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Bureau of Air Safety Investigation

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Summary

The Bureau of Air Safety Investigation recognises that advanced technology aircraft such as the Boeing 747-400 and the Airbus A320 have brought new human and operational issues to the aviation industry. This research project was directed at exploring the emerging safety issues of advanced technology aircraft, the investigation techniques required in the event of an occurrence and the BASI training which is necessary to keep up with new technology.

It was found that overseas safety research involving advanced technology aircraft has concentrated on pilot attitudes and issues generic to advanced aircraft. This project identified a need to address specific operational problems in the Australian context.

It is proposed that a second phase of the project should address the operational issues of advanced technology aircraft in Australia, covering human factors issues related to specific aircraft types.

List of Abbreviations

A/P	Autopilot
AAIB	Air Accidents Investigation Branch
ALT HOLD	Altitude Hold
APPR	Approach
ATC	Air Traffic Control
BASI	Bureau of Air Safety Investigation
CAA	Civil Aviation Authority
CRT	Cathode Ray Tube
CVR	Cockpit Voice Recorder
DES	Descent
EEC	Electronic Engine Control
FADEC	Full Authority Digital Engine Control
FMC	Flight Management Computer
FMS	Flight Management System
FO/ F/O	First Officer
ft	feet
GASIG	Government Air Safety Investigation Group
HCI	Human Computer Interaction
HDG SEL	Heading Select
ICAO	International Civil Aviation Organisation
KAL	Korean Airlines
kt	knots
LNAV	Lateral Navigation Guidance
LOFT	Line Orientated Flight Training
MCP	Mode Control Panel
NASA	National Aeronautics and Space Administration
nm	nautical miles
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TAI	Thermal Anti Ice
TOD	Top of Descent
VCR	Video Cassette Recorder
VNAV	Vertical Navigation Guidance

Chapter 1

Introduction

Accident, incident and anecdotal evidence indicate that the introduction of new technology to aviation has generally resulted in benefits to safety and efficiency (Norman and Abbott 1988). Information published by Boeing Commercial Airplanes indicates that in general, accident rates have been declining with each successive technological advance over the last thirty years (Boeing 1988). However, new technology has also resulted in a range of new human factors and operational difficulties. New tools invariably change the way a job is done and new aircraft are no exception. The work of pilots and other airline personnel is being changed by the introduction of new technology and although most of the changes are likely to be beneficial or benign, some may be undesirable.

Recent accidents involving advanced technology aircraft have indicated that these aircraft are not immune to technological malfunctions and human error, although in many cases "human error" occurs in response to an initial aircraft irregularity. Recent advanced technology aircraft accidents have included the Lauda Boeing 767, Airbus A320s at Bangalore, Habsheim and Strasbourg and the Boeing 737-400 at Kegworth.

The Bureau of Air Safety Investigation began this research project recognising that special safety issues apply to advanced technology aircraft and that the investigation of accidents to these aircraft will require special methods. Given the rapidly advancing state of technology, few government investigation agencies can hope to maintain expertise in all areas of advanced technology. An important part of this project involved exploring the options for international cooperation in this area.

1.1 DEFINITION

For purposes of this study, advanced technology aircraft or automated aircraft are defined as aircraft with cathode ray tube displays and flight management systems, such as the Boeing 757 & Boeing 767, Boeing 737-400, Boeing 747-400, McDonnell-Douglas MD88 and Airbus A-310 and Airbus A320. (Palmer 1988).

1.2 OBJECTIVES

The primary objective of the Advanced Technology Aircraft Research Project was:

1. To gain an appreciation of the safety issues associated with advanced technology aircraft systems.

Two secondary objectives were:

2. To develop techniques to be used in the investigation of an accident or incident involving advanced technology aircraft.

3. To develop a training package for BASI staff to familiarise them with issues related to advanced technology aircraft systems.

The main body of this paper addresses the first objective by considering the safety issues associated with advanced technology aircraft. Appendix 1 and 2 describe the work undertaken to meet the two secondary objectives.

