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HUMAN FACTORS DIGEST No. 3

TRAINING OF OPERATIONAL PERSONNEL IN HUMAN FACTORS

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Foreword

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 influence on the improvement of flight safety.

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."

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.

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.

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Introduction

1. Although human failure is the predominant factor contributing to aviation accidents and incidents, it has never been clear what aspects of human capabilities and limitations should — or could — be addressed by training. On the other hand, it has been equally clear for some years that Human Factors education and training within the aviation system could be improved. The purpose of this digest is to introduce and review the design and content of training courses in aviation Human Factors. It is directed to those having responsibility for the development and implementation of Human Factors training courses for operational personnel, and includes the following:

a) an outline ICAO training syllabus for Human Factors training;

b) a brief commentary on various problems associated with initiating aviation Human Factors (HF) training;

c) information for States, training establishments and instructors to assist in the development of suitable training syllabi and materials;

d) a discussion of issues which arise when considering the content and presentation of Human Factors training; and

e) samples of Human Factors training courses already in use, or under development.

2. The production of this digest, and much of its content, have been influenced by changes to ICAO Annex 1 — *Personnel Licensing* which became effective in November 1989. These changes relate to Human Factors training requirements in respect of pilot licensing; their importance is discussed in Chapter 1. However, the approach taken in this digest anticipates continuing development in Human Factors training during coming years; it therefore addresses the subject in a manner which goes beyond a narrow interpretation of the training needs dictated by the Annex 1 revision.

3. The ICAO approach to Human Factors has been outlined in Digest No. 1 — *Fundamental Human Factors Concepts* (ICAO Circular 216). This present digest, which builds upon the contents of Digest No. 1, has pilot training as its primary focus but should be equally helpful when considering the needs of other operational personnel, including air traffic controllers. Additional information relevant to *applied skills* training in some specific aspects of Human Factors is contained in Digest No. 2 — *Flight Crew Training: Cockpit Resource Management (CRM) and Line-Oriented Flight Training (LOFT)* (ICAO Circular 217). Digest No. 3 is mainly directed towards meeting Human Factors *knowledge* requirements, including those specified in Annex 1.

4. The contents of this digest are as follows:

— Chapter 1 introduces the subject of Human Factors in the context of the pilot training requirements of Annex 1.

— Chapter 2 provides a sample Human Factors curriculum which States and training establishments may wish to consult when designing their own training courses. The training discussed in this chapter is not intended as a substitute for training aimed at improving operational Human Factors *skills*, such as pilot decision making (PDM) and crew resource management (CRM) training. Rather, the ICAO syllabus supplements such skills-based training and, since it particularly addresses basic *knowledge*, preferably should precede it.

— Chapter 3 provides the rationale and basic information which interested States might take into account when selecting instructors and developing and implementing their own training courses.

— Appendices 1 to 3 provide examples of syllabi currently in use, or under development.

— Appendices 4 and 5 provide a simplified, condensed version of Chapters 2 and 3 respectively. They are intended for use as quick reference checklists.

— Appendix 6 provides one way of verifying knowledge of Human Factors, through a sample questionnaire.

5. As a result of the changes to Annex 1, Human Factors training for operational personnel is presently undergoing rapid development. There appears to be widespread consensus on the content of appropriate training courses, with a steady evolution in training substance and methods anticipated. In particular, it is envisaged that various innovations, especially with respect to the teaching of Human Factors skills, will also evolve. ICAO will closely monitor such developments and requests States to forward information on Human Factors training courses to ICAO Headquarters in Montreal. If appropriate, a timely review of this digest will be considered in the light of such information.

6. This digest is written in a manner intended to offer the maximum possible assistance to all those having responsibility for Human Factors training, regardless of their positions. Because the needs of administrations, operators, training establishments and individual instructors may vary widely within a State or from State to State, however, the digest's contents should be interpreted accordingly.

7. This digest was produced with the assistance of the ICAO Flight Safety and Human Factors Study Group, based on an original proposal by Study Group advisor Captain Neil Johnston.

CHAPTER 1

Human Factors Training for Operational Personnel

An Introduction and Overview

BACKGROUND AND JUSTIFICATION

1.1 Apart from the notable impact of shortcomings in human performance upon aviation safety, an important reason for the development of this particular Human Factors digest was the publication of the Eighth Edition of Annex 1 — *Personnel Licensing*, which became applicable in November 1989. This Annex contains a new Human Factors *knowledge* requirement for each category of flight crew licence holder, namely:

> ". . . human performance and limitations relevant to [the licence being issued]".

This knowledge requirement has the same status as knowledge required in respect of meteorology, navigation, principles of flight, or any other part of the traditional pilot training syllabus. It therefore necessitates the production of an appropriate training syllabus and the integration of new training concepts into the pilot training syllabus.

1.2 Furthermore, Annex 1 requirements for the demonstration of skill have been augmented in a manner which dictates increased attention to certain elements of human performance. An example of these changes is the requirement that the holder of an airline transport pilot licence:

> ". . . shall have demonstrated the ability to . . .:
>
> . . . .
>
> (c) exercise good judgement and airmanship;
>
> . . . .
>
> (f) understand and apply crew co-ordination and incapacitation procedures; and
>
> (g) communicate effectively with the other flight crew members."

Each of these Annex 1 provisions bears upon some element of Human Factors; they dictate a need for education and background knowledge, as well as development of the necessary skills for implementation.

1.3 In addition to the changes mandated in Annex 1, additional impetus for change has come from Human Factors experts within the aviation industry. The participation of such experts in research and accident/incident investigation has been steadily growing. In addition to the immediate effect of their published findings, such experts have played an important role in identifying potential solutions to various Human Factors safety and training deficiencies.

1.4 The publication of the Eighth Edition of Annex 1 confirms a growing international consensus that training in aviation Human Factors is a necessity. This digest is an early response to the consequent need for training materials.

THE SITUATION PRIOR TO THE EIGHTH EDITION OF ANNEX 1

1.5 As long as human beings are part of the aviation system, human capabilities and limitations will influence safety. Given the predominant role of human beings in the accident record, it comes as no surprise that the consequences of some human deficiencies have been well identified in accident reports and other publications. International licensing requirements and the design of equipment, training and operational procedures are amongst those elements of the aviation system which have changed steadily as a result of such experience.

1.6 However, change has been both slow and piecemeal. There are disparate understandings of Human Factors within the aviation community. The limitations in our current state of knowledge about the nature of human capabilities and limitations in aviation have resulted in a somewhat incoherent and incomplete approach to Human Factors training in the past.

1.7 With respect to pilot training, there is a similar diversity of strategies responding to Human Factors problems. These strategies range from dedicated training courses in Human Factors aimed exclusively at factual knowledge, through to training focused exclusively on the development of specific skills, such as communications, crew co-ordination, resource management and decision-making.

1.8 These solutions are limited by being only partially implemented, as well as by a lack of both national and international co-ordination. Recent developments within the United States have led to the publication of an FAA Advisory Circular on the subject of cockpit resource management. Similarly, in Canada national programmes on pilot decision making and risk management have also been instituted. These are among the few national safety initiatives which have addressed the need for a uniform response to an identified aspect of human performance within the aviation system.

HUMAN FACTORS HIGHLIGHTS

1.9 The following paragraphs highlight a number of general Human Factors considerations, intended essentially as an introduction to Human Factors for those readers who do not have available Digest No. 1 — *Fundamental Human Factors Concepts* (Circular 216) which, ideally, should be read before any training courses are developed.

Human Factors: an overview

1.10 Human Factors is about people: it is about people in their working and living environments, and it is about their relationship with equipment procedures and the environment. Just as importantly, it is about their relationships with other people. Human Factors involves the over-all performance of human beings within the aviation system; it seeks to optimize people's performance through the systematic application of the human sciences, often integrated within the framework of system engineering. Its twin objectives can be seen as safety and efficiency.

Disciplines and applications

1.11 Human Factors is essentially a multidisciplinary field, including but not limited to: psychology, engineering, physiology, medicine, sociology and anthropometry (see Figure 1). Indeed, it is this multidisciplinary nature and the overlapping of the constituent disciplines that make a comprehensive definition of Human Factors difficult.

1.12 Human Factors has come to be concerned with diverse elements in the aviation system. These include human behaviour and performance; decision-making and other cognitive processes; the design of controls and displays; flight deck and cabin layout; communication and software aspects of computers; maps, charts and documentation; and the refinement of staff selection and training. Each of these aspects demands skilled and effective human performance.

1.13 Given the contemporary emphasis upon the social sciences within Human Factors, it should be remembered that physiology is among the many other important sources of Human Factors knowledge. Thus, for example, anthropometry and biomechanics — involving measurements and movements of the human body — are relevant to the design of the workplace and to the equipment therein; similarly, biology and its subdiscipline, chronobiology, are necessary for an understanding of those bodily rhythms which influence human performance.

1.14 In spite of the academic sources of information on the various Human Factors disciplines, aviation Human Factors is primarily oriented towards solving practical problems in the real world. As a concept, its relationship to the human sciences might well be likened to that of engineering to the physical sciences. And, just as technology links the physical sciences to various engineering applications, there are a growing number of integrated Human Factors techniques or methods; these varied and developing techniques can be applied to problems as diverse as accident investigation and the optimization of pilot training.

