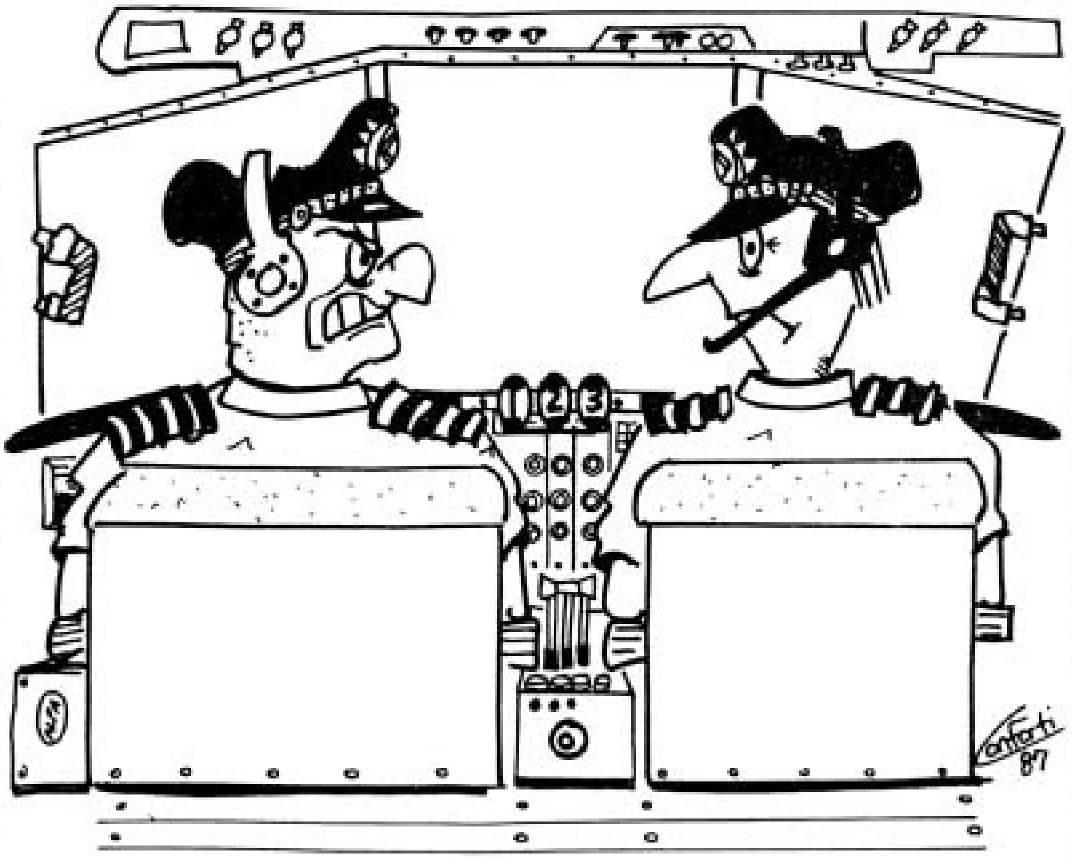
Human Factors training concerns those areas of knowledge or skill which are not included in the technical training curricula. They are briefly covered because they are in the mainstream of Human Factors.

3.1 Leadership

3.1.1 A leader is a person whose ideas and actions influence the thought and the behaviour of others. Through the use of example and persuasion, and an understanding of the goals and desires of the group, the leader becomes a means of change and influence.

3.1.2 It is important to establish the difference between leadership, which is acquired, and authority, which is assigned. An optimal situation exists when the two are combined. Leadership involves teamwork, and the quality of a leader depends on the success of the leader's relationship with the team. Leadership skills should be developed for all through proper training; such training is essential in aircraft operations where junior crew members are sometimes called upon to adopt a leadership role throughout the normal performance of their duties. This may occur when the co-pilot must take over from an absent or incapacitated captain, or when a junior flight attendant must control the passengers in a particular cabin section.

