SAFETY OF EUROPEAN CIVIL AVIATION: AIR CREW DUTY TIMES AND COCKPIT AUTOMATION

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The European Transport Safety Council

The European Transport Safety Council (ETSC) is an international non-governmental organisation which was formed in 1993 in response to the persistent and unacceptably high European road casualty toll and public concern about individual transport tragedies. Cutting across national and sectoral interests, ETSC provides an impartial source of advice on transport safety matters to the European Commission, the European Parliament and, where appropriate, to national governments and organisations concerned with safety throughout Europe.

The Council brings together experts of international reputation on its Working Parties, and representatives of a wide range of national and international organisations with transport safety interests and Parliamentarians of all parties on its Main Council to exchange experience and knowledge and to identify and promote research-based contributions to transport safety.

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1. Aim and scope

The aim of this review is to formulate from international research findings a set of recommendations to policy makers on actions and regulations in the field of air crew duty times and cockpit automation that could be taken to further improve the safety of civil aviation.

As is explained in the introduction, air crew duty times and cockpit automation have been selected as the topic of the first review of ETSC's Air Safety Working Party, in view of the current developments in duty time regulations and increasing concern about automated flight decks after several recent accidents and the potential for safety improvement.

2. Introduction

Air transport is an increasingly important transport mode. It is estimated that the number of air travel passenger movements in Western Europe will more than double between now and 2010. Over the past 40 years the safety of civil air transport has improved significantly. Whereas in 1950 the passenger fatality rate was 2 per 10^8 passenger kilometre, in 1991 this rate had decreased to 0.03 per 10^8 passenger kilometre. Nevertheless around 1000 people die world-wide as a result of air traffic accidents annually and increased travel will bring further exposure to risk of such accidents.

By comparison with road transport, it is difficult in aviation to identify with confidence the factors that are responsible for safety shortfalls. The principal reason for this is the relatively small number of accidents within normal public air transport operations. Moreover, it may appear that a given type of accident, for example the type often characterised as "controlled flight into terrain", is relatively prevalent, but close investigation of each accident may well reveal quite idiosyncratic features in its aetiology. It has also been argued that a further factor making the identification of safety improvements difficult is the tendency for aircraft that crash to do so in a way that generates massive loads on the airframe.

It is often suggested that the capacity to improve passenger survival through improvements in secondary safety features is limited. However many accidents occur to aircraft on take-off and landing, when speeds are relatively low and the crash potentially survivable. The provision of better passenger restraints, stronger seat design (and rearward facing seats), improved seat anchorages and floor strength, more crashworthy overhead bins, fire suppression systems and smoke hoods may all be of importance if system safety is to be improved.

Nevertheless, the level of technical reliability, and hence primary technical safety, of modern aircraft is high and still raising. Nowadays, the most prevalent primary cause of aircraft accidents is human error, notably around 75 per cent. Since such errors, frequently made on the flight deck, are the principal obvious source of system failure, the goal of identifying the mechanisms of human error and reducing their incidence is now widely accepted in aviation. It is also a current trend in aviation safety to adopt an overall system approach rather than a topic based approach to safety in the belief that the higher in a system a shortcoming can be identified, the more widespread will be the effects of rectifying the shortcoming. The Air Safety Working Party, however, feels that identifying discrete topics, at least initially, is most appropriate to the needs of its task.

Two topics that are likely to be of current importance in this regard have been identified as follows:

- <u>Air crew duty times.</u> Aviation presents combinations of factors that influence fatigue not encountered in any other pursuit. Highly skilled operators are required to evaluate situations and to perform well under stress after work periods, at night, and after crossing many time zones. Not only must the short term well-being and performance of these pilots be safeguarded, but they must also be protected from the possible effects of fatigue build-up over the course of weeks or months. It is essential that effective regulation of duty times is in place since, in many respects, limiting the flexibility of pilot availability and restricting working hours impose potential commercial penalties that some aircraft operators - particularly those experiencing financial stress - may wish to avoid. It should also be noted that in the only current system operating in Europe that permits pilots to report their own errors in confidence (the UK CHIRP system), about a third of pilots submitting reports express concerns with regard to the perceived effects of fatigue. There is therefore a clear need to ensure that the variability that currently exists in flight duty time legislation between different European countries is resolved by a system that is primarily sensitive to the requirements of safety, and that is based on the best available scientific understanding of the subject.

