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Human error on the flight deck

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Despite terrorist bombs and structural failures, human error on the flight deck continues to account for the majority of aircraft accidents. The Royal Air Force (RAF) Institute of Aviation Medicine (IAM) has investigated the psychology of such error since the early 1970s, and to this end has used two principal techniques. The first has involved assisting in the official inquiries into both RAF and civil flying accidents, and the second has involved setting up a reporting system that permits any commercial pilot to report his own everyday errors, in complete confidence, to the RAF IAM. The latter system possesses the clear benefit of gathering error data untainted by considerations of culpability, and sometimes permits system rectification before the occurrence of accidents. This paper examines selected examples of errors associated with the design of equipment and with the social psychology of crews, and suggests that some consideration of the psychology of organizations may be necessary to ensure that the problems of human error are given the degree of consideration they require.

INTRODUCTION

It has become clichéd for those writing about aircraft accidents to point out that flying is, compared with other forms of transport, safe. Commercial jet transport aircraft are lost at a rate of about one per million flying hours, so there is some degree of contradiction in including the consideration of such events in a symposium on hazardous situations. The individual perception of ‘risk’ is determined, however, not just by the probability of a certain outcome, but by the subjective utility of that outcome. The negative utility of being involved in an aircraft accident is enormous, and this naturally affects the importance of the subject to the passenger. It is also true that when an aircraft accident occurs, it is such a large and public event that it cannot be ignored, and this may help to generate the measure of perhaps irrational anxiety about flying that undoubtedly exists in a significant proportion of the population.

The attention consequently focused on flying accidents has meant that errors in aviation have been investigated more thoroughly than errors in any other sort of endeavour, and the solutions that have been put in hand may well have lessons for those in less well-researched disciplines. What then, makes flying safe? A common belief is that the commercial pilot is a singular individual, carefully selected for his or her high degree of astuteness and particular aptitude for the job. In fact, the average holder of a commercial flying licence in the U.K. has a performance on a test of adult intelligence about equal to that of the average student at a teacher training college, and rather lower than the average undergraduate’s. The range of intelligence scores achieved by pilots is very wide, yet even the poor performers have been able to demonstrate sufficient competence at flying to gain a commercial licence. If safety does not appear to stem from the intrinsic quality of the pilots, what is its source?

There are probably two main factors safeguarding flying from human error. The first, and probably most important, is that commercial flying has become extremely regulated and

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‘proceduralized’. In flying there is a ‘procedure’ for every predicted eventuality. In leaving any airport the pilot will be provided with a set of standard departure patterns that define the routes and heights that he must achieve during that departure, and the same goes for arriving at an airport. If an engine catches fire, the pilot will not need to invent or think through the best course of action: it will be written down in his flight reference cards. In starting or shutting down the aircraft, the safest procedure will have been worked out and embodied in a drill. This process has meant that everything possible in flying has been reduced (in terms of one set of jargon) to a ‘rule-based’ activity (Sanderson & Harwood 1988). High-level decisions are made as infrequently as possible on the flight deck as every conceivable set of circumstances will have been discussed, and the best solution and procedure decided upon in advance. This has not always been so in flying, however, since there was natural resistance among pilots to see every aspect of their job reduced to the exercise of some predetermined set of responses, leaving much less within their immediate locus of control. The pressure for standardization has come from safety considerations, and O’Connor (1987) has pointed out that in 1933, when flying in the U.S.A. was regulated in a way that did not happen in the U.K. until the 1950s, U.S. airlines flew 21 686 515 passenger miles per fatality, whereas the British figure was 1 080 000.

The second major reason why the system is safe is the emphasis that is placed on the training and competency checking of airline pilots. The pilot must not only demonstrate his general competence at flying before gaining a commercial licence, but he must hold specific endorsements on his licence for each aircraft type that he flies. Even then, he must pass regular checks in the simulator and when flying on the line so as to remain legal, and he must be retested if his level of flying activity (or skill maintenance) drops below certain prescribed minima. It is probably true to say that in no other profession in which errors can threaten life, such as medicine or air traffic control, is the maintenance and checking of competence so thoroughly addressed.