3.1.3 Skilled leadership may be needed to understand and handle various situations. For instance, personality and attitude clashes within a crew complicate the task of a leader and can influence both safety and efficiency. Aircraft accident and incident investigations have demonstrated that personality differences influence the behaviour and performance of crew members. Other situations requiring skilled leadership may be rooted in the frustrations of first officers over slow promotions, or of pilots who are employed as flight engineers.



*"Oh, I believe in resource management all right . . .
you're the resource and I'm the management!"*

Reprinted from Air Line Pilot, April 1988.

3.2 Personality and Attitudes

3.2.1 Personality traits and attitudes influence the way we conduct our lives at home and at work. Personality traits are innate or acquired at early stages of life. They are deep-rooted characteristics which define a person, and they are very stable and resistant to change. Traits such as aggression, ambition and dominance may be seen as reflections of personality.

3.2.2 Attitudes are learned and enduring tendencies or predispositions, more or less predictable, to respond favourably or unfavourably to people, organizations, decisions, etc. An attitude is a predisposition to respond in a certain way; the response is the behaviour itself. It is believed that our attitudes provide some sort of cognitive organization of the world in which we live, allowing us to make rapid decisions on what to do when facing certain situations.

3.2.3 Accidents have been caused by inadequate performance by people who had the capacity to perform effectively and yet failed to do so. Reports from the Confidential Human Factors Reporting Programme (CHIRP) and the Aviation Safety Reporting System (ASRS) support the view that attitudes and behaviour play a significant role in flight safety. This indicates the need for more research into desirable and undesirable personality characteristics in crew members, and the importance of an effective assessment of personality during crew selection. If personality or attitude differences on the flight deck have indeed been cited as the cause of accidents and incidents, then we should also look at the extent to which it may be possible to influence attitudes through training.

3.2.4 The difference between personality and attitudes is relevant, because it is unrealistic to expect a change in personality through routine training, or captaincy or management training. The initial screening and selection process are the place and time to take appropriate action. On the other hand, attitudes are more susceptible to change through training. The effectiveness of the training depends on the strength of the attitude(s) which are to be modified. To this end, some States have demonstrated the safety benefits – particularly for single-pilot operations - of programmes for improving the pilot decision-making process by identifying hazardous thought patterns. Modifying attitudes or behaviour patterns through persuasion is also of direct relevance to safety and efficiency. Crew bulletins, staff notices and advertising are examples of persuasion.

3.3 Communication

3.3.1 Effective communication, which includes all transfer of information, is essential for the safe operation of flight. The message might be transferred by speech, by the written word, by a variety of symbols and displays (e.g. instruments, CRT, maps) or by non-verbal means such as gestures and body language. The quality and effectiveness of communication is determined by its intelligibility: the degree to which the intended message is understood by the receiver.

3.3.2 There are several hazards which reduce the quality of communications:

- failures during the transmitting process (e.g. the sending of unclear or ambiguous messages, language problems);
- difficulties caused by the medium of transmission (e.g. background noises or distortion of the information);
- failures during receiving (e.g. the expectation of another message, wrong interpretation of the arriving message or even its disregard);

- failures due to interference between the rational and emotional levels of communication (e.g. arguments); and
- physical problems in listening or speaking (e.g. impaired hearing or wearing of the oxygen mask).

3.3.3 It is the task of Human Factors training to prevent communication errors. This task includes the explanation of common communication problems as well as the reinforcement of a standard of language to ensure the error-free transmission of a message and its correct interpretation. Ambiguous, misleading, inappropriate or poorly constructed communication, combined with expectancy, have been listed as elements of many accidents, the most notorious one being the double 747 disaster in Tenerife.

3.4 Crew Co-ordination

3.4.1 Crew co-ordination is the advantage of teamwork over a collection of highly skilled individuals. Its prominent benefits are:

- an increase in safety by redundancy to detect and remedy individual errors; and
- an increase in efficiency by the organized use of all existing resources, which improves the in-flight management.