Accidents and incidents

1.15 Human error is, by far, the most pervasive cause of accidents and incidents in technologically complex systems such as air transportation, with studies indicating that between 80 and 90 per cent of all aviation accidents are attributable to human error in one form or another. One major data base of jet transport accidents world-wide indicates that 65 per cent of all such accidents have been attributed to flight crew error. It also indicates that for the approach and landing phases of flight, which account for 4 per cent of total flight exposure time and 49 per cent of all accidents, flight crew error is cited in 80 per cent as a causal factor. Other sources of human error, including maintenance, dispatch and, importantly, air traffic control, account for another significant proportion of accidents.

1.16 In tragic terms, these accidents have been responsible for many deaths. It must also be kept in mind that accidents involving commercial jet transport are only the tip of the iceberg; in one major aviation State there are nearly 3 000 accidents and 1 000 fatalities each year in general aviation alone. Studies have shown that human performance is involved as a cause in nearly 90 per cent of these accidents, making it abundantly clear that human performance is the critical and enduring issue facing those who have responsibility for the design, operation and supervision of our aviation system. The solution of these long-standing and perplexing Human Factors problems is therefore essential.

Discipline	Definition	Specific area of interest	Typical area of application
Psychology	The science of mind and behaviour.	Sensory characteristics, perceptual laws, learning principles, information processing, motivation, emotion, research methods, psychomotor skills, human errors.	Display requirements and design, control systems design, allocation of function, training system requirements and methods, selection methods, effects of emotional and environmental stress on performance, simulation requirements.
Engineering	Applying the properties of matter and the sources of energy in nature to the uses of man.	Hydraulics, mechanical, structural, electrical, electronic, and aerodynamics design, systems analysis, simulation, optics.	Design of displays, design of controls, design of control systems, design of complex systems, design of optical systems, simulator design.
Human physiology	Deals with the processes, activities and phenomena characteristic of living matter, particularly appropriate to healthy or normal functioning.	Cell structure and chemistry, organ structure and chemistry, interaction of the various body constituents to promote health and function, functions and requirements of body systems.	Environmental systems, diet and nutrition, effects of environmental factors (heat, cold, hypoxia), establishment of environmental requirements.
Medicine	The science and art of preventing, alleviating or curing disease and injuries.	Effects of various forces, radiation, chemical and disease agents; appropriate preventive methods of protecting health and well-being.	Toxicology of smoke, chemicals, impact protection, maintenance of health.
Sociology	The study of the development, structure and function of human groups.	Small and large groups or "teams"; crew composition; behaviour of passengers in emergency situations.	Crew selection, passenger safety.
Anthropometry	Study of human body sizes and muscle strength.	Anatomy, biodynamics, kinesiology.	Ground support equipment, access door size for maintenance, work station layout (reach, range of adjustment of seats, etc.)

Figure 1. Disciplines frequently involved in Human Factors activities*

* *Other disciplines with representatives actively engaged in Human Factors activities include education, physics, biochemistry, mathematics, biology, industrial design and operations research.*

Human error

1.17 It is most important that all concerned with the operation and administration of the aviation system recognize that, no matter how determined the effort to prevent it may be, human error will have an impact on the system. No person, whether designer, engineer, manager, controller or pilot, can perform perfectly at all times. Also, what could be considered perfect performance in one set of circumstances might well be unacceptable in another. Thus, people need to be seen as they really are; to wish that they be intrinsically "better" or "different" is futile, unless such a wish is backed by a recommendation for remedial action, which itself must be further supplemented by the provision of means to achieve better design, training, education, experience, motivation, etc., with the objective of positively influencing relevant aspects of human performance.

1.18 It is therefore intended that ICAO Human Factors digests will become a source of both information and practical measures to be used in the effort to improve education, training and remedial measures in Human Factors. The brief review above sets the context for the detailed consideration of Human Factors. It represents the consensus view of the ICAO Flight Safety and Human Factors Study Group.

THE SHEL MODEL

1.19 No discussion of constituents can capture the essence of the various processes and interactions that characterize an operational system. One objective of the introductory ICAO Human Factors digest was to identify the many and varied topics in Human Factors so as to describe their different operational implications. It was also necessary to find a way of describing the various processes of control, information exchange, etc., which occur in practice. To achieve these objectives, ICAO's Human Factors Digest No. 1 introduced the "SHEL" model (see Figure 2).

1.20 The SHEL model provides a conceptual framework to help understand Human Factors. It illustrates the various constituents and the interfaces — or points of interaction — which comprise the subject. Human Factors elements can be divided into four basic conceptual categories:

Software: documentation, procedures, symbols, etc.
Hardware: machinery, equipment, etc.
Environment: both internal and external to the workplace
Liveware: the human element.

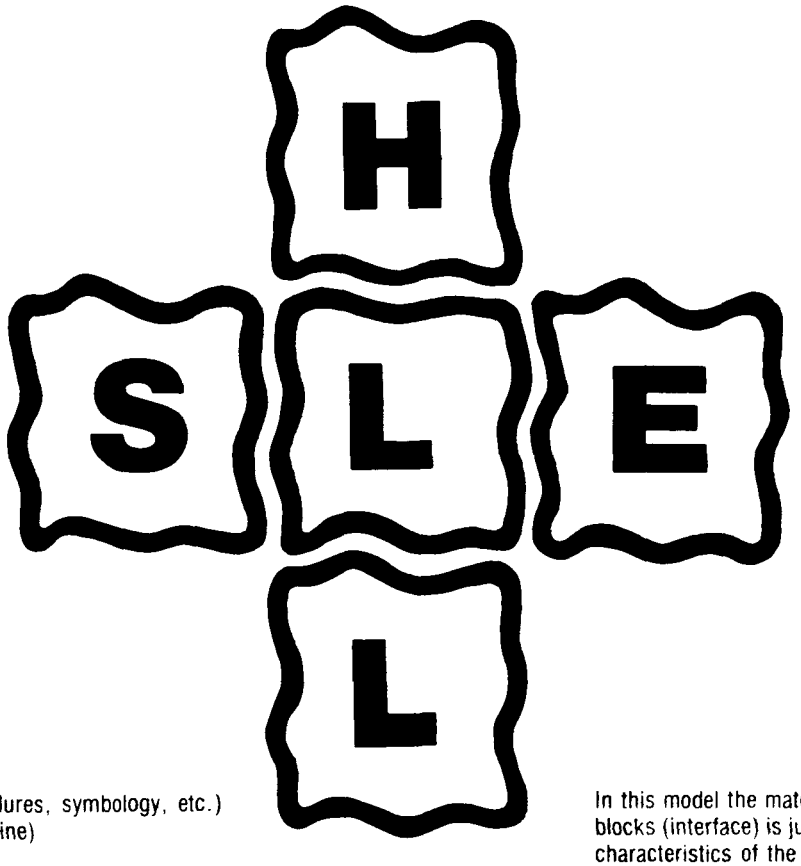
Interactions between human beings and the other elements of the SHEL model are at the heart of Human Factors, which involves the interfaces between:

— humans and machines — "Liveware-Hardware"

— humans and materials — "Liveware-Software"

— humans and their colleagues — "Liveware-Liveware"

— humans and the operating environment — "Liveware-Environment".



S = Software (procedures, symbology, etc.)
H = Hardware (machine)
E = Environment
L = Liveware (human)

In this model the match or mismatch of the blocks (interface) is just as important as the characteristics of the blocks themselves. A mismatch can be a source of human error.

Figure 2. The SHEL model

The SHEL model provides the structure around which the syllabus in Chapter 2 was developed and written. With use, the advantages of this model in guiding instruction on Human Factors should also become clear.

THE IMPLICATIONS OF THE EIGHTH EDITION OF ANNEX 1

1.21 The ICAO licensing/training Human Factors requirements may present some problems for training institutions, airlines and licensing authorities. In the case of pilot technical training, for instance, there is a wide international consensus as to training requirements, methods, objectives and course content. Guidance material is readily available, syllabi are easy to develop, and training methods are well established. However, there is no similar consensus as to the appropriate focus for training in aviation Human Factors. This partly reflects the uncertainty which characterizes our current state of knowledge about the nature of human capabilities and limitations in aviation. However, it also reflects different beliefs as to the practicality and effectiveness of dedicated Human Factors training.

1.22 There are different and legitimate perspectives in this matter. A central problem for many States is the difference in international practices regarding the application to such training of medicine, ergonomics, and the social/behaviourial sciences. Further differences relate to the relative importance accorded to knowledge and skills training. Perspectives on training content and strategies can be strongly influenced by different cultural and social practices.

1.23 While ICAO regulations serve to promote common international Standards and Recommended Practices, considerable international differences remain in the practical achievement of various ICAO requirements. For instance, in some countries the predominant pilot training and licensing emphasis is directed at the individual licence holder, while in others the maintenance of standards is primarily addressed through the airline operator. In the former States, much thought tends to be given to the training and checking of individual pilots, while in the latter it is the industry operating practices and procedures which receive greater attention.

1.24 Associated with these contrasting perspectives are different approaches to aviation safety problems. Some specialists favour a broad, industry-wide systems approach to analysis and remedial action, while others prefer to focus on specific problem areas. Some authorities believe that the most effective action takes place at the point of aircraft and procedural design, and thus feel that any action at the level of the individual pilot is misplaced. Others see line management within the aviation industry as providing an appropriate focus for implementation of change. Thus, airline operators vary considerably in the practical emphasis they allocate to operational aspects of Human Factors.