The two factors considered above address exclusively human factors considerations: minimizing the scope for error in flight-deck decision making through proceduralization, and ensuring that pilots are competent at exercising the procedures for their aircraft. Neither of these factors has required the application of any particular psychological expertise as the requirements and solutions have been largely obvious. Unfortunately, serviceable aircraft continue to crash, and the remainder of this paper is concerned with the human factors that remain relatively unaddressed in flying. The data for the conclusions that are drawn come from two main sources. The first is the attendance of psychologists from the Royal Air Force (RAF) Institute of Aviation Medicine (IAM) at the inquiries into (and interviews with the crews involved in) both military and civil flying accidents. The second data source is a scheme known as the Confidential Human Factors Incident Reporting Programme (CHIRP)†. This enables all civil airmen and air traffic controllers to report their errors, not anonymously, but in complete confidence, to the RAF IAM. Each year about 200 pilots and air traffic controllers take the opportunity to use this scheme to tell us about the mistakes they have made in the air and why they believe they made them. No attempt is made here to give a comprehensive account of the human factors that cause incidents and accidents but only to provide a set of examples that typify certain problem areas.

† The Confidential Human Incident Reporting Programme was initiated and is sponsored by the Civil Aviation Authority and is operated by the RAF Institute of Aviation Medicine, Farnborough, Hants, U.K. Information on the scheme and its publication, *Feedback*, may be obtained from this Institute.

HARDWARE

The first area that is always assumed to attract a great deal of attention in aircraft development is that of the design of the controls and displays used by the pilot, and this is, at least to some extent, true. Unfortunately cockpit designs are constrained by cost, space, and the number of operators that have been decided upon. There are also many problems that can arise through the life of an aircraft as it is modified to meet new requirements that may render an initially adequate arrangement less acceptable. The following report was submitted to the CHIRP system by a helicopter pilot, and concerns the way in which pressure settings were demanded and displayed on his helicopter's altimeters. 'At 2000 ft my co-pilot said, "You've gone below 2000 ft!". I replied that I had not, but then saw that my altimeter was set on 1030 mb and not the correct QFE (airfield ground level pressure setting) of 1020 mb'. Consider the altimeters shown in figure 1. The altimeters are viewed from a distance of some 50 cm, while the instrument panel is acknowledged to suffer from shake. In the AS332 fleet of aircraft, the individual helicopters are fitted with altimeters of types (a) and (c) or (b) and (c). As the pilots fly from either seat, according to crewing requirements and convenience, a pilot may find himself using an instrument of type (a), (b) or (c).

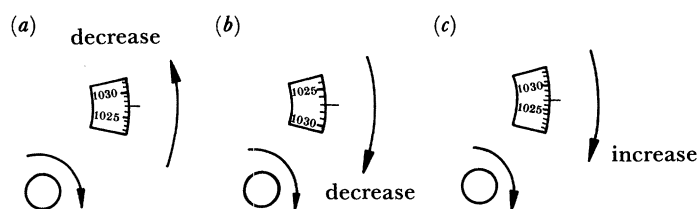


FIGURE 1. Arrangements of barometric setting controls and displays on helicopter altimeters.

These altimeters are superficially similar, but the sub-scales and the mode of changing the datum pressure setting are all different. It seems that most of my colleagues have difficulty in seeing and setting the correct pressures. Whatever happened to the altimeters with veeder counters for the pressure setting that we used to have 20 years ago?

It requires no knowledge of ergonomics of man-machine interface design to see what is wrong with the altimeters described above, or to imagine the nature of the accident that they could bring about since a wrongly set altimeter can easily cause ground impact. The practical decision that has to be made, however, is whether these altimeters are so unsatisfactory that the regulatory authority should compel the operating companies to go to the expense and trouble of replacing or standardizing them. The altimeters clearly function, and who is to assign a probability to their causing an accident during their operational life? Had the altimeters actually caused an accident, however, they would obviously be changed since we would know that the above probability is 1, and it is this fact which determines that flight safety is a process driven far more powerfully by failures that result in accidents than by identified system shortcomings. An airline operator has justified this situation as follows:

Aircrew should be expected to be reasonably intelligent alert human beings who are able to assimilate that they are liable to normal human error. Consequently, they should be prepared to accept these errors are their own responsibility and not palm everything off on some designer or management who expect a fair day's work for a fairly generous salary. A crew member who by his own admission is previously aware that the switch positions are reversed on two similar aircraft is surely capable of considering mis-selection as soon as a problem appears.