3.4.2 The basic variables determining the extent of crew co-ordination are the attitudes, motivation and training of the team members. Especially under stress (physical, emotional or managerial), there is a high risk that crew co-ordination will break down. The results are a decrease in communication (marginal or no exchange of information), an increase in errors (e.g. wrong decisions) and a lower probability of correcting deviations either from standard operating procedures or the desired flight path. Additionally, emotional conflicts in the cockpit may result.

3.4.3 The high risks associated with a breakdown of crew co-ordination show the urgent need for the crew resource management training which will be addressed in CAP 720 (previously ICAO Digest No. 2). This kind of training ensures that:

- the pilot has the maximum capacity for the primary task of flying the aircraft and making decisions;
- the workload is equally distributed among the crew members, so that excessive workload for any individual is avoided; and
- a co-ordinated co-operation – including the exchange of information, the support of fellow crew members and the monitoring of each others' performance – will be maintained under both normal and abnormal conditions.

4 Motivation

4.1 Motivation reflects the difference between what a person can do and actually will do, and is what drives or induces a person to behave in a particular fashion. Clearly, people are different and driven by different motivational forces. Even when selection, training and checking ensure capability to perform, it is motivation that determines whether a person will do so in a given situation.

4.2 There is a relationship between expectancy and reward as motivators, since the utility of a reward and the subjective probability of its achievement determine the level of effort which will be applied to obtain the reward. This effort must be accompanied by the proper abitities and skills. It is important for high performers to see that they are in a better position than poor performers to achieve a reward, otherwise motivation may decline. Job satisfaction motivates people to higher performance.

4.3 Modifying behaviour and performance through rewards is called positive reinforcement; discouraging undesirable behaviour by use of penalties or punishment is called negative reinforcement. Even though positive reinforcement can be more effective in improving performance, both must be available to management. Different responses are to be expected from different individuals in relation to positive and negative reinforcers. Care should be taken not to generate an effect which is opposite from that which is intended.

5 Flight Documentation

Inadequacies in aviation documentation have a twofold impact: there is a monetary aspect associated with increased time or the impossibility of performing a particular task and there is also a safety aspect. With reference to documentation, some basic aspects require Human Factors optimization:

a) written language, which involves not only vocabulary and grammar, but also the manner in which they are used;

b) typography, including the form of letters and printing and the layout, has a significant impact on the comprehension of the written material;

c) the use of photograph diagrams, charts or tables replacing long descriptive text is advantageous to help comprehension and maintain interest. The use of colour in illustrations reduces the discrimination workload and has a motivational effect;

d) the working environment in which the document is going to be used has to be considered when print and page size are determined (for example, an airport chart which is too small may induce error during taxiing).

6 Flight Deck Design

6.1 For design purposes, the flight deck should be considered as a system, as opposed to a collection of particular aspects or systems such as hydraulic, electrical or pressurization. Expertise should be applied towards matching the characteristics of these systems to those of humans, with due consideration to the job to be performed. Proper matching of working areas to human dimensions and characteristics is important – for instance, size, shape and movements of the body provide data used to ensure adequate visibility in the flight deck, location and design of controls and displays, and seat design.

6.2 The importance of the standardization of panel layout relates to safety, since there are numerous reports of errors arising from inconsistent panel layouts, involving inadvertent reversion to an operating practice appropriate to an aircraft flown previously. Seat design considerations include seat controls, headrests, seat cushion and fabric, lumbar support, thigh support, etc.

6.3 A display is any means of presenting information directly to the operator. Displays use the visual, aural or tactile senses. The transfer of information from a display to the brain requires that information is filtered, stored and processed, a requirement which can cause problems. This is a major consideration in the design of flight deck displays. The information should be presented in such a way as to assist the processing task, not only under normal circumstances, but also when performance is affected by stress or fatigue.