Chapter 2

Safety Issues Pertinent to Advanced Technology Aircraft

2.1 METHOD

The safety issues associated with advanced technology aircraft were investigated by conducting a literature review and by reviewing significant accidents involving advanced technology aircraft. The literature review provided an overview of the safety concerns of overseas authorities and provided a starting point for original research by BASI. For the most part the literature review focused on human factors, as purely technical issues were considered to be outside the scope of this report. The review of significant accidents involving advanced technology aircraft provided an opportunity to consider the safety issues which had emerged during the investigation of these events. However, the review was hampered by the unavailability of some foreign accident reports.

2.2 RESULTS

2.2.1 Review of Accidents to Advanced Technology Aircraft

The following section comprises a brief review of four major accidents to advanced technology aircraft. The review, while not comprehensive, provides an introduction to some of the safety issues which have emerged from such accidents.

British Midland Airways Ltd Boeing 737-400 near Kegworth, UK
8 January 1989

On climb out of Heathrow for Belfast, the aircraft sustained a fan blade failure on the left engine. There was then a series of compressor stalls in the left engine which resulted in airframe shuddering, fluctuations of the left engine parameters and the appearance of smoke and fumes on the flightdeck. In response to these indications, the crew throttled back the right engine. At this point, the noise and shuddering caused by the malfunctioning engine ceased, probably because the autothrottle had been disengaged. Having misdiagnosed the fault as one in the right engine, the crew shut down that engine and diverted to East Midlands airport. The left engine apparently operated relatively normally during the descent, although vibration levels remained high.

At about 2.4 nm from the runway, the left engine lost power abruptly and efforts to restart the right engine were unsuccessful. The aircraft subsequently struck terrain in the vicinity of the M1 Motorway. The accident claimed the lives of 47 of the 126 occupants.

The AAIB report into the accident raised issues of general relevance to advanced technology aircraft. The flight crew were relatively inexperienced on the aircraft type and the AAIB questioned the adequacy of the training they had received. A particular concern was that the operating company did not have access to a flight simulator equipped with the engine instrument system which was fitted to the aircraft. It was considered that the engine vibration indicators needed to be more "attention-getting". The AAIB recommended that pilot training should include familiarisation with electronic flight displays and that pilots should be trained to develop a better appreciation of aircraft technical systems. The report also addressed the apparent deficiencies in decision making which occurred in the cockpit and recommended that the British CAA evaluate the use of simulator training in flightdeck decision making.

(AAIB Report 4/90)

Indian Airlines Airbus A320, Bangalore, India
14 February 1990

The following description of this accident is adapted from a 1991 NASA report (Billings 1991)

This aircraft crashed short of the runway during an approach to land in good weather, killing 94 of 146 persons aboard including the pilots. The best available data indicate that the aircraft had descended at idle power in the "idle open descent" mode until shortly before the accident. Although an attempt was made to recover by adding power, there was insufficient time to permit engine spool-up prior to impact. The aircraft was being flown by a Captain undergoing a route check by a check airman.

The crew allowed the speed to decrease to 25 kt below the nominal approach speed late in the descent. The recovery from this condition was started at an altitude of only 140 ft, while flying at minimum speed and maximum angle of attack. The check captain noted that the flight director should be off, and the trainee responded that it was off. The check captain corrected him by stating, "But you did not put off mine." If either flight director is engaged, the selected autothrust mode will remain operative, in this case, the idle open descent mode. The declining speed and increasing angle of attack automatically activated the alpha floor mode which caused the autothrust system to advance the power. However, this occurred too late for recovery to be affected before the aircraft impacted the ground.

Air France Airbus A320, Mulhouse-Habsheim , France
26 June 1988

The following description of this accident is adapted from a 1991 NASA report (Billings 1991)

This aircraft crashed into tall trees following a slow, low flyover at a general aviation airfield during an air show. Three of 136 persons aboard the aircraft were killed; 36 were injured. The Captain, an experienced A320 check pilot, was demonstrating the slow-speed manoeuvrability of the then-new aircraft.