1.25 In many countries further problems derive from a lack of suitable resources, including appropriately trained physiologists, psychologists, ergonomists, aviation specialists, managers and legislators (see also 3.5 regarding instructor qualification and selection). Furthermore, some national authorities are proactive in pursuit of their regulatory activities, while others are not.

1.26 This short review of possible sources of difficulty underlines the potential for confusion and misunderstanding, at both national and international levels. The resulting uncertainty and lack of definition have sustained inaction in this field over many years. However, given the need to respond to ICAO's call for pilot education in human performance and limitations, perhaps the industry can now move forward, while bearing these difficulties in mind. While there are undoubtedly some significant and difficult decisions to be made, the development of appropriate training courses can now proceed.

CHAPTER 2

Human Factors Training Curriculum

An ICAO Proposal

GENERAL

2.1 This chapter identifies specific areas of knowledge to be included in the design of Human Factors training programmes. Annex 1 provides that the licence holder shall demonstrate knowledge on human performance and limitations commensurate with the level of the licence (PPL, CPL, ATPL, etc.). In order to comply with this requirement, specific programmes should be designed for each level of licence. For the purpose of this document, however, and in order not to make this proposal too binding, a single programme is proposed as a baseline, with differences in its applicability to different levels of licence to be made as appropriate.

THE KNOWLEDGE REQUIREMENT

2.2 The outline curriculum provided below meets the training requirements for the airline transport pilot licence (ATPL) holder; with minor adjustments it can easily be made applicable to the commercial pilot licence (CPL), to the instructor/instrument ratings and to the private pilot licence (PPL). For instance, the curriculum for the PPL holder might explicitly address pilot judgement and decision-making. On the other hand, the curriculum for the ATPL and instructor/instrument ratings should address crew co-ordination, communication with other crew members/personnel, small group dynamics and crew management. Currently, skills in these areas are covered by cockpit resource management training programmes (see Circular 217).

2.3 A general survey within the industry indicates that approximately 35 hours is the time required to properly present Human Factors training similar to that in the proposed syllabus. The minimum is estimated to be 20 hours. In order to provide an indication of the relative importance of each topic, the following indicates the percentages of total time to be given to each subject:

Module	*Title*	*Time*
1	Introduction to Human Factors in Aviation	5% (1.75 hrs)
2	The Human Element (Aviation Physiology)	20% (7.00 hrs)
3	The Human Element (Aviation Psychology)	30% (10.50 hrs)
4	The Human Element (Fitness for Duty)	5% (1.75 hrs)
5	Liveware-Hardware: Pilot-equipment Relationship	5% (1.75 hrs)
6	Liveware-Software: Pilot-software Relationship	10% (3.50 hrs)
7	Liveware-Liveware: Interpersonal Relations	15% (5.25 hrs)
8	Liveware-Environment: The Operating Environment	10% (3.50 hrs)

Total: 35 hours

2.4 Whatever the total amount of hours allocated to any given programme, a balanced introduction to Human Factors training should be achieved if these relative percentages are applied. Given this general guidance, any aviation Human Factors specialists involved in course development should be able to provide advice on appropriate course content. The following outline is therefore not intended to be exhaustive, but it will provide guidance to the specialist in the development of a satisfactory course.

Module 1: Introduction to Human Factors in Aviation

In this module, the rationale for Human Factors training should be explained. A good point of departure is the fact that since 1940, three out of four accidents have had at least one contributory factor relating to human performance.

The introduction has to be carefully prepared in order to capture the pilot's interest. It is desirable that training directed at meeting any examination or test requirement associated with the revised Annex 1 be kept relevant to operational aspects of flight. A practical orientation is therefore essential to effective training. The relevance of the programme must be made quite clear to pilots — *this is not intended as an academic exercise.* Therefore, only that information which relates to pilot performance should be included. Training personnel should present the information according to their particular operational needs and may wish to take specific aspects of their local accident/incident experience into account.

The SHEL model might be usefully introduced in this module as one of the possible aids to understanding the interactions between the different components of the system, as well as the potential for conflict and error arising from the various mismatches which can occur in practice.

Module 2: The Human Element (Aviation Physiology)

Breathing; recognizing and coping with:
- hypoxia
- hyperventilation

Pressure effects; effects on ears, sinuses and closed cavities of:
- trapped or evolved gases
- decompression
- underwater diving

Limitations of the senses
- visual
- aural
- vestibular
- proprioceptive
- tactile

Acceleration effects; positive and negative "G's"
- — aggravating conditions

Disorientation
- — visual illusions
- — vestibular illusions
- — coping mechanisms

Fatigue/alertness
- — acute
- — chronic
- — the effects on skill and performance

Sleep disturbances and deficits

Circadian dysrhythmia/jet lag

Module 3: The Human Element (Aviation Psychology)

Human errors and reliability

Workload (attention and information processing)
- — perceptual
- — cognitive

Information processing
- — mind set and habit patterns
- — attention and vigilance
- — perceptual limitations
- — memory

Attitudinal factors
- — personality
- — motivation
- — boredom and complacency
- — culture

Perceptual and situational awareness

Judgement and decision-making

Stress
- — symptoms and effects
- — coping mechanisms

Skills/experience/currency vs. proficiency

Module 4: The Human Element (Fitness for Duty)

Personal health

Effects of:
- diet/nutrition
- alcohol
- drugs (including nicotine/caffeine)
- medications (prescribed; over-the-counter)
- blood donations
- aging

Psychological fitness/stress management

Pregnancy

Module 5: Liveware-Hardware: Pilot-equipment Relationship

Controls and displays
- design (movement, size, scales, colour, illumination, etc.)
- common errors in interpretation and control
- "glass" cockpits; information selection
- habit patterns interference/design standardization

Alerting and warning systems
- appropriate selection and set-up
- false indications
- distractions and response

Personal comfort
- temperature, illumination, etc.
- adjustment of seat position and controls

Cockpit visibility and eye-reference position

Motor workload

Module 6: Liveware-Software: Pilot-software Relationship

Standard operating procedures
- rationale
- benefits
- derivation from human limitations and the accident/incident record

Written materials/software
- errors in the interpretation and use of maps/charts
- design principles and correct use of checklists and manuals

Operational aspects of automation
- overload/underload and phase of flight; complacency and boredom
- staying in the loop/situational awareness
- automated in-flight equipment; appropriate use, effective task allocation, maintenance of basic flying skills

Module 7: Liveware-Liveware: Interpersonal Relations

Note.— Liveware-Liveware deals with interpersonal contacts happening at the present time (here and now), as opposed to the interpersonal contacts involving people outside of the current operating situation (the latter are considered in Module 8).

Factors influencing verbal and non-verbal communication between and with:

- flight deck crew
- cabin crew
- maintenance personnel
- company management/flight operations control
- air traffic services
- passengers

How verbal and non-verbal communication affects information transfer and thus safety and efficiency of flight

Crew problem solving and decision-making

Introduction to small group dynamics/crew management (see also Circular 217 for further information on this topic).

Module 8: Liveware-Environment: The Operating Environment

The physical environment (internal)
- temperature, pressure, humidity
- noise, vibration
- lighting
- radiation
- pollutants/contaminants/carbon monoxide poisoning

The physical environment (external)
- terrain: mountains, water, desert, "white-out", "black hole"
- weather: turbulence, wind shear, icing
- other air traffic
- time of day
- take-off and landing conditions: density altitude, runway conditions

The socioeconomic environment
- legal and regulatory
- company organizational structure and economic climate
- employer operating pressures
- employer/employee relations/unions
- family relationships
- peer groups and professionalism
- pairing of inexperienced crews (experience in the operational context)

THE SKILL REQUIREMENT

2.5 While the initial emphasis in Human Factors training should be upon knowledge and comprehension of basic Human Factors, instructors must also bear in mind the need to develop appropriate operational behaviour and skills. In other words, to make this academic knowledge useful, pilots must develop those skills and attitudes necessary to maximize their operational performance. For example, a pilot with proper knowledge of physiology should be able to identify an unfit condition with potentially dangerous and undesirable consequences and elect not to fly, thus exercising what can be considered as a *judgement skill*. Obviously, training activities directed towards the development of suitable attitudes and skills should always be given the highest possible priority.

2.6 Human Factors skill identification and training applications remain a relatively undeveloped field in pilot training and can be expected to undergo considerable development in years to come. For many skills, the major training requirement will be to identify and specify suitable training materials and techniques, and to successfully integrate these into the ground and airborne training syllabi. In one major training school, for instance, the heading "pilot judgement" and supplementary notes have been included in *all* briefing and instructional materials, including those used during ground instruction. This serves as a trigger for instructors to discuss relevant pilot judgement skills.