6.4 A fundamental consideration in display design is to determine how, in what circumstances, and by whom the display is going to be used. Other considerations include the characteristics of visual displays and aural signals; light requirements; the selection of analogue or digital alternatives; the applicability of LEOs (light-emitting diodes), LCDs (liquid- crystal displays) and CRTs (cathode-ray tubes); the angle at which the display is to be viewed and its related parallax; viewing distance, and possible ambiguity of the information.

6.5 Three fundamental operational objectives apply to the design of warning, alerting and advisory systems: they should alert the crew and draw their attention, report the nature of the condition, and, when possible, guide them to the appropriate corrective action. System reliability is vital, since credibility will be lost if false warnings proliferate, as was the case with the first generation of ground proximity warning systems. In the event of a technical failure of the display system, the user should not be presented with unreliable information. Such information must be removed from sight or clearly flagged. For example, unreliable flight director command bars should disappear. Invalid guidance information which remained on display has been a factor in accidents.

6.6 A control is a means of transmitting discrete or continuous information or energy from the operator to some device or system. Control devices include push buttons, toggle or rotary switches, detented levers, rotary knobs, thumb wheels, small levers or cranks. The type of device to be used depends on functional requirements and the manipulation force required. Several design features apply to controls:

a) location;

b) control-display ratio (control movement related to that of the moving element of the associated display);

c) direction of movement of the control relative to the display;

d) control resistance;

e) control coding, by means of shape, size, colour, labelling and location;

f) protection against inadvertent actuation.

6.7 The application of automation to flight deck displays and controls may breed complacency and over-reliance on the automated system, which have been suggested as factors in accidents and incidents. If the Human Factors-related issues (e.g. the limited performance of the human as monitor and effects on motivation) are properly addressed, there may be a justification for introducing automation. It may contribute to improved aircraft and system performance and over-all efficiency of the operation. It may relieve the crew of certain tasks so as to reduce workload in phases of flight where it reaches the limit of operational acceptability.

7 Cabin Design

7.1 Human Factors considerations for the cabin include aspects of workspace and layout as well as information on human behaviour and performance.

7.2 Human size and shape are relevant in the design of cabin equipment (toilets, galleys, meal carts and overhead bins); emergency equipment design (life-jackets, life-rafts, emergency exits, oxygen masks); seats and furnishings (including in-flight entertainment); jump seats and rear-facing seats. Knowledge of the user’s height and reach determines location of equipment and controls. Proper access and room to work must be provided in cargo compartments. Human forces required to operate doors, hatches and cargo equipment have to be realistic. Anthropometry (the study of human dimensions) and biomechanics (study of the movement of parts of the body and the forces which they can apply) are the sources of the required information for those purposes.

7.3 Due consideration has to be given to handling special passengers: the physically handicapped, the intoxicated, and the fearful. Passenger behaviour, including group influences, and expected human behaviour when facing a crisis are of relevance here.

7.4 Recent accidents and incidents have documented the need for Human Factors information for those involved in ground operations, such as maintenance and inspection managers, flight line supervisors and others. Similarly, persons involved in the design of aircraft systems should recognize human limits in maintaining, inspecting and servicing aircraft. Such factors as training, work environment, communication methods, physiological limitations and human engineering of equipment should be considered.

8 Visual Performance and Collision Avoidance

8.1 A proper understanding of how the visual system works helps in the determination of optimum working conditions. The characteristics and measurement of light, the perception of colour, the physiology of the eyes and the way the visual system works are relevant in this area. Also important are factors involved in the ability to detect other aircraft at a distance, either in daytime or at night, or to identify outside objects in the presence of rain or other contamination on the windscreen.