- <u>Cockpit Automation</u>. The last ten years have seen a rapid change in the design of new aircraft flight decks, to the extent that the introduction of cockpit automation has brought about a revolution in the pre-existing evolution of flight deck information presentation. It is not only instrument design that has changed, however, since the flight deck revolution has been paralleled by automation of training methods. It may be argued that these two factors have brought about material changes in the way that a pilot conceives his situation, controls the flight, and deals with emergencies. It appears that pilots perhaps trust cockpit instrumentation too much, that they lack anything more than a superficial understanding of their systems, and that they may easily be unaware of the mode of automated flight (and its implications) that is engaged at any given time. Good evidence exists that pilots actually prefer to fly highly automated aircraft, but recent accidents have caused anxieties to be raised specifically with regard to the appropriateness of current training techniques in use for these aircraft, and concerning the capacity of regulatory authorities to approve and to certificate such flight decks effectively.

The above issues are not unrelated. Cockpits have become automated in parallel with other technical developments that have enabled aircraft to fly for long periods of time. Non-stop flights of 18 hours duration will shortly be commonplace, and these will be undertaken by crews who still have little to do for most of the flight. The ways in which flight duty time legislation and the requirement for pilots simply to stay in flying practice cope with this quite new, automated long haul environment are not clear, and only experience will reveal the adequacy of the in-flight rest provision that is provided for such crews. There is thus great potential for these types of aircraft to have a major impact on the way in which we conceive the pilot's job.

Both of the above areas would benefit from co-ordinated action on a European basis. Indeed, flight duty time regulation is in the process of being drafted within European countries by the Joint Aviation Authorities (JAA) and it is important that such regulation makes the fullest use of the scientific knowledge that is available. Such information should be as readily and widely accessible as possible.

The problem of automation is one of great current concern. It may have been an important factor in the aetiology of several recent accidents, and there is some feeling within the industry that such accidents, although low in number, are more associated with European than North American built aircraft. Such beliefs could well influence the future purchasing decisions of airlines and have a major impact on the economics of EU aircraft manufacture.

It is therefore critically important for both safety and for the European economy that such issues are fully understood by all those involved and are effectively dealt with.

3. Air crew duty times

3.1 Introduction

Early in the history of commercial aviation it was recognised that serious performance degradation could occur as a result of pilot fatigue. Pilots and airline managers had a natural interest in maximising the utilisation of air crews. For pilots, the more hours per day that they could work, the greater the amount of money or days off received. For management, more hours of utilisation per pilot meant that fewer pilots would be required on the payroll. However, this economic interest was in conflict with flight safety and with the safety of the travelling public in commercial air transport.

As a consequence, government regulatory bodies were established to guide aviation operators in adopting operational policies and practices that were directed to ensure flight safety and to minimise the risk to the travelling public. Regulations were established that limited the scheduled flight time of air crew in any 24-hour period, seven-day period, month, etc.

Similarly, requirements for minimum rest times were defined in the legal provisions. A violation of these regulations could result in fines, suspension or revocation of licences and operating rights.

Although these standards of pilot utilisation have been accepted since their inception early in the evolution of commercial aviation, the current flight time limitations are increasingly questioned as to their adequacy to realistically reflect workload and fatigue of today's air crews. In fact, government regulations have tended to adapt very slowly, while the operational environment of aviation has undergone rapid and radical changes.

