focus will be on the general techniques used for analysing the interface between human beings and other complex systems An attempt has been made to concentrate on aviation interface issues as most informative to HCI Even with this limited definition, it is hard to review the vast amount of available material and so specific focus will be made on a series of very general 'lessons' which would be well drawn from aviation considered in this narrow sense Many of these 'lessons' have been hard won so ignoring them might well seem extremely parochial and ungracious

It is important to make clear that this is not anything remotely like the claim that aviation has found all the answers to the problems of HCI As is so often the case in science, answering one question tends to generate five further questions and the aviation field remains full of difficult HCI related issues In illustration of this, an example of a current aviation interface debate is given in the penultimate section of this paper

The claim made is not the simplistic one that aviation studies have solved difficult HCI questions It is rather that long term changes in methodology which have been prompted by the need to improve aviation safety, have important lessons for other disciplines in general and HCI in particular one genuinely moves to the goal of preventing recurrence there can be no such thing as unforeseeable circumstances The historical fact that they were not foreseen by the relevant people in this case is a human error which can now be rectified To prevent recurrence one analyses the circumstances that obtained and makes the necessary interventions to prevent that particular set of circumstances (and maybe sets closely resembling it) from recurring

Of course, aviation had a strong advantage over many other areas of human activity in learning that blaming the user is unhelpful Of course, pilots (like all human beings) are error prone Pilots undoubtedly do make many errors However, captured in grim aviation slogans such as 'They bury pilots with their mistakes' are at least two important truths The first is that pilots are very strongly motivated not to make mistakes The second is that they are highly unlikely to make a serious mistake more than once (in sharp contrast to spreadsheet users or doctors, for example) These two truths provided a motivation for looking beyond the dismissive 'pilot error'

However, the advocates of 'pilot error' did not give up so easily In commercial terms it is usually much cheaper to blame a pilot than to alter an aircraft design for example Also there are many accidents where little else seems involved but an obvious error by the pilot In these cases, relapse to headers That's not a bug, that's pilot error His sendmail cf' is hosed

This is computing mimicking 4 s aviation attitudes It's time to move on

Of course, this sort of lesson is beginning to permeate other areas It is not unknown for IT companies to claim that they have a 'no blame culture' Medicine in particular has deliberately sought to imitate aviation practice What the aviation experience suggests is that this process will be extremely difficult and that much, much more than pious hopes will be required to move from a blame model Determined conviction to eliminate the 'blame

included a digital readout. An example of this instrument is shown at Pic. . The differences in readability should be obvious. For the record the altimeter in Pic. 1 is showing a pressure altitude of 90 feet and that in Pic. . 1 0 feet.