8.2 Visual illusions and disorientation in flight operations may be directly related to safety. During all phases of flight, but in particular during approach and landing, visual illusions are believed to have played a significant role in accidents for which it is difficult to find any other explanation. Factors of specific consideration here include sloping terrain, runway width, lighting intensity, the ”black hole” phenomenon and lack of runway texture. An effective step in reducing the risks associated with visual illusions in flight operations is the recognition through training that visual illusions are a natural phenomenon. Training should also help in understanding that the circumstances in which they occur are often predictable. The use of additional information sources to supplement visual cues (radar, attitude displays, radio altimeters, VASIs, DMEs, etc.) is the most effective protective measure against disorientation and illusions. To some extent the risk from visual illusions may be alleviated by design features such as high optical quality windshield glass, adequate visibility, eye position guidance, effective windshield rain and ice protection, etc.

Chapter 4 Education and Expertise

1 Overview

The previous chapters have served as an introduction to Human Factors in transport aircraft operation. The meaning of the term has been explained, the need for such a technology has been assessed, and multiple applications in flight operations have been enunciated and briefly described. In this chapter formal approaches to education are presented, according to the different levels of expertise required to perform specific tasks safely and efficiently. To put it in simple words, the objective of this final chapter is to help to understand who should know what, and how and where to get the knowledge.

2 Levels of Expertise Required

Almost everyone involved in the design, certification, maintenance and operation of aircraft is concerned in one way or other with the human component, so they all need some basic Human Factors knowledge. The following levels of expertise are considered adequate for each grade of staff within any organization in civil aviation.

2.1 Level 1: All Staff

2.1.1 When supervisors or managers publish bulletins on technical subjects, such as engines, weather problems, or aircraft systems, these are likely to be effective communications because flight deck crews and technical personnel have had formal education which forms both the framework and background for their comprehension and subsequent response. A similar bulletin on Human Factors topics is unlikely to generate the same response and comprehension if there is an absence of background. This means that all staff should be exposed to a general level of Human Factors education so as to be able to understand the scope and significance of this technology and to be more aware of human performance, capabilities and limitations.

2.1.2 Such exposure should provide education for large numbers of staff at low cost per person and it should be mobile so as to meet the typical needs of companies whose staff may be dispersed around a network of bases.

2.2 Level 2: Supervisory Staff

2.2.1 Staff in supervisory positions are constantly involved in decision-making in which human performance plays a role. Some may be concerned with training and checking, others with designing procedures or controlling operational standards, and still others may be concerned more directly with trying to develop suitable professional attitudes towards flying.

2.2.2 All these activities must be based upon a background of education in Human Factors. Short courses of one or two weeks introduce the technology and enable the supervisor or manager to see each human problem in a new light and to tackle the more straightforward ones with a greater chance of success. The supervisor will learn when and from where to obtain further assistance, and will use the course as a foundation upon which expertise in the field may be gradually built.

2.3 **Level 3: The In-house Specialist**

2.3.1 There are valid reasons for large aviation companies to employ one or more degree-qualified Human Factors specialists on a full-time basis. In fact, without some level of in-house expertise, Human Factors problems are not likely to be recognized adequately. A close association with flying will be necessary if the specialist is to work effectively and with credibility on operational problems.

2.3.2 This specialist will establish a link with a Level 4 consultant and will thus be able to take advantage of a higher level of expertise, as well as of advice on experimental procedures and solutions to problems which may have already occurred elsewhere.

2.4 **Level 4: The Human Factors Consultant**

The specialist with this level of expertise is able to analyse specific problems when so required and can offer advice free from any internal organizational pressures. The consultant will maintain extensive contacts in the industry and these will be available for use in providing a consulting service of benefit to the client, as the problems presented may have already been encountered elsewhere. The consultant will hold an advanced academic degree in one of the psychology based Human Factors areas.

3 Courses Available

3.1 We shall look now at the general educational programmes which are available. The programmes described below were those readily available to ICAO; they are presented as examples only, and their selection does not constitute any endorsement. New programmes are being almost constantly developed, and to the extent that ICAO is aware of new programmes, the Organization will provide information to those interested. Cockpit resource management programmes (CRM) and line-oriented flight training (LOFT) programmes are not described, as they refer to one specific aspect of Human Factors – the L-L interface – and are the subject of CAP 720 (previously ICAO Human Factors Digest No. 2).