It has been implied that although ergonomic problems may be powerful progenitors of human error, they do not demand intellectual solution but simply an appropriate appreciation of the balance between risk and cost on the part of operators and regulators. It is clearly part of the task of the applied psychologist to evaluate the risk that may be inherent in a piece of design, but broader interests will inevitably need to be taken into account, and the role of the psychologist may be less clear, in evaluating the balance between the probability of hazardous failure and the economic cost of rectification.

Unfortunately, not all ergonomic problems on flight decks are as amenable to solution as that described above. A problem of current interest concerns engine instrumentation. Such instruments may be divided into those required for setting engine parameters and those providing status information such as oil temperature. The 'setting' instruments have traditionally been located on the front panel of the cockpit, arranged in columns aligned with the appropriate throttles and in rows of identical instruments (see figure 2*a*). The 'status' instruments may, on a three-man flight deck, be displayed on a panel behind the pilots as it will be the third pilot or engineer whose task it is to monitor them.

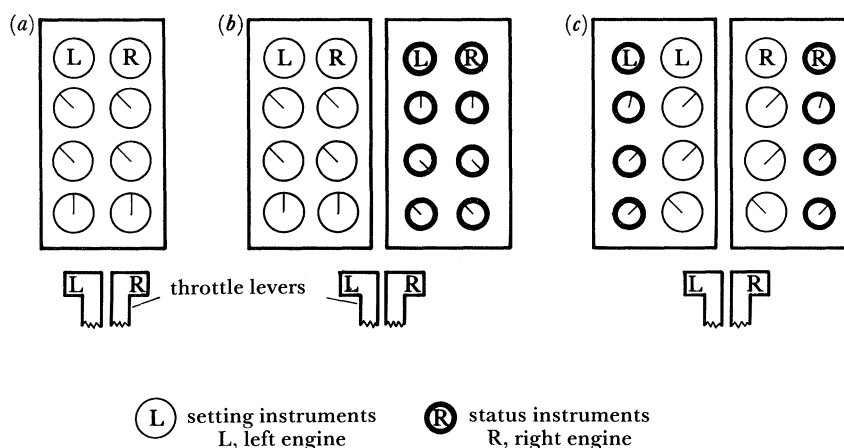


FIGURE 2. Possible arrangements of engine instruments on twin-engine aircraft.

On a two-man flight deck, however, all of the engine instruments must be accommodated in view of the two pilots. Since the front panel is limited in height, is it better to have arrangement (b) shown in figure 2, in which the status instruments have displaced the setting instruments to the left, or is it better to leave the setting instruments aligned with their respective throttle levers and split the status instruments so that they are placed on either side of the setting instruments (arrangement (c)?) (c) Has the advantage that the instruments for each engine are kept together and in line with the landmarks provided by the throttles, but B has the advantage of keeping similar instruments together and making deviant readings easier to identify. In fact, most two-pilot aircraft have arrangement (b), but a recent accident in which the crew shut down the serviceable rather than the faulty engine will doubtless cause some attention to be given to the wisdom of the practice.

Aircraft equipment today is far more flexible and capable of being more closely tailored to the human's requirements than ever before, and this means that the onus has moved from training the pilot to cope with what is practically achievable to designing a system that matches the human's abilities. A specific example of this process is provided by the display of attitude

(pitch and roll) information to pilots. Traditional attitude indicators (AIs) appear as they do because the original devices consisted of a vertical gyro with a horizon card and aircraft symbol attached to its front. Although the attitude indicator in a modern aircraft is likely to derive its data not from a gyro but from a laser inertial platform, the image on its electronic display would be familiar to the users of the very earliest gyro instruments.