According to the ICAO convention on civil aviation, flight time limitations are established for the sole purpose of reducing the probability that fatigue of flight crew members may adversely affect the safety of a flight. Basically, two kinds of fatigue are taken into consideration: the transitory fatigue caused by a normal period of work, and the cumulative fatigue resulting from a delayed or incomplete recovery from normal workloads or from workloads exceeding normal and recurring without sufficient opportunity for recuperation. From this definition, the following principles for the reduction of fatigue to an acceptable level can be derived:

1) to limit the amount and degree of workload (e.g. by restricting flight duty periods of excessive length or by reducing maximum flight time for night hours); and

2) to specify the rest period to provide sufficient recovery from a preceding workload before a new duty period is commenced (e.g. by extending the normal rest time or by also including the period of habitual sleep time).

These principles can be formulated as clearly and easily as the methods of their realisation in the regulations of countries are multiple and complex.

3.2 Limitations in work and workload

In reviewing the national regulations presently in existence in the countries of the European Union, a number of factors can be identified which play a major role in the formulation of the rules and criteria regarding work and workload. The most important ones are presented in Table 1, as well as whether or not they are considered in the provisions of each country.

Consensus exists on the need to limit the duration of the flight assignment, but this relatively simple and basic need gives rise to different interpretations. Some countries consider only *flight time*, whereas other countries consider either both flight and duty time or duty time only. Flight *duty time* encompasses, in addition to flight time, time spent on the ground for pre-flight preparation and post-flight shutdown activities as well as time between flight sectors. There is sufficient scientific evidence that, for evaluating fatigue in current air transport operations, duty time is a far better measure than mere flight time, since the effects contributing to air crew fatigue are not confined to the time an aircraft is airborne, but are also produced while on the ground.

Table 1: Work and workload factors regarded (+) or disregarded (-) by the regulations of 11 Member States of the EU (information from Luxembourg not available)

	B	DK	E	F	D	GR	IRL	I	NL	P	UK	TOTAL
Flight time*	-	+	+	-	-	+	+	+	-	-	-	5
Flight duty*	+	+	+	-	+	+	+	+	+	+	+	10
Time of day**	-	-	+	-	-	-	+	-	+	-	+	4
Night flight	+	+	+	-	+	-	+	-	-	+	+	7
Time zones	-	+	+	-	+	-	+	-	+	+	+	7
No. of sectors	+	+	+	-	+	-	+	-	+	+	+	8
No. of pilots***	+	-	+	-	-	+	-	+	+	+	-	6
Augmentation	+	-	+	-	+	+	+	+	+	+	+	9
Flight range	-	-	+	+	-	+	-	+	-	-	-	5
Air craft type	-	-	-	+	-	-	-	-	-	+	-	2
TOTAL	5	5	9	2	5	5	7	5	6	7	6	

* per duty period ** except night flight *** except relief pilots

The factors *time of day*, *night flight* and *time zones* consider different aspects of the human circadian system and their involvement in air operations caused by what may simply be called shifted work and shifted time. The first effect implies flight duty to be performed at abnormal times within the 24-h rest/activity cycle. The second effect to be accounted for is when flight scheduling includes transmeridian routes. There is a broad consensus among scientists that flying at unusual times is more stressful than performing the same operations during normal hours. This is particularly true for night flights. It seems, therefore, somewhat surprising that these factors are not stipulated in the provisions of all countries. Sleep during the habitual night hours must be regarded as more effective for recovery than daytime sleep, but most regulations do not consider this. It also seems somewhat surprising that not all of the regulations cover the aspect of circadian rhythmicity specifically evolving from operations on transmeridian routes.

The *number of sectors* (equal to the number of take-offs and landings) are taken into account as a factor with fatiguing effects sufficient to be incorporated into legislation. This conclusion is based on medical evidence demonstrating that each take-off and, to an even higher degree, each landing result in workload peaks. In addition, these peaks are additive to total workload when more sectors are flown. In principle, two possibilities are seen as a solution to this problem: to limit the number of sectors within a duty period, or to reduce the duty time for certain numbers of sectors or for each single sector flown.