The French Commission of Inquiry found that the flyover was conducted at a height lower than the minimum of 170 ft specified by regulations and considerably lower than the intended 100 ft level pass briefed to the crew by the captain prior to flight. It stated that, "The training given to the pilots emphasised all the protections (sic) from which the A320 benefits with respect to its lift which could have given them the feeling, which indeed is justified, of increased safety...However, emphasis was perhaps not sufficiently placed on the fact that, if the (angle of attack) limit cannot be exceeded, it nevertheless exists and still affects the performance." The Commission noted that automatic go-around protection had been inhibited and that this decision was compatible with the Captain's objective of maintaining 100 ft. In effect, below 100 ft, this protection was not active.

The Commission attributed the cause of the accident to the very low flyover height, slow and reducing airspeed, engine power at flight idle, and a late application of go-around power. It commented on insufficient flight preparation, inadequate task sharing in the cockpit, and possible overconfidence because of the envelope protection features of the A320.

Lauda Boeing 767-300, Suphan Buri Province, Thailand
26 May 1991

The aircraft had departed Bangkok for Vienna. The flight appeared to be normal until five minutes and forty five seconds after takeoff at which point the crew began to discuss a cockpit indication of a fault in the thrust reverser system. The pilot in command stated "that keeps coming on". The crew discussed the fault indication for about four and a half minutes. During this time the co-pilot read sections of the Airplane Quick Reference Handbook including the following "Additional systems failures may cause in-flight deployment" and "Expect normal reverser operation after landing" . The pilot in command remarked "...its not just on, its coming on and off" ... "its just an advisory thing" and "could be some moisture in there or something".

Fifteen minutes into the flight, the co-pilot said "Ah, reverser's deployed". At this time the CVR recorded sounds of airframe shuddering, metallic snaps and the pilot in command stating "here wait a minute". The investigation revealed that there had been an uncommanded deployment of the thrust reverser of the left engine.

Control was lost and the aircraft broke apart before impact with the ground. All 223 occupants died in the accident.

Tests conducted as part of the investigation indicated that recovery after an in-flight deployment of reverse thrust on one engine was only possible if the flightcrew applied full wheel and full rudder within six seconds of reverser deployment.

(Ministry of Transport and Communications, Thailand 1991)

2.3 SAFETY IMPLICATIONS

The accidents raise a number of human factors issues which will be dealt with fully in the following section. In brief, the issue of complacency is particularly relevant to the Habsheim accident. Crew co-ordination and decision making feature significantly in the Bangalore, Kegworth and Habsheim accidents. A lack of monitoring and situation awareness also appears to have been a factor in some of these accidents. The Lauda accident, far from reflecting crew complacency with regards to automation, may indicate a level of scepticism towards alerting systems, which could be called the "cry wolf syndrome". Crew training was a particular focus of the Kegworth investigation, and it appears that training may be an important but overlooked factor in other accidents.

Chapter 3

Literature Review, Human Factors of Advanced Technology Aircraft

This review will first outline the history of research into the safety issues of advanced technology aircraft before considering the safety issues in accord with the Reason model of accident causation.

Major research into the operation of advanced technology aircraft has been conducted by many research, commercial and development groups. In the realm of human factors, research organisations such as NASA-Ames (Weiner 1989, Weiner et al 1991) and the Institute of Aviation Medicine at Farnborough (James et al 1991) have conducted field studies.

One of the earliest studies of pilot's experiences with an advanced aircraft was conducted by Lufthansa in the late 1970s (Heldt 1988). A survey was distributed to pilots across the Lufthansa fleet, including pilots of Airbus A310-200 aircraft. In keeping with the limited scope of human factors research at the time, pilots were asked questions on ergonomic issues such as contrast and brightness of screens and the ability to see displays and reach controls. In general, pilots liked the advanced features of the aircraft, although there were signs that problems were occurring when pilots interfaced with the automated FMS.