2.7 The following is a list of Human Factors skills areas identified using the SHEL model (some skills are of necessity included in more than one interface). This guidance material may assist trainers with the identification of the required Human Factors skills, and should help to fill the void between the written word and its practical application. Possible skills areas for training development are:

Liveware-Liveware (L-L)
- Communication skills
- Listening skills
- Observation skills
- Operational management skills; leadership and followership
- Problem solving
- Decision-making

Liveware-Hardware (L-H)
- Scanning
- Detection
- Decision-making

Cockpit adjustment
Instrument interpretation/situational awareness
Manual dexterity
Selection of alternative procedures
Reaction to breakdowns/failures/defects
Emergency warnings
Workload; physical, allocation of tasks
Vigilance

Liveware-Environment (L-E)
Adaptation
Observation
Situational awareness
Stress management
Risk management
Prioritization and attention management
Coping/emotional control
Decision-making

Liveware-Software (L-S)
Computer literacy
Self-discipline and procedural behaviour
Interpretation
Time management
Self-motivation
Task allocation

The proposed ICAO curriculum detailed above includes an interface not considered as such in the SHEL model, namely the Human Element. Human Factors skills under this heading include those relating to the psychological state and well-being of operational personnel themselves (this should not be confused with the "Liveware-Liveware" interface, which deals with interpersonal contacts):

The Human Element
Recognition/coping: disorientation (motion systems), stress
Fatigue
Pressure effects
Self-discipline/control
Perception
Attitudes and the application of knowledge and exercise of judgement

2.8 It will be readily appreciated from the foregoing that the development of skills for practical application during flight operations is an important evolution from theoretical Human Factors knowledge to actual operational settings. While the emphasis in this digest is necessarily directed mainly toward pure knowledge requirements, it is important to reiterate that, where possible, practical Human Factors considerations should be built into all relevant aspects of instructional activity. This should apply throughout all stages of pilot and instructor training. Instruction directed at the acquisition of Human Factors *skills* is the activity which is expected to yield the greatest benefits in the future.

2.9 It is anticipated that specialist training directed towards the acquisition of suitable skills will be further developed in the coming years and that suitable training techniques will be fully integrated into all pilot training activities. It is especially *undesirable* that, after meeting the Annex 1 knowledge requirement, trainees come to see Human Factors training as an academic exercise lacking in operational relevance.

CHAPTER 3

Considerations in Training Implementation and Curriculum Development

OVERVIEW

3.1 To assist in making courseware design decisions and in planning training implementation, the following paragraphs identify essential elements of the Human Factors training and educational tasks. An attempt has been made to respond to needs across the training spectrum, from those of the individual instructor to those of major training establishments. The discussion therefore avoids too restrictive a view as to how actual training courses might be conducted in practice. A concise version of this section is repeated as Appendix 5, thus providing a checklist for interested parties.

DETERMINATION OF TARGET AUDIENCE

3.2 The curriculum, training objectives and training effort will vary for different categories of aviation personnel. Obviously, all personnel do not need the same knowledge or skills.

3.3 Among operational personnel — the prime focus of the ICAO initiative — it will be important to differentiate among the specific requirements of the different pilot categories included in Annex 1 (private, commercial, ATPL, etc.). When developing training courses, the pilot categories to be considered include *ab initio*, general aviation, commercial, air carrier, management/supervisory and instructor pilots. Some States or organizations may also wish to develop training for other operational categories such as aircraft maintenance personnel, air traffic controllers and flight operations officers.

3.4 Although only limited knowledge of Human Factors may be required for senior management, appropriate background information is widely considered to be essential. Supervisory and other personnel will need specialist knowledge by virtue of their particular function. Thus, for instance, there will clearly be different knowledge and competency requirements for senior management, accident prevention/air safety officers, accident investigators, flight operations management/supervisory personnel, and supervisory flight instructors (for instance, suitable introductory information for supervisory staff is included in paragraphs 1.9 to 1.18).

SELECTION OF THE TRAINERS

3.5 The selection and education of those who will administer training programmes in Human Factors have been a matter of concern in some States, perhaps because of the understandable idea that only a trained psychologist can deal with subjects related to human behaviour. In their

daily activities, however, pilots and instructors deal with and teach subjects related to aerodynamics without being aeronautical engineers, to meteorology without being meteorologists, to powerplants without being mechanics, and so on. There is no reason why this line of reasoning cannot be applied to the teaching of Human Factors.

3.6 Within the aviation community, flight and ground instructors are among the obvious individuals capable of teaching Human Factors. If flight and ground instructors are thoroughly familiar with the contents of the proposed programme — whether thorough formal training or self-education — they will be able to fulfil the training objectives. Digest No. 1 is one useful starting point for instructors since it includes an extensive bibliography. Alternatively, specialists in the subject will be in a good position to teach Human Factors. However, it will then be important to ensure that these specialists are themselves able to relate their knowledge in a practical manner to the operational environment.

TRAINING PHILOSOPHY AND OBJECTIVES

Introduction

3.7 General issues for attention during course design and development are discussed in this section. It is intended that consideration of these issues will help to clarify desirable training goals and techniques.

Training philosophy

3.8 Among the more important topics requiring attention here are:

a) the roles to be given to theoretical and practical, or experiential, learning activities. This will prove to be a most important dichotomy in practice, so clarity is essential;

b) the integration of knowledge-based training into briefing, debriefing and practical exercises conducted during flight training; and

c) the role of training activities which promote experiential learning (e.g. role-playing, line-oriented flight training, etc.)

Training objectives

3.9 Once the philosophical direction of the training has been established, the training objectives must be specified. These will influence the design of the training courseware and the priority accorded to Human Factors in briefing, debriefing and performance appraisal.

3.10 When determining training objectives, and instructor training activities, it is often useful to divide the learning task into appropriate sub-categories such as "memorizing", "understanding", "doing", and "attitudinal aspects" and to identify the post-training competency, or command of the subject matter, expected of the trainees within each category. These four categories or domains of trainee competence may be characterized as follows:

— knowledge-based (memorization)
— comprehension-based (understanding)
— skill/technique-based (doing)
— attitude-based

3.11 *Knowledge* covers factual knowledge, and may include memorizing appropriate procedural information. Suitable teaching and assessment techniques are currently used in the theoretical and procedural training of pilots.

3.12 *Comprehension* of relevant general principles and theory is often essential in order to achieve competency. This category will sometimes overlap with other categories.

3.13 Pilots are expected to acquire and display certain practical *skills and techniques.* Skills in any domain must be exercised in a suitable fashion, in the appropriate context and at the correct time. In aviation, psychomotor and procedural skills have traditionally received most attention; in the case of Human Factors training, some additional skills are necessary, such as the development of appropriate communications/crew skills.

3.14 *Attitudes* play an important part in determining over-all pilot performance. Philosophical aspects relating to piloting practice, desirable professional attributes and dispositions conducive to good airmanship can be considered under this heading. The process of corporate/professional induction and socialization can also be considered under this heading for those operators involved in the *ab initio* training of pilots. Attitudes have been strongly emphasized by a number of Human Factors specialists, who have noted the role of appropriate attitudes in sustaining and implementing safe and effective operational practices.

Subject content

3.15 The outline syllabus contained in Chapter 2 of this digest should provide an overview of essential subject matter, as well as a suitable point of departure for detailed syllabus development.

Training materials, techniques and educational technologies

3.16 A division can be made here between training *hardware*, training *strategies/techniques* and the actual training *courseware.* It is anticipated that the better Human Factors training courses will make creative and imaginative use of the available resources. Optimal training will address the Annex 1 requirement whilst giving appropriate emphasis to training the essential Human Factors skills.

Training hardware

3.17 While simulators come immediately to mind, there are many other potentially useful training devices, such as part-task trainers, computer-based training equipment, as well as video cameras/recorders, interactive video and other developing hardware.

Training strategies and techniques

3.18 Associated with the new training hardware is an increasing differentiation of training methods, many of which utilize modern instructional technology. Thus, for instance, the merits of interactive media and the effectiveness of video feedback in training are now widely recognized.

3.19 At the other extreme, valuable learning experiences can arise from the use of suitable role-playing exercises, case studies or simulation gaming. While such activities depend on careful and time-consuming preparation, they are cheap and can be highly effective.

3.20 Recent changes in educational practice reflect a growing trend towards open and experiential learning, which address both individual and crew skill development and training needs. For pilot training in Human Factors, some such learning is seen by most specialists as highly desirable, notably in areas as communications and crew co-ordination skills. Indeed, it is the acquisition of necessary skills, rather than the mere demonstration of theoretical understanding, that is the desired objective of such training.

3.21 In achieving training objectives the value of multi-method training should be noted. This is a means of integrating individual training techniques into multi-method "integrated training technologies". Notable examples in current use are optimal LOFT programmes and fully developed CRM training. These "integrated training technologies" comprise carefully designed training programmes which facilitate both individual and crew-centred learning. Operationally relevant experiential learning is promoted by the provision of extensive feedback, often using video recordings and other means to facilitate reflection and student-lead debriefing.

Training courseware

3.22 The content of fully developed training courseware will clearly depend on training objectives, time, equipment and the available resources. It should, desirably, integrate ground and airborne training activities. Courseware should be prepared so as to explicitly include Human Factors points for consideration during briefing and debriefing. While the essential focus of the latest Annex 1 amendment is upon the provision of Human Factors knowledge, the training of preference will best achieve this when operational skills are also addressed during instructional design and development. The choices made at the courseware design stage will help to define the relevant instructor/trainee learning activities.

SKILL DEVELOPMENT, PILOT ASSESSMENT AND TRAINING COURSE EVALUATION

3.23 Regular assessment is very much a part of aviation industry practice and provides one means of meeting standards and determining training effectiveness. Decisions as to suitable and productive means of pilot assessment will be an important influence in Human Factors courseware design. While traditional methods of assessment have unquestioned value in measuring factual knowledge and various aspects of comprehension, an alternative form of performance appraisal is generally considered essential when judging the efficacy of experiential

learning activities. Experiential learning, such as that seen in the best LOFT/CRM programmes, cannot be optimized if formal assessment is conducted simultaneously with the training.