Such consistency is obviously advantageous in minimizing the likelihood of negative transfer of pilot skill between one aircraft and another, but pilot disorientation continues to be a lethal problem in flying, and conventional AIs may have a lot to answer for. They provide information to the central or focal part of the visual system that provides the dominant visual input to conscious attention, but do not drive the peripheral retina that is so important in detecting the movements of the world, vection cues, which are probably essential for providing a normal perception of orientation. Traditional AIs therefore compel instrument flying to be a conscious and rather complex skill rather than an exploitation of natural human abilities. Attempts are now being made by life scientists (Green & Farmer 1985) to develop wide field of view attitude indicators to match the machine to the man instead of vice versa.

The balance between the work that is done by man and that which is done by machines on the flight deck has progressively shifted since the first jet airliners were developed. On these it was common for there to be two pilots, a navigator, a flight engineer, and a radio operator. Automated engine management and navigation have caused all but the two pilots to be dispensed with, and automation in military aircraft has reached the stage at which the term 'electronic crew member' has become part of the accepted jargon (Taylor 1988). How to integrate this electronic individual with the other crew members is more than a simple design problem, as the manner in which the pilot models his environment may be changing in a fundamental way.

On older aircraft the pilot knew that the airspeed indicator was driven by the pitot head sensor in a way that he could comprehend. By integrating information from various simple displays like this, the pilot was able to generate his model of what the aircraft was doing in space. Today, however, information is sensed in highly sophisticated ways and combined by the aircraft's computers to be presented on an integrated electronic display. Such displays are generally reliable, well engineered, easy to interpret, and a pleasure to use. The potential problem is that as they are so seductive, and since the pilot cannot possibly understand the technology involved in the generation of the display, he is compelled to use the display itself as his world model rather than creating his own internal model from the raw data. Although this shift in modelling mechanisms is likely, overall, to reduce error, it may generate a different class of problem in which the pilot, used to trusting his technology, actually trusts it too much and fails to utilize cues that should suggest to him that an error has crept in. The most spectacular example of his form of error that has so far occurred concerned the Air New Zealand DC10 that collided with Mount Erebus in Antarctica. The aircraft's inertial navigation system's computers had been programmed with an incorrect position, but the crew trusted them and were probably seduced into interpreting external visual information in a way that conformed with the world model generated for them by the aircraft.

Although equipment design, or traditional ergonomics, is not a topic that is presently in vogue among those who theorise on human error, the purpose of the foregoing has been to emphasize that these micro-factors in the aviation system are still matters of critical importance that must constantly and individually be addressed by those human factors specialists who are engaged in bringing about practical improvements to safety.

SOCIAL FACTORS

Equipment deficiencies have their effects, by and large, on the individual operator, and there are many perceptual and skill problems of flying not addressed here of which the same could be said. The individuals on a flight deck are required, however, to operate as a team or social group and it is only relatively recently that this flight deck team has been studied to identify the ways in which their interactions may affect operational safety. Such a study suggests that many of the concepts, such as conformity and compliance, already existent within social psychology are adequate to describe the events observed in reported breakdowns of team behaviour. The idea of 'risky shift' in group decision making (that a group is likely to make a more risky decision than the average member) is clearly illustrated in the following CHIRP report from the first officer of an aircraft that had already been forced to overshoot from two approaches in poor weather.

A suggestion was made that we should fly down 50 feet lower (than the decision height – the height at which the runway must be visible for the approach to continue) but as this was not legal, it was ruled out. We then managed to delude ourselves that flying level at the decision height of 220 feet was a legal and reasonable way to achieve our landing... From my position I studied the information on the flight instruments with a growing feeling of unease... We touched heavily on the centre line. Heavy braking followed what can only be considered a 'max performance' stop... The pregnant silence which followed served to reinforce our feelings that we'd been party to an act of supreme folly and bravado and were lucky to escape with a few grey hairs and severely battered pride.

Perhaps a more common problem in the flight deck team is that associated with the way in which leadership is exercised by the captain and the influence that this has on the propensity of the junior members of the crew to question his or her decisions. Examples of such problems are quoted by both Wheale (1983) and Foushee (1984), and the two which follow are from the transatlantic analogue of CHIRP. The first concerns a captain who was ignoring a speed restriction from air traffic control. After the co-pilot had attempted a number of times to bring the captain's attention to the restriction, the captain's response was 'I'll do what I want'. Air traffic control issued further requests which the copilot attempted (unsuccessfully) to persuade the captain to comply with, until eventually the captain told the co-pilot 'just to look out the damn window'. Breakdowns in coordinated behaviour are not always associated with such obvious dominance on the part of one crew member, however, as the second example makes clear.