By the 1980s, there was an increasing level of concern about the transition to advanced technology aircraft in the US. In 1985 NASA contracted Earl Weiner to study the transition of pilots from the traditional airline cockpits of the McDonnell Douglas DC9 to the advanced technology McDonnell Douglas MD-80 (Weiner 1985). Weiner found that although pilots expressed favourable views about automation, they were concerned that pilots were being left "out of the loop" or were "along for the ride" in modern aircraft. In addition, most pilots considered that automation was safety neutral.

In 1989 Weiner published the results of a three year field study of Boeing 757 crews from two US airlines. His report summarised the opinions of the pilots concerning the advanced features of the aircraft and also covered issues of training, workload and cockpit errors. Weiner found that although pilots were generally enthusiastic about the aircraft, there was evidence of operational problems. The problems can be divided into workload issues, cockpit errors, crew coordination and training issues.

Weiner did not find evidence that automation had reduced workload. Perhaps paradoxically, many pilots reported that at times of high workload, they would switch off flight guidance automation (LNAV and VNAV) and revert to flying the aircraft as though it were an older generation model.

Weiner gathered numerous reports of errors made in the cockpit of the Boeing

757. The most common reported errors were mode errors or set-up errors in systems which had multiple modes, failures to engage automated systems such as LNAV, data entry errors, unexpected or surprising events and workload management problems. Two examples from Weiner's study follow:

Copilot made an autoland approach to a landing and roll out. During the latter part of the roll he gave me control of the aircraft. Not realising that the aircraft had not been disconnected from the A/P, I attempted to exit the runway, putting considerable stress on the landing gear. Finally realised that the A/P was still trying to maintain center line. Problem was lack of experience and crew co-ordination. p104

Selected an FMC route and then failed to select LNAV. There should be a better warning system if you have not selected LNAV after programming the FMC. p108

In a more recent NASA study, Weiner, Chidester, Kanki, Palmer, Curry and Gregorich (1991) compared simulator performance of crews flying either the traditional cockpit McDonnell Douglas DC9 or the new generation McDonnell Douglas MD88. Weiner et al found no evidence to indicate that the crews of advanced technology aircraft performed any better or worse than those flying the older generation aircraft. As in the Weiner study of 1989, Weiner et al collected error anecdotes from pilots. A large proportion of the errors experienced by the crews of the advanced technology aircraft involved altitude deviations.

In the UK, James, McClumpha, Green, Wilson and Belyavin (1991) surveyed over 1000 pilots on attitudes to advanced aircraft. The respondents were enthusiastic about flight deck automation, but were concerned that pilots may become over-reliant on automation and may allow flying skills to deteriorate.

While generally recognising the benefits which have resulted from the introduction of automation, many researchers have expressed concern about possible safety issues associated with the operation of advanced technology aircraft.

The remainder of this literature review applies the Reason framework to the major issues which have been raised by researchers and other authorities.

The Reason model emphasises that accidents or system breakdowns involving complex technological systems are rarely the result of an isolated error or unsafe act. Rather, accidents are seen to result from a combination of failures at all levels of the organisation from management down. In most cases, an accident is immediately precipitated by an unsafe act committed by a worker. For the unsafe act to lead to an accident, there must be an inadequacy in system defences. The unsafe act may be either an error or a violation of standard procedures. However, unsafe acts do not occur in isolation but occur in the context of error or violation conditions such as haste, fatigue or other psychological influences. These conditions in turn reflect longstanding organisational failures.

An important principle of the Reason model is that safety cannot be enhanced by merely addressing the *active* failures such as unsafe acts. An effective accident prevention program must also address the less obvious *latent* failures in the organisation which may be present long before the accident occurs.

The following section considers the safety issues of advanced technology aircraft under the broad headings of Unsafe Acts, Error or Violation Producing Conditions and Organisational Failures. Full descriptions of the Reason model have appeared elsewhere (e.g. Reason 1990).