3.24 Furthermore, the general difficulty of evaluating the effectiveness of communications skills, CRM and similar training is well known. Indeed, the difficult issues addressed here arise regularly in discussion, both in terms of justifying the training effort and in evaluating the effectiveness of all such training courses.

3.25 On the other hand, skill acquisition in aviation has traditionally been achieved on the job or in the course of high-fidelity simulation. Skill assessment and associated operational techniques have traditionally been conducted in the same environment. However, notwithstanding the influence of current practice, the desire for formal assessment of Human Factors skills must always be counterbalanced by full consideration of any negative learning consequences which may arise from that very assessment.

3.26 In this context, it should be noted that training activities such as role-playing and LOFT are considered to be especially good training techniques *because* they explicitly concentrate on the skill development needs of trainees, while avoiding the negative learning connotations associated with the checking/testing environment. While there may be no international consensus as to the best means of addressing the difficult issue of Human Factors training evaluation (and trainee performance appraisal), it is clearly important that the general issues discussed above are fully understood by trainers and instructional designers. Such an understanding will help prevent premature moves to assessment and testing in circumstances where they could prove counterproductive to longer term learning needs.

3.27 Appendix 6 provides a sample questionnaire to illustrate one suggested approach to the assessment of Human Factors factual knowledge.

APPENDIX 1

KLM Human Factors Awareness Course (KHUFAC)

LIST OF UNITS

UNIT 1 — THE MEANING OF HUMAN FACTORS

Definition

— Ergonomics/Human Factors — twin objectives

Course preview

— Liveware; hardware; software; environment

Human Factor deficiencies

— Examples; displays; controls; seats; procedures; lighting; illusions; cabin deficiencies

— "Murphy's Law"

— Accident (CVR) Sequence simulated; analysis of errors

Staff involved

Conceptual model of Human Factors
- — Interfaces between liveware, software, hardware, environment; characteristics of man

Questions and misconceptions
- — Ergonomics vs. medicine (operations management)
- — Sleep and body rhythms; sleeping tablets; alcohol (stewardess)
- — Line crew member interest and involvement (pilot)
- — Ergonomics and common sense (central engineering)
- — Disciplines used in ergonomics
- — Financial aspect of ergonomics (financial controller)

Recommended reading

Roscoe, Stanley N. *Aviation Psychology.*
Warr. *Psychology at Work.* Penguin Education.
Applied Ergonomics Handbook. IPC Science and Technology Press.
Murrell, Hywell. *Men and Machines.*

UNIT 2 — THE NATURE OF HUMAN ERROR

Introduction
- — Historical background of error; increasing consequences of error

Occurrence
- — Not confined to crews; crew responsibility as last in chain; normal error rates vs. acceptable rates in aviation

Classification
- — Mismatching between components of conceptual model (Unit 1); random, systematic, sporadic errors; omission; commission; substitution; reversible and irreversible

Information processing
- — Where errors occur in system; examples and location; capacity and overload

Variability of human performance
- — Circadian rhythms of performance; attention

The false hypothesis
- — Situations when likely to occur

Motivation
- — Relation to error rates

Recommended reading

Fitts and Posner. *Human Performance.* Brooks and Coles.
Swain, A.D. *Design Techniques for Improving Human Performance.* In Com. Tec.

UNIT 3 — MEETING THE CHALLENGE OF HUMAN ERROR

Introduction
- — Need to take action on error
- — Minimizing error; reducing the consequence of error
- — Identification of errors with serious consequences

System component interfaces
- — Hardware; controls and displays; Murphy's Law; effect of stress
- — Procedures; environment; temperature

Allocation of tasks between man and machines
- — Examples; motivation

Arousal level
- — Optimum; sleepiness; boredom; job stress
- — Vigilance and monitoring tasks

Correction programmes
- — ECR; ZDP; improved training; application of procedures
- — Personnel selection; training; checking; self-pacing; workload distribution

Living with residual errors
- — Reversible; monitoring; avoidance of critical situations; discussions of errors

Summary

Recommended reading

Fitts and Posner. *Human Performance.* Brooks and Coles.
Swain, A.D. *Design Techniques for Improving Human Performance.* In Com. Tec.

UNIT 4 — FATIGUE, BODY RHYTHMS AND SLEEP

Relevance to safety and efficiency
- — Views of specialists
- — Effects on attention; perception; motivation etc.

Categorization
- — Three types of fatigue; sources of fatigue

Associated problems
- — At work; at home

The nature of sleep
- — Types; stages

The function of sleep and effect of sleep loss
- — Amount of sleep required; effect of sleep loss on motivation and performance

Body rhythms
— *Examples of rhythms; shifting rhythms; brain and performance rhythms*

Operational consequences of sleep and body rhythm disturbance
— Summary; variability in human performance

Minimizing effect of sleep loss

Avoiding sleep loss
— Sleeping drugs and performance; relaxation techniques; individual differences; optimizing sleeping environments; diet; adapting lifestyle; crew scheduling

Recommended reading

Meares, Ainslie. *Relief Without Drugs.* Fontana.
Benson. *The Relaxation Response.* Avon.
Selye, Hans. *Stress Without Distress.*
Carrington. *Freedom in Mediation.* Anchor.
Hartmann. *The Functions of Sleep.* Yale University Press.
Segal and Luce. *Sleep.* Arena Books.
Luce. *Body Time.* Bantam Books.
Hawkins. *Sleep and Body Rhythm Disturbance in Long-Range Aviation.* London: Churchill Memorial Trust.

UNIT 5 — VISION AND VISUAL ILLUSIONS

Introduction
— Ames room; importance of sense of vision

Light
— *Light waves; colour detection and vision; description of light*

The eye
— Description; adaptation; visual acuity
— Blind spot

Brain
— Attention; information processing; perception; distance/size judgement
— Perspective; hypoxia/smoking

Optical illusions
— Geometric illusions
— Aviation illusions:
  — general: autokinetic effect, rain on windshield
  — taxiing: loading bridge, windshield discontinuity, drifting snow
  — in flight: low visibility, XYZ position, black hole, sloping r/w, sloping terrain, wide r/w, false horizon

Protection from illusion hazards
- — Recognition of personal vulnerability
- — Support visual cues with other information
- — Crew briefing
- — Standard operating procedures
- — Smoking limitation

Recommended reading

Gregory, R.L. *The Eye and the Brain.*
Robinson, J.O. *The Psychology of Visual Illusion.*
Spatial Disorientation in Flight. AGARD.

UNIT 6 — FITNESS AND PERFORMANCE

Fitness
- — Ergonomics vs. medicine; arguments to support definition; fitness and performance

Exercise
- — Scientific programmes; modifying life-style; walking, jogging, cycling, swimming, ball games; adrenaline/noradrenaline

Smoking
- — Tar, nicotine, carbon monoxide; association with cancer and cardiovascular disease and performance; effect of filters; effect on non-smoker; pregnancy; statistical controversy

Alcohol
- — Cost of alcoholism; effect on performance; absorption characteristics; relative alcohol content of drinks; alcohol and drugs; sleep; detecting and treatment of alcoholism

Drugs
- — Sleeping drugs, tranquilizers, antihistamines

Stress
- — Correlation of life change events and performance; "human function curve"; avoid effect of stress

Diet
- — Hypoglycemia; balanced diet; incapacitation

Recommended reading

Carruthers and Murray. *Fitness on 40 Minutes a Week.*
Cooper, Kenneth H. *The New Aerobics.*
Cooper, Kenneth H. *The Aerobics Way.*

Smoking or Health. Royal College of Physicians.
Alcohol and Alcoholism. Royal College of Psychiatrists.
Manual of Nutrition. Ministry of Agriculture, Fisheries and Food.
Eating for Health. Health Department of Great Britain and Northern Ireland.
Looking after Yourself. Health Education Council.
Iyengar, B.K.S. *Light on Yoga.*

UNIT 7 — MOTIVATION AND LEADERSHIP

Motivation

Accidents
— Inadequate human behaviour in accidents
— "What and why"

Definition
— Can and will; performance when unsupervised

Effort and performance
— Conceptual model

Kinds of motivation
— Hunger and sexual drives
— What motivates people; performance and supervision; achievement; affiliation

Influencing motivation
— Sticks and carrots; internalization of rewards and punishment; Maslow's hierarchy; achievement and affiliation motivation

Job satisfaction
— Job enrichment; job enlargement; relation to performance; money as motivator; satisfiers and dissatisfiers

Behaviour reinforcement
— Positive and negative reinforcement; cautions; feedback; magnitude; timing

Leadership
Dominator, leader, chief; nature of leadership; participation

Characteristics of leader
— Dependent on situation; common traits

Task of leader
— Motivation, modification, example; personal function; captain and purser; skills beyond technical competence

Professionalism
- — Definition; self-discipline and definition; appraisal of professional performance; role of supervisor

Conclusion

Environment
- — Changing technically and economically; behaviourial changes required; standard operating procedures; need for broader training concept progress through understanding

Recommended reading

Vroom, Victor H., and Edward L. Deci. *Management and Motivation.*
Murrell, Hywell. *Motivation at Work.*

UNIT 8 — COMMUNICATION
Language and speech

Introduction
- — Kinds of communications; SHEL interfaces; scope

Language of communication
- — Intelligibility
- — Frequency of use of words and phrases; word length; words in context; standardization; repetition
- — Non-verbal language; body and sign language