General consensus exists to consider the *augmented flight crew* (one or more relief officers) as a suitable expedient to extend the flight or duty time maximally allowed for the minimum crew in long range operations. For adequate in-flight relief, special rest facilities are required on board, consisting of either reserved seats (usually first class seats) or crew bunks (usually separated from cockpit and cabin).

The remaining two factors included in Table 1 are *flight range* (short- vs. long-haul operations, domestic vs. international flights) and the *type of aircraft.* Incorporation of these special rules into regulations is most often based on historical developments and should be taken only as reminiscences of the earlier days of aviation. Otherwise it is hardly understandable that short-haul flights should be less demanding and less fatiguing than long-haul flights, or that flying jet-propelled aircraft should be more stressful than piloting planes powered by piston-engines.

3.3 Short term work limitations

Flight/duty time limitations in this Section comprise only those related to a single assignment. Restrictions concerning cumulative flight time will be covered in the following Section.

Almost all countries in the EU agree upon the necessity to prescribe limits for the maximum permissible flight or duty time on a daily basis. The purpose is to ensure that flight crew members are not being unduly fatigued and to force airline operators and their economic interests to comply with safety requirements. As mentioned before, most countries rely more on flight duty time than on flight time as an appropriate dimension for evaluation of flight deck workload and fatigue.

It is worth noting that some countries establish what they consider to be the 'normal' length of duty time. The standards range from 10 to 12 hours. A duty of 12 hours appears a rather long 'normal' working day in view of the normal pattern of life, which is for a person to sleep 8 hours and to be awake 16 hours. In this context it should not be forgotten that a crew member often spends considerable time travelling between his residence or hotel and the airport. Thus, two or more hours must be added to the 12 hours of duty to arrive at the total work time.

Generally accepted is the necessity to define the upper limit, i.e. the maximum number of duty hours permitted for the most favourable operational conditions. A rather good congruence exists between countries in the limitation of maximum duty hours for the minimum crew as well as for the augmented crew. Fourteen hours appear to be the longest period tolerable for the minimum crew and 18 hours in the majority of cases for the crew with one or more relief officers. There is also agreement that, under adverse conditions of flight operations, the maximum permissible duty time for the basic crew must be reduced to 9 to 11 hours. Particularly noteworthy is the regulation of one country that does not restrict the flight time when the crew is augmented; also for these conditions no minimum rest requirements are defined. These omissions lead to the undesirable effect that flight crew members on long-distance routes try to accumulate a maximum flight time en route within as short time as possible. Upon returning to their home base, they have earned so much off-time that they are able to attend to the activities of an additional profession and, in fact, there are may cases that fall into this category.

3.4 Long term work limitations

There is considerable consensus among the various countries on the concept of preventing cumulative fatigue by restricting the maximum amount of flying which can be accumulated during certain periods of the calendar year, i.e. per week, per month - or a multiple - and per year. Contrary to the daily limitations, the long-term limitations are given in flight time, and not in duty hours (with some exceptions). Only a few regulations define weekly restrictions, but almost all of them specify limitations per month and per year. Only one regulation does not provide any long-term limitations. This was not deemed unsafe since extensive provisions for rest requirements preclude the accumulation of excessive flight duty time. There is also the other extreme, stipulating limits for 1, 2, 3, 6 and 12 months. This extreme differentiation must be seen as the consequence of a less comprehensive rest requirement system in order to maintain appropriate safety standards.

Long term limitations are established to minimise fatigue that is not compensated by short-term recovery and to reduce excessive accumulation over longer periods of time. To date, there is more scientific data available to support guidelines for short term limitations than to determine specific cumulative limitations. Nevertheless, long-term limitations remain an important issue.

3.5 Rest time requirements

In most EU Member States rest time requirements depend on whether the operational conditions of the preceding duty period were more ('maximum') or less ('minimum') fatiguing. Minimum figures for rest periods vary between 8 and 12 hours, maximum figures are in the range of 13 to 18 hours. Contrary to the fixed numbers of rest hours, some regulations prefer a flexible rating (two to four times the amount of the duty or flight hours). In addition, some regulations include provisions to ensure that rest periods include night hours, regularly or within certain intervals, to provide flight crews with the more recuperative night sleep. There are also provisions prescribing that the period immediately prior to a flight duty period must be used for rest, whether it occurs in a rest period or in the time off of a crew member relieved from all duties. This appears logical from the premise that, for an actual flight assignment, it is most important to ensure adequate rest before the flight and not at all significant to provide it afterwards (which, of course, disregards the following flight duty).