3.1 UNSAFE ACTS

a. Data entry errors

Field studies such as those of (Weiner 1989), Weiner et al (1991) and Sarter and Woods (1992) have confirmed that data entry errors do occur on advanced flightdecks. Weiner and Curry (1980) predicted that advanced technology systems would create opportunities for gross data entry errors. Such errors have been implicated in a number of occurrences, including two events involving older technology aircraft, (the shooting down of KAL 007 and the Air New Zealand Mt Erebus accident).

b. Mode misapplication

Crews occasionally make mode selection errors when using automated systems (Norman and Steinmetz 1988). It has been suggested that the Strasbourg crash of an Airbus A320 involved a mode misapplication, in which the crew confused the digital flight path angle display with the rate of descent display (Gosling 1992).

c. System "workarounds"

It has been observed that crews will sometimes intentionally input incorrect data into the FMC to achieve a desired result (Weiner 1989). Such workarounds are common in automated systems and reflect a desire of crews to smooth out inelegant automation. For example, on climb to cruising level, pilots may temporally enter incorrect altitude information to ensure a smooth capture of the assigned altitude. Weiner (1989) provided the following example of a what his pilot participants referred to as "tricking the computer":

Crews who wished to start a VNAV descent earlier than their computed top of descent (TOD) point discovered at least two ways to cause the FMC to recompute the TOD. One was to enter a point for use of thermal anti ice (TAI) on the DES page, even though there was no intention of using it. The other method was more precise, simply entering a fictitious tailwind. These methods of course, would achieve the desired result, but would tend to defeat the purpose of VNAV *b. Crew complacency*

There is a risk that pilots may become complacent in the face of reliable functioning of automatic equipment (Gabriel and Braune 1989, Palmer 1988). Incidents have occurred in which pilots have apparently failed to adequately monitor system performance out of a mistaken belief in system infallibility. The following example was reported to Weiner (1989):

My F/O was going to land threshold minus 10 kts. decreasing, nose up 12 degrees increasing -- because it was a practice autoland. We would not only have gotten the tail, but probably would have wiped out. When I told him to take it around he said it was an autoland. I took over and made it from about five feet. An EEC (Electronic Engine Control) on the right had screwed up, which we found out at the gate. The big factor was his attitude that some computer would do it all and he didn't have to watch the company seven degree nose up and threshold speed. The autosystem is great, but we (pilots) are the "break glass" if all else fails and we must put out the fire. I don't think his blistered ear made much difference. p112

In recognition of the seriousness of complacency, Singh Molloy and Parasuraman (in press) have recently produced a twenty item rating scale for use in a variety of environments where automated systems are used.

c. Inadequate mental models and knowledge deficiencies

Sarter and Woods (1992) provide evidence to indicate that pilots of advanced aircraft frequently do not have a complete understanding of all the automated features available, do not understand the interrelationships between various systems and may not always understand why their input results in the desired outcome. Sarter and Woods found that, faced with very flexible automated systems with a range of modes, many pilots rely on a limited repertoire of strategies to operate the aircraft. In unusual situations however, pilots may be required to have a thorough understanding of obscure or little-used aspects of the automation. Mode selection issues are discussed in more detail in a later section.

Weiner (1989) also highlighted the knowledge deficiencies among the pilots of advanced technology aircraft. However, it is not possible to consider knowledge deficiencies without considering training for advanced technology aircraft.

d. Training for advanced technology aircraft

Sarter and Woods (1992) noted that conversion training to advanced technology aircraft may involve "recipes", or standard solutions to standard problems. This appears to be a rule-based approach to operating aircraft, which may not give sufficient emphasis to the need for pilots to have a good knowledge of aircraft systems. There may be a need to ensure that pilots have a deeper understanding of the systems they are operating.

e. Automation at times of high workload

The designers of advanced technology aircraft no doubt hoped that advanced systems would reduce pilot workload and would assist the pilot to cope with emergencies or abnormal situations. However, evidence gathered by Weiner (1989) and others indicates that many pilots faced with abnormal situations, prefer to disengage one or more automatic systems and revert to more manual modes of operation.

f. The increased monitoring role of the pilots.