Speech
- — Vocal system
- — Characteristics of speech; intensity, frequency, harmonic composition
- — Redundancy; false hypothesis
- — Expectation
- — Masking; source, solutions, information content of consonants and vowels, signal/noise ratio
- — Articulation index; speech interference level
- — Noise; annoyance; effectiveness of speakers/listeners

Conclusion
- — Communication equipment
- — Communication breakdown
- — Reference books; suggested reading

Recommended reading

Communication. England: Open University Press.
R/T Handbook. London: CAA.
Carpenter, A. *Human Factors in Speech Communication.*

UNIT 9 — ATTITUDES AND PERSUASION

Introduction
— Examples, importance, definition

Nature
— Opinions, beliefs, components, attitudes vs. behaviour, stereotypes

Functions
— Satisfy needs, define individuality, ego-defensive, organization aid

Measurement
— Indirect measurement, Thurstone/Likert scales

Origins
— Early life; the media

Changing attitudes
— Resistance to change; communication function; optimizing communicator; message and audience; "boomerang" effect

Conclusion
— Importance for safety and efficiency

Recommended reading

Attitudes and Beliefs. England: Open University Press.
Reich and Adcock. *Values, Attitudes and Behaviourial Change.*
Brown. *Techniques of Persuasion.*

UNIT 10 — TRAINING AND TRAINING DEVICES

Introduction
— Application to all skilled staff
— Scope of unit
— Definitions; training, education, instruction

Training principles
— Alternative solutions, apart from training
— Transfer of training
— Feedback, open and closed-loop system
— Guidance, cueing and prompting
— Pacing

Training, learning and memory
— Training and learning; student participation
— Learning processes; stages
— Memory; short and long-term; effects of coding information

— Rehearsal, age, sleep
— Practise, overlearning
— Handicaps to learning; anxiety, motivation, reading skill communication
— Learning methods, individual preferences

Training systems
— Systems approach to training
— Model of training system
— Programmed instruction

Training devices
— Aids vs. equipment
— Human Factors requirements
— Fidelity in simulation; need for, time deviations
— Fidelity/transfer/cost
— Components of fidelity

Instructors
— Acceptability, cognitive typing
— Lecturing techniques, classroom optimization

Conclusion

Recommended reading

Stammers and Patrick. *The Psychology of Training.*

UNIT 11 — DISPLAYS AND CONTROLS

Introduction
— Development history, electronics and ergonomics, responsibility for development

Displays
— Definition, function
— Information processing and display optimization
— Allocation to different senses
— Design principles
— Display classifications
— Alphanumerics
— Dials and scales
— CRT
— HUD
— Warning systems

Controls
— Design principles
— Control/display ratio, direction of movement, control resistance, control coding, prevention of inadvertent actuation

Evaluation
- — Exercise in panel evaluation

Conclusion
- — Need for operator input
- — Reference books and papers

UNIT 12 — SPACE AND LAYOUT

Introduction
- — Size, shape movement
- — Application to flight deck, cabin, maintenance, loading

Data collection
- — Anthropometry, biomechanics
- — Data collection
- — Designing for extremes
- — Distribution; mean + SD, percentiles
- — Differences; ethnic, male/female

Flight deck geometry
- — Constraints, aerodynamic, commercial
- — Visibility
- — General dimensions; column separation and pilot/instrument alignment

Layout
- — Individual situation analysis
- — Sight and reach, controls and displays
- — Panel space
- — Flight deck layout for three-crew, task distribution

General application
- — Cabin, galley, toilet, hatracks, doors, stowage
- — Safety aspects, escape, impact

Conclusion
- — Compromises, penalties

Recommended reading

Reichmann, W.J. *Use and abuse of statistics.*
Moroney. *Facts from Figures.*

UNIT 13 — DOCUMENTATION

Introduction
- — Cost of documentation deficiencies

General principles
- — Language; appropriate for readership
- — Writing; word/sentence length, syntax, telegraphese, abbreviations, simplicity, jargon, ambiguity, negative/positive, readability formulae
- — Printing; typography, upper/lower case
- — Layout

Manuals, handbooks and papers
- — Function, individual preferences, index and contents, paragraph and page numbering colour coding
- — Diagrams, charts, tables
- — Illustrations, avoiding error, colour
- — Technical papers, simple writing
- — Need for testing

Questionnaires, forms
- — Questionnaire surveys
- — Survey design, elements
- — Technical selection, open/closed questions
- — Checklists, inventories, rating scales
- — Questionnaire preparation, ground rules
- — Bias, leading questions, loaded words, layout

Conclusions
- — Other documentation, navigation, passenger information
- — Importance of awareness for writer and reader

Recommended reading

Oppenheim, A.N. *Questionnaire Design and Attitude Measurement.*
O'Connor, M., and F.P. Woodford. *Writing Scientific Papers in English.*

APPENDIX 2

Draft Syllabus on Human Performance and Limitations

European Civil Aviation Conference (ECAC)

1. ALTITUDE FLYING: RESPIRATION AND BLOOD CIRCULATION

1.1 Basic concepts

- Metabolism
- Oxygen requirements of tissues
- Composition of the atmosphere
- The gas laws

1.2 The respiratory system and circulation of the blood

- Interrelationship of respiration and circulation
- Composition and function of the blood
- Blood pressure
  - control of blood pressure
  - hypo- and hypertension
  - hemodynamic effects of acceleration
- Functional anatomy of the respiratory system
- Ventilation of the alveolar space, respiratory control
- Hypoxia
  - definition and causes of hypoxia
  - symptoms of oxygen deficiency and treatment
  - time of useful consciousness
- Hyperventilation
  - definition and causes of hyperventilation
  - symptoms and treatment

1.3 The pressure cabin

- Rapid decompression, effects and countermeasures
- Entrapped gases, barotrauma

2. HUMAN INFORMATION PROCESSING

2.1 The general system

- Central and peripheral nervous system
- Sensory threshold, sensitivity, adaptation, habituation
- Reflexes and biological control systems
- Information processing by the central nervous system
  - mental set, attention (selective, divided, failure)
  - channel capacity, filtering
  - mechanisms of perception, constancies, selective perception

2.2 The senses

- Vision
  - functional anatomy of the eye
  - physiology of the visual system
  - visual acuity, refraction and refractive errors, presbyopia
  - the visual field, scanning of the environment
  - binocular vision
  - the intraocular pressure, glaucoma
  - hypoxia and vision
  - night vision (dark adaptation)
  - defective colour vision

- Hearing
  - functional anatomy of the ear
  - physiology of hearing
  - hearing loss (perceptive, conductive)
  - flight-related hazards to hearing; noise-related hearing loss, barotrauma

- Equilibrium
  - functional anatomy and physiology
  - detection of rotary and linear acceleration
  - the subjective vertical
  - motion sickness

2.3 Integration of sensory inputs: spatial disorientation and illusions

- Basic concepts and definitions
- Categories of disorientation
  - flight circumstances
  - vertigo, coriolis effect, pressure vertigo, flicker vertigo)
  - visual illusions (the leans, approach and landing problems)
  - prevention and handling of disorientation

2.4 Memory

- Functional description
- Information storage and recall
  - short-term memory
  - long-term memory
  - working memory
  - effects of stress and time of day

3. HUMAN BEHAVIOUR

3.1 General concepts

- Personality
  - characteristics
  - individual differences in personality
  - self concept
  - attitude development
  - cognitive dissonance
- Behaviour and skills
  - drives
  - learning
  - motivation and performance
- Human error and reliability
  - error model
  - types of error
  - prevention and countermeasures
  - reliability of behaviour
  - errors induced by external factors (ergonomics, organizations)
- Working in an automated cockpit
  - advantages
  - disadvantages
  - coping behaviour

3.2 Cockpit management

- Crew co-ordination
  - distribution of responsibilities
  - working with a crew concept
- Crew co-operation
  - small group dynamics (norms, atmosphere, pressure, communication, structure) management
  - conflict management
- Leadership, style of management
  - concern for performance
  - concern for people
  - democratic vs. autocratic style
  - encouraging inputs and feedback

- optimizing of crew performance in flight
- correcting crew co-ordination deficiencies

— Communication
- verbal and non-verbal communication
- one- and two-way communication
- effects of different communication styles
- miscommunication (including cultural differences)

3.3 Judgement and decision-making

— Pilot judgement concepts
- *types of judgement*
- motor skills and human factors

— Aeronautical decision-making
- decision-making concepts
- pilot responsibilities
- behavioral aspects

— Identification of hazardous attitudes
- physical factors
- psychological factors
- social influences and interface between people

— Pilot judgement awareness
- risk assessment
- cockpit stress management

— Applying decision-making concepts
- practical application
- managing resources
- safety awareness

4. FLYING AND HEALTH

4.1 The high-altitude environment

— Ozone, radiation, humidity

4.2 Physiological and mental fitness

4.3 Incapacitation

— Main causes and symptoms
- gastrointestinal
- cardio-vascular
- side effects of drug and medication
- migraine
- epilepsy
- brain disorders

— *Recognition; insidious and sudden incapacitation*

— Procedures for dealing with incapacitation

4.4 Intoxication

- Tobacco
- Alcohol
- Drugs and self-medication
- Various toxic materials

4.5 Body rhythm disturbances

- The biological clock
- Disturbances of circadian rhythms
  - causes (shift work, time-zone crossing)
  - symptoms
  - treatment
- Sleep
  - functions
  - patterns
  - effects of disturbances and treatment

4.6 Fatigue

- Definition
- Causes
- Types and symptoms
- Prevention and treatment

4.7 Stress and anxiety

- Definition of stress
- Stress components
- Causes, stressors
- Coping behaviour
- Identifying and reducing stress
- Life stress management
- Effects on performance
- Anxiety
- Defense mechanisms
- Effects of anxiety and defense mechanisms

4.8 General health aspects

- Common minor aliments (colds, influenza, gastrointestinal upsets)
- Tropical climates; risk, regulatory aspects
- Personal hygiene; oral, external, internal hygiene
- Diabetes
- Hyper/hypotension
- Obesitas, lack of exercise
- Epidemic diseases

APPENDIX 3

The University of Newcastle

Course AVIA103: Introductory Human Factors in Aviation

Professor Ross Telfer

Credit point value: 6
Prerequisites: Nil
Corequisites: Nil
Hours: Six hours per week for semester one
Examination: Progressive assessment based on class texts, seminars, assignments and a two-hour examination

Contents

Vision/visual illusions; balance/spatial illusions; memory; learning and skill acquisition; attention, workload and fatigue

Texts

Wiener, E.L., and D.C. Nagel, eds. *Human Factors in Aviation.* London: Academic Press, 1988.