Several regulations provide for an extended rest period regularly once a week (or per 7 days). According to the precepts of different countries, this must comprise an uninterrupted time of 24 or 36 hours. Some provisions also require the inclusion of two consecutive nights.

Providing an extended rest period every week is based on scientific grounds to minimise the cumulative effects of sleep loss and fatigue. Two consecutive nights of normal sleep is a minimum requirement to stabilise sleep patterns and return waking performance and alertness to normal levels. Two consecutive nights of sleep can provide recovery from sleep loss.

3.6 Conclusions and recommendations

To submit all details that regulations are providing would be beyond the scope of this review. For the benefit of greater clarity, such intricate issues as, for instance, definitions and waivers were not considered. The main purpose has been to present the major elements of the various provisions and to convert them into a comparable form. This, of course, implies simplification in one or another aspect, not to mention the problem of interpreting legal texts in general terms.

In general terms, the following conclusions can be drawn and recommendations made:

- Considerable differences exist in the manner in which the national regulations are formulated, in their scope, flexibility and applicability.

- National regulations vary to a great extent as to precision of prescriptions, key-factors taken into account, definitions of these factors, values given to limits and requirements.

- In view of the developing Single Market of the EU, there is an urgent need for harmonising national rules and to create a common framework to ensure high standards of safety, but at the same time, also to ensure fair and equal conditions of competition.

- Harmonisation can be accomplished. Despite diversities in ethnological, social, economic, and operational premises, there is international scientific consensus to allow for the formulation of essential and reasonable standards to prevent excessive fatigue from adversely affecting flight safety.

- It is the case, however, that existing and proposed flight duty time regulations do not recognise sufficiently this scientific consensus and may be based more on economic and political considerations.

- Three areas in particular, are worthy of note, and it is recommended that future standards should recognise the existing scientific literature in these regards:

    - Two v. three pilot operations. Present and proposed regulations contain a markedly different treatment of these types of operation, though the scientific grounds for doing so are slight or non-existent.

    - Night flying. Here the opposite is true, in that scientific findings show a need for greater differentiation to be made between night and day flying than is currently recognised by any regulation.

- Minimum rest. The minimum proposed rest period between flights is not as great as scientific evidence would suggest may be necessary.

4. Cockpit automation and the human interface

4.1 Introduction

Throughout the history of aviation there have been consistent trends towards isolating the pilot more and more from the ambient physical environment, relieving him of all activities that could be automated, and making the controls that he uses less directly connected to the aerodynamic surface or engine component being operated. Thus, early aircraft had the pilot sitting in the airstream (even though the passengers may have been in a cabin), all controls connected by rods and wires to the control surfaces, and all navigation, calculation, and management functions carried out by the crew.

The change from this situation to the pressurised shirtsleeve environment enjoyed by present crews is obvious, but this change has been enabled only because the pilot has, for many years, been provided with a set of instruments that represent to him his aircraft's situation in space - its height, speed, heading, and orientation. Gradually, parts of the pilot's task became automated. Early autopilots merely held a constant heading while the aircraft was in the cruise, but succeeding improvements eventually produced sophisticated systems in which a combination of autopilot and a parallel engine management system enabled large parts of the pilot and engineer's task to be carried out automatically.

A change has occurred to such systems recently, however, that has probably resulted in a rather more fundamental shift in the nature of such systems. The use of sophisticated and fast computers has enabled the management of all aircraft control functions to be integrated and automated. Large information stores are programmed with massive amounts of data that enable the aircraft to 'know' the location and radio frequency of navigational aids, and to 'know' the whole route that it is to fly. It can combine this geographical knowledge with an integrated flight and engine management system that enables almost totally automated flying of complex routes. Thus, the aircraft can manage everything from the throttle setting for take-off, selecting and checking all of the navigational functions (both horizontal and vertical), managing the approach, and executing the landing. It can do all of these things with a sophistication and accuracy beyond the ability of human pilots.