A large body of research has indicated that in general, people are poorly suited for passive monitoring tasks, (e.g. Wickens and Flach 1988). Of particular concern in aviation is the vigilance decrement, where a person monitoring a display is likely to suffer a reduction in performance as time passes.

Advanced aircraft are shifting the role of the crew away from direct controlling and towards system monitoring (e.g. Weiner and Curry 1980). Monitoring failures may be an inevitable result of this development. The monitoring role of the pilot becomes particularly difficult on long haul flights and hence it should be of particular concern to Australian operators.

g. Increased head down time.

Automation may increase the proportion of time that crews must spend with their "heads down" attending to tasks such as instrument scanning and data entry. As a consequence, in comparison to the crews of older generation aircraft, the crews of advanced technology aircraft may spend less time scanning the external environment (ICAO 1992). Crews must be particularly vigilant for traffic in busy terminal areas below 10,000 ft. It is of particular concern that in this environment ATC clearances are frequently changed, requiring attention in the cockpit while the FMS is reprogrammed (Weiner 1989).

h. Crew preparedness to deal with failures.

System failures are rare, and crewmembers may be un-prepared to deal with them if they occur. In 1987, the SAE G10 Automation Subcommittee warned that relaxed crews may have insufficient time to properly assess a situation and take effective action. The 1991 Lauda Boeing 767 accident may be related to such a problem.

i. Mode awareness

It is becoming increasingly apparent that crews are not always fully aware of FMS modes. Weiner (1989), in a study of pilots flying the Boeing 757 found that only about 70% of pilots claimed to always know what mode the autopilot or flight director was in. Sarter and Woods (1992) found that the most frequently observed problems during transition to the Boeing 737-300 were knowledge of what modes were available on the FMS, how to disengage modes and keeping track of automatic mode transitions. The following example of an inability to disengage mode is taken from Sarter and Woods:

During the final descent, the pilots were unable to de-select the APPR mode after localizer and glideslope capture when ATC suddenly requested that the aircraft maintain the current altitude and initiate a 90 degree left turn for spacing. They tried to select the ALT HOLD and HDG SEL modes on the MCP to disengage the APPR mode and comply with the clearance, but neither mode would engage and replace the APPR mode. They finally turned off all autoflight systems. p 311

In addition, pilots were sometimes unaware of the current active target values in automated systems and occasionally had difficulty getting the systems to accept data. In light of the apparent problems with FMS modes, Sarter and Woods believe that advanced technology aircraft need better FMS mode indicators.
The Airbus A320 accident at Strasbourg appears to confirm the significance of mode confusions in advanced technology aircraft.

j. Pilots operating advanced and traditional aircraft

It has been suggested that if pilots become accustomed to the automated features of advanced technology aircraft, they may be less able to adjust to less automated aircraft. (Norman and Steinmetz 1988) This is of particular concern in airlines which have mixed fleets of new generation and older aircraft, and where pilots may progress from an advanced aircraft to an older generation type in the course of their career.

k. Pilots "out of the loop"

An important distinction is made between loss of situation awareness and loss of system awareness.

(i) Loss of situation awareness has come to refer to a situation where the pilot develops an erroneous perception of the state of the aircraft in relation to the outside world (Schwartz 1988). As an example, a number of authors have suggested that the pilots of the Korean Airlines flight KAL007 may have incorrectly programmed the flight management computer and then failed to detect the diversion from planned track. Although this aircraft was not an advanced technology aircraft according to the definition in this report, the issue is relevant to advanced aircraft.

(ii) Loss of system awareness refers to the situation in which a pilot is unaware of the system state of the aircraft or develops an erroneous idea of how the systems perform in particular situations. An example of this is the incident involving the China Airlines Boeing 747 *Classic* where the crew lost control of the aircraft whilst in the cruise at 41000 feet. The crew was apparently unaware that the autopilot was progressively increasing angle of attack in a futile attempt to maintain a constant altitude when the aircraft is not capable of maintaining altitude on only three engines at 41000 feet.

l. Reduced crew numbers.