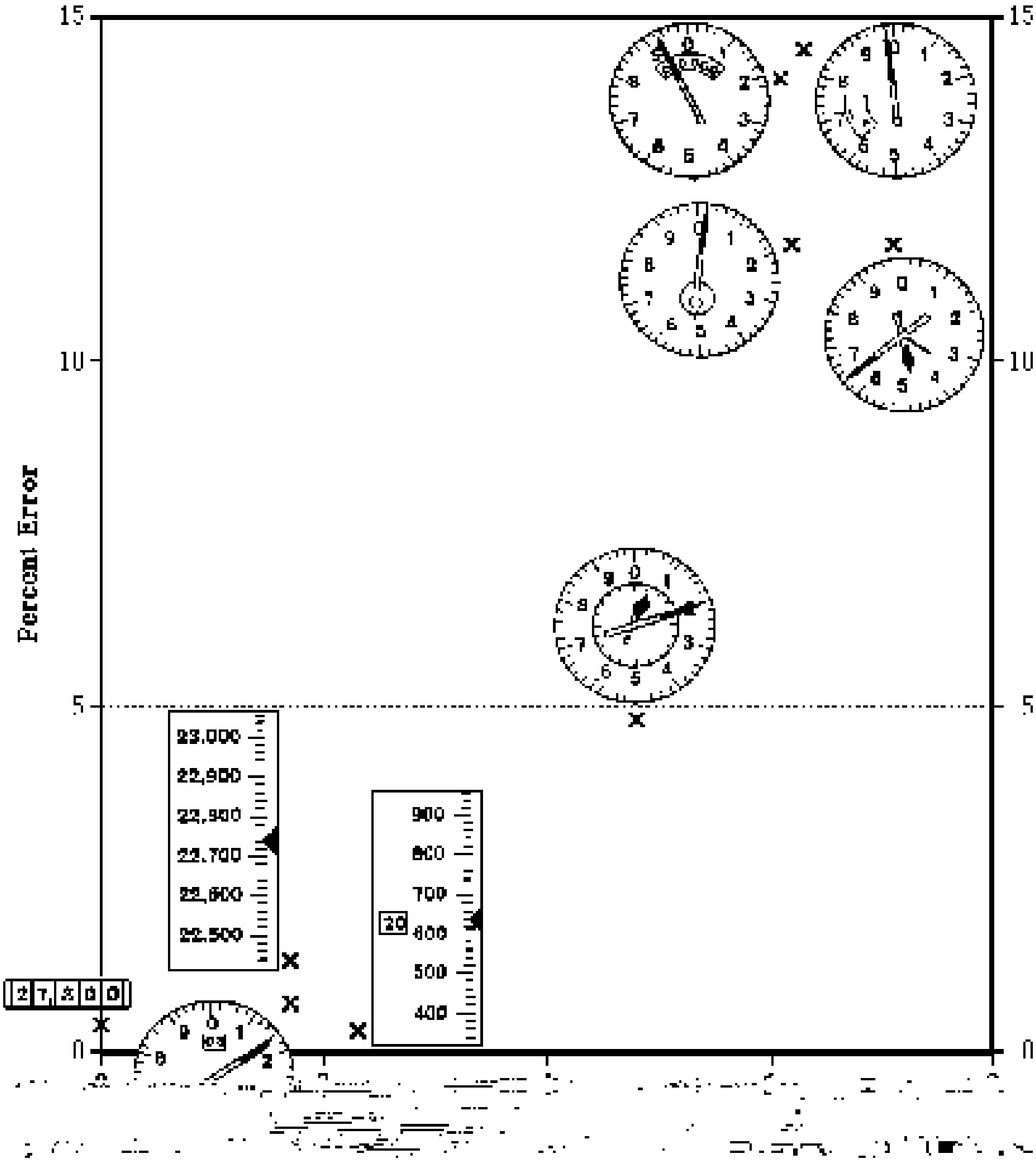

Fig Interpretation times and error rates for various types of display

introduction of the servo altimeter would probably have broken the chain leading to the accident

On most occasions, misreading of a three pointer would have caused no serious problem, of course This shows the importance of gathering data from events that do not lead to accidents Some of the most important ways in which this has been done in aviation are described in the next section

A final ironic note to this lesson might be struck by returning to the highly unhelpful 'aircraft striking the ground' category mentioned at the start to this section. Probably the most recalcitrant category of aircraft accidents during the 1990s has been the CFIT (controlled flight into terrain). As the name implies this is the situation where an aircraft under full control and with no known problem flies straight into the ground. In spite of the servo altimeter and the second-generation of highly sophisticated GPWS (ground proximity warning system - which delivers a spoken warning or instruction to the crew) this remains a large category with little sign of decrease. The response of the accident investigators is therefore to subdivide. The largest sub-category of CFITs is that of ALAs (approach and landing accidents). The hope of the investigators is that this category may turn out to have more links in common than did CFITs. We have yet to see whether this will turn out to be the case, but it is a good example of the use of flexible categorization as a tool.

L sson It s b tt r to co ct w ran n ata by constant on tor n b or ana ys n a part cu ar prob

Adoption of the 'no-recurrence' model and the use of flexible categorization as an analytic tool naturally suggest a rich data approach. That is to say that more data - particularly on near-misses - will help to identify the similarities in the various chains of events which precede accidents. Collection of this rich data has proceeded and developed over the historical period with which this paper is concerned. The principle techniques employed have been anonymous reporting, monitoring and recording, and telemetry.