Automated cockpits have changed in their appearance in accomplishing the above. Massive numbers of dials are no longer required since the on-board computers can integrate and fuse the large amount of available data to produce a relatively simple 'picture' of the aircraft's state that can be displayed on a small number of cathode ray tubes (CRT) or TV style displays. The important feature of this change is that in earlier aircraft types, it was the pilot's function to integrate the information from disparate displays to provide an overall mental picture. This picture is now created for the pilot by the machine, and it is essentially this change that has produced many of the difficulties described below, since the machine has removed not just the type of tedious and routine control function taken over by the early autopilots, but also an important aspect of the pilot's cognitive skill.

Part of this cognitive skill was the ability to memorise and execute procedures or drills (e.g. of actions to be taken in the event of an engine fire), and it is probably this proceduralisation of flying that has made it safe. It is now largely true, however, that any aspect of the pilot's task from which a drill can be envisaged can be automated, leaving the pilot there to deal only with those emergencies that have not been anticipated as potential problems. This is an uninviting prospect, and one that we must seek to avoid.

By comparison with the change that has overtaken flight management and the display of cockpit information, the changes to control systems have been relatively recent and less profound. Many automated aircraft still have controls with physical connections to elevators and ailerons, but some aircraft - notably Airbus aircraft - have only electronic connections. This means that there is no longer a requirement for a large control yoke, and small single-handed joysticks are sufficient.

4.2 The benefits

Many benefits have accrued from the introduction of cockpit automation. The low reliability of electromechanical cockpit displays is now a thing of the past. This increases safety, and it also means that maintenance costs are reduced and spares storage simplified. Automation has also enabled economic gains to be made from the reduction of crew numbers: two operating crew members are the norm on all such aircraft, whereas four or five crew members were common on the early jets. Fuel management is more efficient, and navigational accuracy is greater. Furthermore, automated aircraft will be necessary if they are to be controlled by automatic air traffic management systems to produce more efficient use of Europe's already congested airspace.

Automated systems are also liked by pilots. Surveys show that the more automated the aircraft, the better pilots like it. There is thus no general pressure from pilots to turn the clock back in any way, but there is a recognition by them, as well as by human science researchers and other observers, that there are difficulties associated with automated aircraft, and these are now discussed.

4.3 The problems

Accidents and incidents to automated aircraft, and surveys of pilot opinion suggest the following to be the principle areas of concern with regard to the automated flight deck:

- Pilot Workload. It will have become obvious from the above that the tendency has been for automation to have taken over the 'easy' pilot activities leaving the more difficult tasks that require human flexibility of approach and decision making. The effect of this has been to reduce pilot workload for large parts of the flight, leaving relatively intense activity when pilot involvement is required. It has even been claimed that when such pilot involvement is demanded (e.g. to cope with a late change in landing runway) the pilot workload can be higher in automated aircraft than in conventional aircraft as a result of so called 'clumsy automation'. Thus the relatively even spread of workload through a flight on a conventional aircraft has changed to a long period of relative idleness interrupted by short periods of very intense activity.

- Monitoring and Vigilance. During the protracted periods of automated flight, the pilot's task is essentially one of monitoring the performance of the automatics. People are not very good at staying vigilant in this way for long periods of time, especially when monitoring systems rarely fail. This can lead not only to inefficiency and complacency, but also to an inability to believe that something has failed when it actually has.

- Understanding. The complexity of automated systems means that pilots cannot have the same degree of in-depth knowledge of them as they could maintain for simpler aircraft. There is a concern, however, that the amount of understanding with which pilots are actually equipped may not be sufficient to allow them to 'trouble shoot' when failures do occur. It is this factor that leads to the phrases said to be commonly uttered on automatic flight decks 'I've never seen it do that before', and 'Now I wonder why it's doing that?'.