There is concern that outside traffic search will be detrimentally affected by the reduction in crew numbers (e.g. BASI 1991, Weiner 1989). The need to scan for traffic is greatest at low level in terminal areas, yet this is when crew attention is often required inside the cockpit to input data or monitor systems. It should be noted that in one of the closest air misses involving a small aircraft and a large passenger jet in Australia, it was the flight engineer who first saw the light aircraft.

3.3 ORGANISATIONAL FAILURES

a. Design-induced errors

It is important to recognise that crew errors may reflect inadequacies of system design This point is argued strongly by Norman (1988) . Some of the features which have been implicated in serious errors are; long and tedious keyboard entries, complex operating modes, interactions between modes and automatic compensation for failures without pilot awareness (Gabriel and Braune 1989).

Automation has the potential to eliminate small errors while creating the conditions for large ones (ICAO 1992). At present, there is no evidence to indicate that such errors have increased in frequency with the introduction of advanced technology aircraft. Weiner et al (1991) compared the LOFT performance of McDonnell Douglas DC9 crews with crews on the new generation McDonnell Douglas MD80 and failed to find any differences in the frequency and severity of the errors which occurred in the two types. The field of human computer interaction (HCI) can provide useful methods for the study of errors in high technology, automated systems (e.g. Norman and Draper 1986) where it is recognised that errors frequently indicate design deficiencies.

There are a number of wider, philosophical issues about automation which must be acknowledged. Bainbridge (1988) has argued that designers of automated systems face two ironic problems. The first is that , by attempting to design out an "unreliable" human operator, designers may introduce operating problems of their own. The second is that designers who try to automate the human out of the system, end up with a parcel of unrelated tasks which could not be automated. The human operator is then left to perform these tasks.
Billings (1991) and others have called for aircraft automation to be human centred rather than technology driven.

b. Management attitudes,

It has been suggested that airline management sometimes encourage crews to use automation in situations where crews may feel more comfortable hand flying the aircraft. Weiner (1989) has referred to this as the "we bought it, you use it" attitude.

c. ATC interface with automation

In many respects, the ATC system has not kept up with the features available on advanced aircraft (Weiner 1989). For example, the ATC instructions given to crew do not always make optimal use of the special capabilities of advanced aircraft.

Chapter 4

Summary and Conclusions

The early interest in traditional ergonomic issues of advanced technology flightdecks has given way to more sophisticated human factors evaluations of these aircraft. However, the "knobs and dials" issues of flightdeck design must not be ignored. Accidents such as Kegworth serve as a reminder that cockpit ergonomics remains a significant problem.

In many respects, the new errors types which occur in advanced technology cockpits have more in common with the familiar errors which plague users of everyday computerised equipment than with the traditional problems of stick and rudder flying. These new error types include data entry errors, monitoring failures and mode selection errors. Violations, or system "workarounds" are also common to both advanced aircraft and ground based automated equipment.

To overcome these errors, it is important to deal with the conditions which promote them. Perhaps the most important need is to ensure that pilots are kept "in the loop". That is, that they are aware of the mode status of the aircraft at all times, and have a sufficient understanding of system functioning to the extent that they are no longer "surprised" by the behaviour of the aircraft. To ensure that crews have adequate mental models of automated systems, training must emphasise not only rule based learning, but also a detailed knowledge of the systems.

It is essential that crews know how to manage automation and can move comfortably from high levels of automated flight to lower levels (or vice versa) as the situation demands. Management of automation is particularly crucial at times of high workload. It is of great concern that some pilots report that automation has given them less time for traffic scan in terminal areas.

Finally, some wide ranging organisational and system issues remain to be resolved. These include the interface between advanced aircraft and ATC, management attitudes to the use of automation, the design of automated systems and ultimately, the role of the pilot in future aircraft.