Some of the most effective tools developed in aviation involve the monitoring of 'near misses', 'reportable incidents', and the like. As with the other lessons described above there was powerful and continued resistance to many monitoring procedures. Thirty years ago, if a pilot or air traffic controller handled a potential disastrous situation without any injury or damage; they would feel resentful if the 'incident' were to be fully

incidents that have a certain amount of overlap with HCI. It is important to remember that flexible classification is a tool in aviation investigation and that these classifications are tentative.

The first is a class of accident that might loosely be called 'fascination with the technology'. In this class of accident, the crew seem to become overly preoccupied with a particular problem -often a relatively trivial technical problem - to such an extent that they temporarily 'forget' that they are flying an aircraft. In some cases, this preoccupation lasts long enough to cause problems or even accidents. Many explanations are on offer for this possible category of accidents including the general use of simulators for training and the way in which modern flight decks remove the actual hands-on task of flying leaving flight crews feeling less involved with the real-time aspects of not going to fly it out of this situation and was unable to recover in time by taking over manual control.

This accident has sent many ripples of concern through the aviation world. For many people, including several national aviation authorities, it marked the end of the belief that the latest generation of airliners are easier to fly than their predecessors. Some believe that the only safe option is to train crews to know and fully understand the details of the logic of the FMS computers. This is a considerable extra expense for the airlines and unpopular with the manufacturers.


Pic.

The computers can and do override or ignore the pilots if they consider their input to be inappropriate. The pilots cannot override the computers. An obvious sign of this change in the nature of flight control is the way in which the controls are now presented to the pilots. The small joystick presents the pilots' inputs to the aircraft.

Other features to note in the Boeing cockpit are the throttles (the largest of the white levers on the centre console) which closely resemble real throttles

Pic

even though the engines are in fact controlled by the computers. On the Airbus the throttles are smaller and more like computer switches.

There is a great deal of debate in aviation circles as to the advantages and disadvantages of each of these approaches to the design of flight decks on automated aircraft. One of the issues which readers may find interesting include the way in which providing controls that resemble those in conventional aircraft may generate pilot behaviour which would be appropriate for conventional aircraft, but not for the present aircraft. One should remember that, for existing pilots at any rate, initial training will have been on conventional mechanically controlled aircraft. Thus one would expect them to acquire the sort of model of aircraft behaviour appropriate to conventional aircraft. It may be that such a model is inappropriate for fly-by-wire aircraft. A choice of what in HCI would be called an 'interface metaphor' of conventional aircraft controls may be a factor in encouraging a misleading mental model of the aircraft.

Whether or not this actually happens, and whether or not it actually matters in practice remain open questions. It is perhaps overshadowed by the surprisingly high amount of training required to acclimatize experienced airline pilots to any of the highly automated aircraft of the present generation of airliners. If one accepts the assertions made in the previous section, then one might expect this to have some consequences. A fair summary of the debate would be to state that those who operate and fly each type of aircraft are great enthusiasts for the particular type of flight deck which they operate or fly.

Before coming to any hasty conclusion one should remember the lessons outlined above. There is no overwhelming evidence that either approach to flight deck design contributes to accidents or incidents. However collecting rich data on 'mode confusion' and 'fascination with the technology' incidents may well yield important clues on this. Again, classification is an important tool in dealing with this question. As data on 'mode confusion' is obtained from real incidents, from anonymous reports, and from laboratory experiments interesting conclusions may come to be drawn about which interface metaphor is better. These results would also seem to be significant for HCI in general.

Conc us ons

This paper began with a quotation stating that aviation is not inherently dangerous; this is perhaps the time to state that it is certainly not inherently safe either It is a relatively new field and full of new challenges which require new techniques Do the lessons outlined above work? Well they certainly worked in aviation The fact that aviation has become, in three to four decades, such a safe way to travel is a tribute, I would argue, mainly to the way these lessons have been thoroughly learned and applied Other fields, and I have mind medicine and law just as much as HCI, ignore such lessons at their peril

Picture Credits

Pic Justin Cederholm Orlando Tampa Aviation Photography

Pic 4 Ulrich F Hoppe

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Bibliography