- Overtrust. Because automated systems tend not to be very 'visible' or observable in their operations in that they do not make the 'reasons' behind their decision making obvious, pilots are, in a sense, unable to do anything other than trust them. When combined with the above factors of understanding limitations and complacency, this can lead to a degree of 'overtrust' that is potentially unsafe.

- Mode Awareness. Automatic systems can operate in many different modes or regimes. For example, the aircraft may be commanded to descend at a certain angle or at a certain rate of descent. It is obviously essential that the pilot is aware of what the aircraft is doing, and 'mode annunciation' is therefore critical. If the pilot thinks that one mode is engaged when he has actually commanded another, the results can be (and have been) disastrous. The removal of certain types of feedback on some automated aircraft (e.g. the removal of moving thrust levers) may exacerbate this problem.

The above problems can be ameliorated only by tackling the design of systems and procedures, and by training pilots. The difficulties that presently exist within the former may be summarised as follows:

- There are no agreed national or international standards for a flight deck or its displays and controls.

- There are no objective benchmarks for clarity, user friendliness or effectiveness of the cockpit lay-out and design.

- There is no systematic adherence to an existing scientific database of human factors knowledge and expertise, and the efforts for developing one are hampered by relying on the common sense of test pilots and others instead of relying on systematic scientific study and development.

- The qualification process of certification by regulatory authorities is still 'subjective' by nature and therefore by definition fallible if not performed to scientific standards.

- Industry research focuses, naturally, at realising a product with potential sales to customers. This trend leads to so called 'demonstrators' as an end product of research, instead of the best solution to a problem. Such strategy implies a limitation to the 'verification' of a concept and not its 'falsification'. The result is a bias for conditions where 'it will work' without actively searching the, for safety so important, conditions and circumstances where 'it will not work'.

With regard to training, the principal problems have been the parallel increases in the complexity of modern aircraft and the growth of computer based training systems. This has led to pilot courses being confined to 'need to know' material, i.e. teaching the pilot only that which will enable him to do his anticipated job. The problem is that lack of system knowledge may not give the pilot an appropriate or complete context to act in, may not provide him with the knowledge required to deal with unusual circumstances, and leave him uncomfortable in feeling that he only has superficial knowledge of his aircraft.

With such 'need to know' courses being delivered and assessed by computers, pilots frequently feel that the information they received was efficiently delivered, and stuck for long enough to get them through the immediate assessment. On the other hand, they feel that it was too rapid to allow the development of cognitive structures that enable them to integrate and feel confident that they have a thorough grasp of the course contents. It is as though it is all new when they actually get on the aircraft.

4.4 Recommendations

Apart from the foregoing, there are a number of factors that necessitate action. Future growth in air travel dictates more accurate flying and the highest demands for reliability in order to maintain separation and prevent collisions between aircraft. Runway capacity is limited and operations will have to be performed under high time pressure. Ground ATC systems will also be progressively automated and the future flight deck will be different as a consequence. The performance standards deserve a significant improvement to compensate for the increase in accidents associated with the expanding traffic. This improvement should be in the order of two- or preferably, threefold, in order to allow further expansion to take place.

It is suggested that:

- Training and safety management should be reviewed within an organisational context. Critical design review and evaluation of cockpit concepts should be undertaken by independent organisations capable of simulating varieties of future concept. Recommendations for an upgrade of display and control formats or other measures like special training or crew qualifications should be sought from qualified organisations.

- A human factors certification methodology should be developed.

- Techniques should be developed to enable manufacturers to shoulder the burden of providing (objective) proof for the validity of cockpit designs.

- A study should be undertaken to review the whole role of man in future automated flight operations.

- Training courses should provide pilots with more integrated overall knowledge of the functions of the automated systems, while not excluding knowledge of basic flying mechanisms.

- Standards should be developed for the displays and controls of flight decks ensuring user friendly and effective layout and design.

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