Much of the research into the human factors of advanced technology aircraft has concentrated on pilot attitudes to the new aircraft and in general it has been found that pilots are enthusiastic about advanced technology. However, less research has been directed at describing the operational difficulties which are experienced in the operation of those aircraft. Studies which have addressed operational issues have tended to take a generic, non type-specific approach. All of this research has been conducted outside Australia. There is a need therefore, to address the specific operational problems which have been experienced in Australian line operations with the various types of advanced aircraft.

It is proposed that a second phase of the project should address the operational issues of advanced technology aircraft in Australia, covering human factors issues related to specific aircraft types.

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Appendix 1

Investigative Techniques

Investigation of advanced technology aircraft in Australia has been limited to a few incidents and generally, investigators have not had the exposure to any in-depth investigations which would allow development of investigative techniques.

Method

In recognition that BASI can benefit by sharing resources with overseas investigation agencies, in November 1991 a proposal was presented to the Government Air Safety Investigation Group of the International Society of Air Safety Investigators. This proposal outlined possible areas of cooperation in the investigation of accidents involving advanced technology aircraft. It was agreed that the resources and expertise of overseas government agencies would be surveyed via a questionnaire.

The attendance of investigators on training courses conducted by overseas agencies was considered necessary and was viewed as a way by which BASI could build experience relevant to the investigation of advanced technology aircraft occurrences. An investigator attended a NTSB training course entitled: "Investigating Glass Cockpit Aircraft Accidents".

Results

The NTSB course covered aspects of the Lauda investigation, including how data was extracted from aircraft systems. Glass cockpit displays in airline and general aviation aircraft were examined and the information they can provide to investigators was described. Non-volatile memory in advanced aircraft was covered in several sessions relating to Boeing, Airbus and McDonnell Douglas aircraft.

GASIG provides BASI with the opportunity to utilise the resources of overseas agencies and participate more closely on overseas investigations. It is envisioned that the inter-agency co-operation under GASIG will take the form of advanced technology workshops, familiarisation with advanced technology issues and direct contact between government agencies. The survey of government agencies has resulted in a GASIG directory, listing the expertise and resources of overseas agencies.

Summary

It was considered that BASI investigators should attend future NTSB "Glass

Cockpit" courses, as before long virtually all airline aircraft will be advanced technology aircraft. In light of the complexity of advanced systems in modern aircraft, international cooperation between investigation bodies is considered essential.

Appendix 2

Objective 3 Training

Training Method

Recent training undertaken by BASI personnel was reviewed. This included B747-400, B767-200, B767-300, and the Ansett Advanced Technology course.

Training Results

ANSETT AUSTRALIA-ADVANCED TECHNOLOGY COURSE.

ANSETT AUSTRALIA conducted a course entitled "An Advanced Technology Course for BASI Inspectors". The course was conducted in March 1992, and comprised 60 hours of instruction for 10 BASI Investigators. The course included the following topics:-

Avionics Systems
Simulator, Hangar Visit
Airframe Systems
Composites
Simulator & Component Overhaul
Airframe Systems
Propellers
Power Plant/FADEC
Engine Shop Visit

ANSETT AUSTRALIA BOEING 767-200 COURSE

Two investigators completed the pilot ground school on the B767-200 and passed the requisite examinations on Systems and Emergency Procedures to CAA standards. This was a one month full time course.

QANTAS BOEING 767-300 COURSE.

Two investigators completed the pilot ground school on the B767-300 and passed the requisite examinations on Systems and Emergency Procedures to CAA standards. This was a one month full time course involving simulator flying and an observation flight from Sydney to Auckland and return.

QANTAS BOEING 747-400.

Two investigators have completed the pilot's ground school on the B747-400 aircraft and passed the requisite examinations on Systems and Emergency procedures to CAA standards. This was a 3 week full time course involving simulator flying and an observation flight from Sydney to Melbourne and return. Additional full flight simulator training was made available at the completion of the course extending the training by one week.

Training Summary

Training of investigators in advanced technology aircraft systems was carried out by various airlines during the course of the project. It was concluded that this training can best be provided by industry, rather than via an in-house BASI course.