References

Dhenin, J., ed. 'Physiology and Human Factors', *Aviation Medicine,* Vol. 1 (1978).
Roscoe, S.N. *Aviation Psychology.* Iowa State University Press, 1980.

Course AVIA107: Aviation Psychology and Medicine

Credit point value: 6
Prerequisites: AVIA103
Corequisites: Nil
Hours: Six hours per week for semester two
Examination: Progressive assessment based on class texts, assignments, tutorials and a two-hour examination

Contents

— Stress, anxiety and arousal; judgement and decision-making; personality, attitudes; intelligence; leadership; emotion; flight phobia; displays and controls; communication

— Hypoxia, decompression, hyperventilation; trapped gases and effects; acceleration and effects; circadian dysrhythmia; vision; hypothermia/hyperthermia; toxic substances and performance

Texts

Hawkins, Frank H. *Human Factors in Flight.* U.K. Gower Technical Press, 1987.

References

Dhenin, J., ed. 'Physiology and Human Factors'. *Aviation Medicine,* Vol. 1 (1978).
Roscoe, S.N. *Aviation Psychology.* Iowa State University Press, 1980.

Course AVIA203: Aviation Psychology and Medicine

Credit point value: 6
Prerequisites: AVIA107
Corequisites: Nil
Hours: Six hours per week for semester one
Examination: Progressive assessment plus a two-hour examination

Contents

Personality and attitudes; judgement and decision-making; cockpit design; workload, fatigue and vigilance; leadership; accident investigation and safety; recruitment and pilot selection; simulation.

Texts

Jensen, R.S., ed. *Aviation Psychology.* USA: Gower Publishing Co., 1989.

References

Dhenin, J., ed. 'Physiology and Human Factors'. *Aviation Medicine,* Vol. 1 (1978).
Roscoe, S.N. *Aviation Psychology.* Iowa State University Press, 1980.

Course AVIA206: Aviation Instruction

Credit point value: 6
Prerequisites: AVIA203
Corequisites: Nil
Hours: Two hours per week for semester two
Examination: Progressive assessment based on seminars, exercises (including demonstrated instruction), assignments and a one-hour examination

Contents

Psychology of learning; evaluating instruction and learning; instructional methods; instructional designs; computers and instruction; simulation.

Texts

Telfer, R., and J. Biggs. *The Psychology of Flight Training.* Iowa State University Press, 1988.

APPENDIX 4

Human Factors Training Curriculum for Airline Transport Pilot Licence

MODULE 1: INTRODUCTION TO HUMAN FACTORS IN AVIATION

Rationale for Human Factors training (accident analysis information, "80% argument")
SHEL Model introduced as one of many possible models

MODULE 2: THE HUMAN ELEMENT (AVIATION PHYSIOLOGY)

Breathing; recognizing and coping with:
- — Hypoxia
- — Hyperventilation

Pressure effects; effects on ears, sinuses and closed cavities of:
- — Trapped or evolved gases
- — Decompression
- — Underwater diving

Limitations of the senses
- — Visual
- — Aural
- — Vestibular
- — Proprioceptive
- — Tactile

Acceleration effects; positive and negative "G's"
- — Aggravating conditions

Disorientation
- — Visual illusions
- — Vestibular illusions
- — Coping mechanisms

Fatigue/alertness
- — Acute
- — Chronic
- — The effects on skill and performance

Sleep disturbances

Circadian dysrhythmia

MODULE 3: THE HUMAN ELEMENT (AVIATION PSYCHOLOGY)

Human errors and reliability

Workload (attention and information processing)
- — Perceptual
- — Cognitive

Information processing
- — Mind set and habit patterns
- — Attention and vigilance
- — Perceptual limitations
- — Memory

Attitudinal factors
- — Personality
- — Motivation
- — Boredom and complacency
- — Culture

Perceptual and situational awareness

Judgement and decision-making

Stress
- — Symptoms and effects
- — Coping mechanisms

Skills/experience/currency vs. proficiency

MODULE 4: THE HUMAN ELEMENT (FITNESS FOR DUTY)

Personal health

Effects of:
- — Diet/nutrition
- — Alcohol
- — Drugs
- — Medications (prescribed; over-the-counter)
- — Blood donations
- — Aging

Psychological fitness/stress management

Pregnancy

MODULE 5: LIVEWARE-HARDWARE: PILOT-EQUIPMENT RELATIONSHIP

Controls and displays
- — Design (movement, size, scales, colour, illumination, etc.)
- — Common errors in interpretation and control
- — "Glass" cockpits; information selection
- — Habit patterns interference/design standardization

Alerting and warning systems
- — Appropriate selection and set-up
- — False indications
- — Distractions and response

Personal comfort
- — Temperature, illumination, etc.
- — Adjustment of seat position and controls

Cockpit visibility

Motor workload

MODULE 6: LIVEWARE-SOFTWARE: PILOT-SOFTWARE RELATIONSHIP

Standard operating procedures
- — Rationale
- — Benefits
- — Derivation from human limitations and the accident/incident record

Written materials/software
- — Errors in the interpretation and use of maps/charts
- — Design principles and correct use of checklists and manuals

Operational aspects of automation
- — Overload/underload and phase of flight; boredom
- — Staying in the loop/situational awareness
- — Automated in-flight equipment; appropriate use, effective task allocation, maintenance of basic flying skills

MODULE 7: LIVEWARE-LIVEWARE: INTERPERSONAL RELATIONS

Liveware-Liveware (L-L) deals with interpersonal contacts happening at the present time (here and now), as opposed to the interpersonal contacts which may exist in the liveware-environment interface, which deal with people outside of the current operating situation.

Factors influencing verbal and non-verbal communication between and with:

- Flight deck crew
- Cabin crew
- Maintenance
- Company management/flight operations control
- Air traffic services
- Passengers

How verbal and non-verbal communication affects information transfer and thus safety and efficiency of flight

Crew problem solving and decision-making

Introduction to small group dynamics/crew management

MODULE 8: LIVEWARE-ENVIRONMENT: THE OPERATING ENVIRONMENT

The physical environment (internal)

- Temperature, pressure, humidity
- Noise, vibration
- Lighting
- Radiation
- Pollutants/contaminants

The physical environment (external)

- Terrain: mountains, water, desert, "white-out", "black hole"
- Weather: turbulence, wind shear, icing
- Other air traffic
- Time of day
- Take-off and landing conditions: density altitude, runway conditions

The socioeconomic environment

- Legal and regulatory
- Company organizational structure and economic climate
- Employer operating pressures
- Employer/employee relations/unions
- Family relationships
- Peer groups and professionalism
- Pairing of inexperienced crews (experience in the operational context)

APPENDIX 5

Pilot Training in Human Factors

Considerations in Curriculum Development

TARGET AUDIENCE

1. Possible pilot categories: *ab initio*, general aviation, commercial, air carrier and instructor pilots.

2. Identify non-pilot/supervisor specialist training needs according to occupational function.

TRAINING DIRECTION AND OBJECTIVES

1. Identify the role of theoretical and experiential learning. Determine the role of Open Learning, development of reflective practice, and activities promoting experiential learning.

2. Review the approach to briefing, debriefing and assessment practices.

3. Curriculum/course content categorization under "Memorizing", "Understanding", "Doing" and "Attitudinal aspects".

4. Suggested curriculum categorizations or "domains" of trainee competence:

   a) *Knowledge-based ("memorizing"):* didactic or factual knowledge and appropriate procedural or contextual information.

   b) *Comprehension-based ("understanding"):* understanding of relevant theory, etc.

   c) *Skill/technique-based ("doing"):* acquire and demonstrate required practical skills.

   d) *Attitudes ("attitudinal aspects"):* application and understanding of appropriate professional practices and dispositions.