3.2 Degree courses in applied or industrial psychology and ergonomics – all relevant disciplines – have been available for many years. However, this expertise has not been routinely provided to those involved with operating, designing and certifying aircraft. Even if included on the payroll, a qualified specialist will have only limited influence in a company unless the other employees have at least some knowledge of the subject concerned.

3.3 All staff performing skilled tasks must have an awareness of Human Factors so that they can properly react to advice and adapt their own activities to allow for known human capabilities and limitations. They must be able to recognize the factors which influence behaviour and know when to call in specialized guidance. This requires an awareness on the nature and scope of Human Factors.

3.4 For this level of education in aviation, a typical example is the KLM Human Factors Awareness Course (KHUFAC), a 15-unit audio-visual programme, available in single- and double-screen tape/slide as well as videotape versions to provide maximum flexibility. Large numbers of staff can be exposed to this programme and individual units can be integrated into other training programmes or presented as a separate course.

3.5 At the supervisory level, the University of Southern California (USC) provides a five-day Human Factors course as part of the aviation safety programme offered by the Institute of Safety and Systems Management.

3.6 The College of Aeronautics at Cranfield, United Kingdom offers an "Introduction to Human Factors in Aviation". This one-week residential course provides an introduction to the basic principles of behaviour and related factors which can influence performance in the aviation environment. It is advertised as being of particular relevance to those responsible for Human Factors training or concerned with the performance and welfare of aircrews.

3.7 A Human Factors course lasting four and one-half days is offered annually at the Carl Graus Gesellschaft in Heidelberg. The course, which is given in German, is specifically designed for those working in the design, development and evaluation of aircraft systems rather than for those involved in operating aircraft.

3.8 Human Factors in Transport Aircraft Operation (HFTAO) was offered for several years by Loughborough and Aston Universities in the United Kingdom and can now be provided locally anywhere in the world. It is conducted by the organization Human Technology under the direction of Professor Elwyn Edwards.

3.9 For the in-house specialist, suitable degree courses are available in the United States, Europe and elsewhere. In the United States, it is possible to specialize in aviation Human Factors at universities such as Embry Riddle, Ohio State and Illinois. Directories of Human Factors/ergonomics educational programmes in the United States and internationally are available – free of charge – from the Human Factors Society in Santa Monica, California.

4 Information Available

The lists of Human Factors information provided on the following pages are not exhaustive, since there is much specialized literature available. When preparing the selection, due consideration was given to the background and interests of the audience for which this digest is intended. More easily readable and less expensive books have been selected for the "recommended reading list", with reference books being allocated to the "library list". Not all these books will be currently in print, but unless they have been replaced by a suitable alternative, they have still been listed and may be obtained from libraries or other sources. Lists are presented in three of the languages of the Organization.

Appendix A References

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Applied Ergonomics; United Kingdom; IPC Science and Technology Press quarterly.

Ergonomics; United Kingdom; Taylor and Francis; monthly; official journal of the International Ergonomics Association and Ergonomics Society.

Journal of Applied Psychology; United States; American Psychological Association; bi-monthly.

Human Factors; United States; Sheridan Press; bi-monthly; official journal of the Human Factors Society.

Aviation Space and Environment Medicine; United States; Aerospace Medical Association; monthly.

2 Bulletins

Government Departments

Work Research Unit papers; United Kingdom; Department of Employment; periodically; also includes bibliographies on specific subjects.

Flight Safety Foundation; United States

Cabin Crew Safety Bulletin; bi-monthly;
Human Factors Bulletin; periodically;
Pilots Safety Exchange Bulletins; periodically.

3 Incident Reporting Systems

Callback; United States; NASA-Ames; monthly; bulletin of the ASRS;
ARSR Quarterly Reports; United States; NASA-Ames; quarterly; summaries and analyses;
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