The captain said he had misread his altimeter and thought he was 100 ft lower than he was. I believe the main factor involved here was my reluctance to correct the captain. This captain is very 'approachable' and I had no real reason to hold back. It is just a bad habit that I think a lot of co-pilots have of double-checking everything before we say anything to the captain.

Even when danger is clearly imminent there can still be reluctance to take assertive action. In a recent helicopter accident in the North Sea, the aircraft was manned by two captains, but the handling pilot suffered a temporary incapacitation as he came to the hover before landing on an oil rig. The aircraft descended rapidly, and the cockpit voice recorder shows that although the non-handling pilot appreciated that matters were extremely abnormal, he initially tried to gain the other pilot's attention by asking him what the matter was, and actually took control too late to prevent the aircraft from hitting the sea.

The complexities of the relationship between the pilots on the flight deck are well illustrated by the incident which occurred to a BAC 1-11 aircraft landing at Gatwick on 12 April 1988 (AAIB 1989). The main runway was out of commission and aircraft were landing on runway 08L. This was known as the emergency runway and normally acted as the parallel taxiway for the main runway. When in use as a runway, 08L was lit with good quality edge lighting, but when used as a taxiway it was lit by a set of green centreline lights. There is a further parallel taxiway to the left of 08L and this was also illuminated with green centreline lights. The result of this rather complex description is that when the main runway was in use the pilot was presented with a visual picture of an obvious runway with a taxiway to its left, and when the emergency runway was in use the visual picture was very similar. As many pilots were aware that the emergency runway was 'the taxiway to the left of the main runway', there was a danger that, during main runway closure, a crew might believe the emergency runway to be the main runway and consequently land on the most northerly taxiway believing it to be the emergency runway.

The aircraft that actually landed on this taxiway contained a two-man crew. In the left seat (normally the captain's) was a very steady and unhurried individual who was actually the legal first officer, but who was acting as the captain on his last check trip before being made a full captain. He had given the handling of the aircraft to the man in the right seat who was a rather more assertive sort of individual, was a training captain, was the legal commander of the aircraft, was checking the aspiring captain, but was behaving (for the purposes of the check) as though he were the first officer or co-pilot. The latter individual had aligned the aircraft with the correct, emergency, runway and the approach was progressing normally. The first officer was unhappy with the visual scene, however, and wanted to confirm with the captain that both of them were clear what they were doing. He consequently said to the captain words to the effect of 'You are going for the emergency runway aren't you?'. The effect of this remark on the senior, handling pilot was instantly to make him believe, inaccurately, that he was flying towards the main runway and that he should be flying towards the taxiway to the left of the main runway. Since he did not wish the first officer to think that he had made such an error he replied 'Yes, of course I am', and then surreptitiously changed course for the taxiway while the first officer's attention was directed inside the cockpit. The first officer did not look up until too late to prevent the aircraft from landing on the taxiway and narrowly avoiding another aircraft that was taxiing towards it.

The crew members of this aircraft were mature and competent individuals who were not tired, and who had a friendly and natural relationship with one another, but who nevertheless did not wish to be as frank with one another as system safety dictated. Study of incidents such as these suggests that the four main factors that determine how crew members will interact are their personalities, their statuses, their roles, and their relative abilities. It is obvious that if personality and status act in the same direction (that is, a dominant captain is paired with a submissive first officer), then there is a considerable likelihood that events will have to be serious before the first officer will choose to challenge the captain. Slightly more surprising perhaps, are the examples that show how hazardous the situation has to become before the pilot with the non-handling role will intervene in the behaviour of the handling pilot, especially if he believes the handling pilot to be competent. The Gatwick landing incident involved the interaction of all these factors, but it also required the potential for failure provided by the ambiguous runway lighting.