5. Determine the different types of post-training competency, or subject mastery, expected of trainees.

Training materials, techniques and educational technologies

Division by training hardware, training strategies/techniques, training courseware and assessment/evaluatory practices.

a) Training hardware: identify training hardware relevant to training needs and objectives.

b) Training strategies and techniques:

1) identify training strategies/techniques made possible by the available training technology;

2) determine the need for performance feedback; identify the quality of feedback required and the means of achieving this;

3) determine if psychological testing/evaluation should play a part;

4) identify the means by which individual as well as crew training needs can be successfully addressed;

5) assess the role of multi-method training;

6) determine the potential value of role play, case-studies, simulation gaming, written simulations, etc.;

7) select those methods to best achieve the contrasting training needs outlined in the section above;

8) identify training needs of specialist course instructors.

c) Training courseware:

1) identify resource constraints and training objectives;

2) courseware development as part as a dedicated Human Factors course, as part of recurrent training or for integration into current training practice;

3) identify associated training needs of relevant instructors.

Pilot assessment and training course evaluation

1. Determine if there is a desire for concurrent course evaluation and/or formal pilot assessment. Review available alternatives.

2. Identify appropriate means of assessment for "knowledge", "comprehension", "skill/technique" and "attitudinal" categories (see section above).

3. Address the tension between learning and assessment practices/consequences for skill/technique and experiential learning.

4. Determine the role of crew-based vs. individual performance appraisal.

5. Identify the training needs of those involved in evaluation and/or performance assessment.

APPENDIX 6

Sample Questionnaire to Test Annex 1 Human Factors Knowledge Requirements

1. Name four important disciplines from which information is drawn in understanding human performance and behaviour.

2. What four major interfaces must be optimized on the flight deck to provide the basis of safe and efficient flight operations?

3. About what proportion of civil air accidents result from inadequate human performance?

4. a) What is meant by the authority gradient between pilots?
   b) Why is this important for flight safety?
   c) Name three different potentially unsafe gradients.

5. a) Give two important safety advantages in the development of standard, habitual behaviour in flight deck tasks.
   b) What is meant by *behaviour reversion*? Give an example of this related to flight deck activities which can prejudice flight safety.

6. a) What general aspect of human performance is illustrated by the Yerkes-Dodson curve?
   b) How can the incidence of human error be related to this curve?
   c) Where would you place complacency, boredom and excitement on the curve?
   d) What does this curve suggest about performance of critical tasks?

7. a) What pattern of performance can be expected in tasks requiring continuous vigilance?
   b) Name one flight deck task which could illustrate this.

8. The *false hypothesis* is a dangerous form of human error. Name five different situations in which this is most likely to occur.

9. Give three examples of *zeitgebers* or *entraining agents* related to circadian rhythms.

10. Human performance varies with a circadian rhythm.
    a) What does this mean?
    b) Related to this phenomenon, what is meant by the terms:
       task-dependent,
       post-lunch dip,
       motivation effect, and
       acrophase?
    c) Give four factors, excluding zeitgebers, which may be associated with the rate of resynchronization of biological rhythms after they have been disturbed on a long flight.

11. a) What is the name given to the group of drugs (hypnotics) most commonly used to facilitate sleep?
    b) In this connexion, what is meant by *half-life* and how does this relate to the drug's effect on performance?
    c) State the general precautions (approximately six) that a pilot is recommended to take before deciding to use a hypnotic (sleeping drug).

12. a) What is meant by the *sleep inertia* effect?
    b) What relevance does this have for flight safety on the flight deck?
    c) Is performance likely to deteriorate steadily with increasing sleep loss? Explain.

13. a) Cigarette smoke contains carbon monoxide. What effect does this have on human altitude tolerance and how does this occur?
    b) What other effect on performance related to safety may carbon monoxide have?

14. a) Give four factors which affect the rate at which alcohol is absorbed by the body.
    b) At about what rate does the blood alcohol content (BAC) fall after stopping drinking and is this rather constant between individuals?
    c) From about what BAC have experiments demonstrated a measurable deterioration in brain and body functions?

15. a) What is meant by:
       the *Mandelbaum effect,*
       empty field, and
       dark focus?
    b) Why are these important for safety in visual collision avoidance?

16. a) What is meant by the *blind spot?*
    b) How can this influence safety in visual look-out from the flight deck?
    c) How are the risks form this source reduced?

17. a) What is meant by the *design eye position?*
    b) Why should the pilot assure that his eye is in this position and how can this affect safety?
    c) Can all pilots physically assume this point?

18. a) What visual illusions or reactions in aircraft are related to:
       the *autokinetic effect,*
       the *stroboscopic effect,*
       blowing snow,
       acceleration,
       fog,
       sloping terrain,
       sloping runway, and
       the *black hole?*
    b) What are the general basic stages (give three) in providing protection against the effect of illusions?

19. With respect to vision:
    a) What is meant by *accommodation, dark adaptation, visual acuity?*
    b) How are these related to safety?

20. What principle related to human performance modification is known as the *Hawthorne Effect?*

21. a) What is meant by *behaviour reinforcement?*
    b) Give two examples each of positive and negative reinforcement.
    c) What precautions should be observed when the use of negative reinforcement is indicated (give four)?

22. a) What is meant by *achievement motivation?*
    b) Why is this relevant to the pilot's job and flight safety?
    c) Can this be readily developed?

23. Boredom is often associated with low performance.
    a) Give four basic conditions which tend to be associated with boredom.
    b) Is boredom necessarily created by a given task? Explain.

24. a) What personal characteristics (give five) are often associated with leadership?
    b) Are leaders born or made? Explain.

25. Explain the meaning of and difference between:
    a) leadership
    b) authority
    c) domination

26. Speech communication has been the source of many errors, incidents and accidents.
    a) What dangerous role can expectation play in verbal communication in aircraft?
    b) Give an example from radiotelephony communication.
    c) What means (give four) can be used to provide protection against this danger?

27. a) Explain, with particular relevance to safety aspects, the difference between *personality, attitudes, beliefs* and *opinions.*
    b) Suggest one way each that a personality and an attitude characteristic can adversely affect operational safety.
    c) To what extent is it possible to modify in airline service personality and attitudes of pilots by training?

28. Attitudes may be said to have three components.
    a) Name three components.
    b) Relate these to attitudes towards cockpit checklist use.

29. In what manner may individual judgement be influenced by membership of a group or team with regard to:
    a) risk-taking
    b) inhibition
    c) conformity

30. Education and training are two aspects of the teaching process.
    a) Explain the difference and how they relate to each other.
    b) Which of these covers learning of flying skills, basic Human Factors knowledge, flight planning, aircraft systems, physics, aircraft emergency procedures?
    c) Give an example to illustrate the difference between knowledge and skill.

31. a) What is meant by negative training transfer?
    b) Give an example of this which can jeopardize flight safety.
    c) What is meant by fidelity in training devices and is this necessary for training effectiveness? Explain.

32. Memory can have an important impact on flight safety. In this connexion:
    a) What is mean by overlearning?
    b) What is meant by chunking?
    c) What is the difference between the effectiveness of memory of continuous and serial activities?

33. a) What is meant by *feedback* in training?
    b) What is meant by open- and closed-loop systems?
    c) What is the difference between intrinsic and extrinsic feedback, and why is it important for flight training effectiveness that flight instructors and pilot students recognize this difference?

34. Colour coding is a useful means of distinguishing between different sections of a manual, which can be critical when information must be found quickly, as in emergencies. Name two basic limitations in connexion with reliance on the use of colour coding for this purpose.

35. Evaluation of flight deck and safety equipment is often done by questionnaires completed by pilots. The validity of the assessment of the equipment depends on the validity of the questions and responses. In this respect, what is meant by:
    a) *prestige bias*,
    b) open-ended and closed questions,
    c) order effect,
    d) middle option, and
    e) acquiescence, multiplicity and expectation in questions.

36. a) What are the three sensory channels used to obtain information from flight deck displays in large transport aircraft?
    b) Give two fundamental operational differences between auditory and visual displays?

37. a) Instrument reading difficulty/error can arise from two basic causes when most conventional, round-dial, electromechanical instruments are viewed from an angle. What are these?
    b) Give two operational reasons each why an analogue and a digital display may be preferred.

38. a) Name three basic functions of a flight deck alerting system.
    b) What is meant by a *nuisance warning* and how does it differ from a *false warning?* What behavioural consequences affecting safety can arise from them?
    c) How can an alerting system generate negative training transfer and what risk to flight safety may result?

39. a) What is meant by and what are the operating implications of *control-display ratio* and *control resistance?*
    b) Give four methods of *control coding* to reduce operating errors.

c) Give five methods of protection against the adverse consequences of inadvertent switch operation.
d) What is meant by the *forward-on* and *sweep-on* switch concept and what are the operational and safety consequences of relocating cockpit panels with each concept?

40. a) Name two possible behavioural consequences of automation of flight deck tasks which may adversely affect safety.
b) Give three broad justifications for the automation of flight deck tasks.

41. a) In what cabin conditions can inconsistency in emergency equipment location within the fleet be particularly hazardous?
b) Why should cabin crew be familiar with the operating controls of pilot seats?

42. a) What is meant by the *sterile cockpit?*
b) Does this have any legal or mandatory backing? Explain.
c) Name two cabin and two flight deck activities which would come within the scope of this restriction.

43. a) What basic limitation exists in the use of colour-coding and placarding to optimize emergency equipment use? How can this influence training?
b) Name two important basic problems associated with passenger cabin safety briefing which can prejudice survival in emergency, and suggest two ways in which these problems can be reduced.
c) Name 15 different aspects of cabin interior design which require Human Factors input to optimize safety and explain the relevance to survival in emergencies.

— END —

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