To prevent the recurrence of such an incident it is clear that modification was required to the runway lighting, but incidents such as this also call for a programme of behaviour modification on the flight deck. How can first officers be made to intervene in a timely and firm way that will not exacerbate the situation? How may captains be encouraged to act so as to encourage co-pilots to air their uncertainties? Many airlines are now tackling these problems with programmes of simulator training that attack not only the rule-based elements of flying (shutting down an engine after a fire alarm), but that are aimed to encourage crews to solve unexpected and sometimes vaguely defined problems on a group basis. Such simulation exercises are frequently video-taped to enable, for example, the captain who believes himself to be exercising an appropriate level of authority to see that he is actually presenting himself as something of a martinet. These exercises also enable the naturally submissive first officer to discover, in a benign role-playing environment, that it is possible to air his views and anxieties in ways that contribute to the effectiveness of the team operation without appearing to challenge the authority of the aircraft commander.

The benefits of improving crew coordination training, and enabling crews to practise solving the types of ill-defined problems that are known to have caused accidents, are difficult to quantify as it is extremely difficult to identify the accident that fails to occur. Nevertheless, such training is becoming widespread and generally accepted in airlines, and is likely to become a legal requirement in airline operations in the foreseeable future.

SYSTEM FACTORS

The issue of teamwork training described above represents another example of the type of factor that confronts the operator with a decision that requires cost to be balanced against safety benefit. It is relatively easy for the profitable airline to decide that such training is beneficial, but the airline operating in a more competitive area of the aviation system, where economic margins are extremely constrained, may simply be unable to undertake all of the desirable training and standardization of equipment without going out of business. The regulatory authority may have considerable difficulties in compelling such airlines to undertake costly procedures as the airlines may accurately point out that by doing so they will be made less cost efficient vis a vis foreign operators (possibly operating in a less regulated environment) with whom they compete directly.

The temptation for operator and regulator alike, when faced with an acknowledged but intractable problem, is to undertake some unconscious dissonance resolution by regarding the problem as less serious than they might if it were readily soluble. The example of this provided by the operator quoted above shows that this dissonance resolution can extend to the stage of what might even be termed denial. Although CHIRP was not originally designed to counter such behaviour, it has an important role in doing so.

By enabling pilots to report their anxieties to an agency outside the system within which they operate, constraints on candour are removed, and issues that were previously discussed only in crew rooms and bars become available to be fed back into the system in an overt way. However widespread covert knowledge of a problem may be, it is unlikely to generate remedial action since an operator can scarcely be expected to solve a problem with which he has not been overtly acquainted. A good example of this process is provided by the fatigue reports submitted to CHIRP. A number of these reports are of incidents in which complete airline crews found

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themselves asleep while, for example, crossing the Atlantic. Although flying mythology acknowledged such incidents, it has required the CHIRP system to force the problem of the sleeping crew to be confronted and tackled.

Operation of the CHIRP system suggests that the dominant organizational factor of importance to system safety is attitudinal. Management must be forgiven if, when publicly confronted with a safety problem, they seek to minimize its magnitude, but they must not let themselves believe their own publicity. It should be the responsibility of all managements to ensure that when deficiencies in design or operational procedures are reported, they do not seek to discipline, belittle, or even dismiss individuals so as to maintain the status quo, but attempt instead to come to an understanding of the problem and its likely consequences to ensure that any possible modifications and improvements may be made.

CONCLUSIONS

This paper has attempted to show that human error on the flight deck requires solution at all levels of the aviation system. The examples provided of failures in equipment design, failures in crew coordination, and failures of safety consciousness in system managers suggest that we should not be considering whether there is a particular psychology of human error, but that we should be attempting to marshal all of the psychological knowledge available to solve the perceptual, skill, design, selection, training, social and organizational problems with which the aviation psychologist is presented.

An important tool for the psychologist involved in studying failures in any complex system must be some form of confidential reporting system for human error. To be effective, such a programme must be operated by an agency external to the system but, if successful, such schemes can not only yield information that enables individual system shortcomings to be tackled, but can compel the whole level of safety consciousness in the system to increase. Industry is now so complex that only by involving psychologists closely in the investigation and analysis of incidents and accidents will they achieve the level of applied knowledge that enables a real and practical contribution to system safety to be made. Aviation has fully adopted this philosophy, and, fortunately, other industries are rapidly following suit.

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