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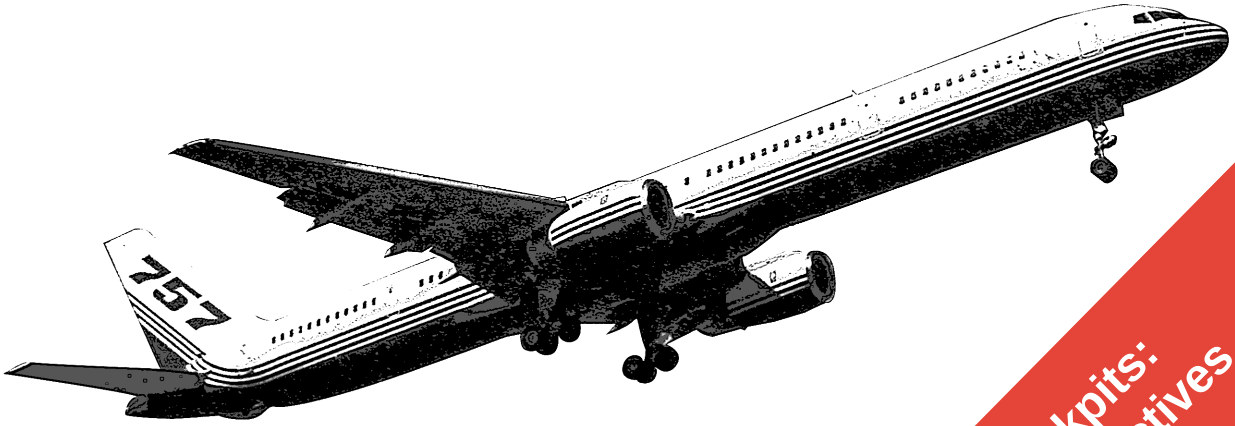
Transition to Glass: Pilot Training for High-technology Transport Aircraft

Advanced-technology Aircraft Safety Survey Report



Glass Cockpits: Pilots' Perspectives

FLIGHT SAFETY FOUNDATION
1947–1999

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In This Issue

About the cover: A Boeing 757 is shown on takeoff. The advanced-technology aircraft has a highly automated flight-management system and an electronic flight instrument system. (Illustration by FSF Production Staff)

Flight Safety Foundation (FSF) is an international membership organization dedicated to the continuous improvement of flight safety. Nonprofit and independent, FSF was launched in 1945 in response to the aviation industry’s need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 700 member organizations in 80 countries.

Foreword

This special issue of *Flight Safety Digest* presents two reports on the experiences of pilots who fly aircraft with "glass cockpits" — that is, modern aircraft with highly automated flight management systems and electronic flight instrument systems. The reports sample the views of line pilots regarding the advantages and disadvantages of flying these advanced-technology aircraft.

The reports resulted from studies conducted by the U.S. National Aeronautics and Space Administration (NASA) and the Australian Bureau of Air Safety Investigation (BASI).

The NASA study used data obtained from surveys of approximately 100 pilots at a major U.S. airline. The surveys were conducted in three phases: during the first day of training to operate an advanced-technology aircraft; approximately three months to four months after the transition training; and approximately 12 months to 14 months after the pilots' initial operating experience in the aircraft.

The BASI report used data obtained from a survey of 1,268 airline pilots flying advanced-technology aircraft in the Asia-Pacific region.

Flight Safety Foundation provides these reports to the aviation community in an effort to ensure wide distribution of useful information on training for, and operation of, advanced-technology aircraft, which are key issues in aviation safety worldwide.

— FSF Editorial Staff

Transition to Glass: Pilot Training for High-technology Transport Aircraft

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Summary

This report examines and details the activities of a major U.S. airline during the period of late 1993 to late 1997, as it acquired two fleets of advanced-technology aircraft, the Boeing 757 and the 737-500. The host airline had planned to purchase 767s during the period of the study, but delivery was delayed for economic reasons. The 767 and 757 are considered a single fleet due to the commonality of their cockpits.

All three aircraft were equipped with electronic flight instrument systems (EFIS), colloquially known as "glass cockpits." There are aircraft with flight management systems (FMSs), but with traditional instrumentation (e.g., some models of the B-737-300). But generally, the glass aircraft have both FMSs and instrument panels that are driven by computer-based color graphics. These are not simply electronic replications of traditional aircraft instruments, but are highly versatile displays that can do what traditional instruments cannot (e.g., the horizontal situation indicator (HSI) moving map display, the display of radar returns on the map, the display of the wind vector and the position predictor vector).

Prior to the delivery of the first 737-500 in January 1994, the airline had no glass airplanes. The most modern aircraft was the 737-300 non-EFIS ("round dial"), with a modern FMS (see above).

Although the primary focus of the study was upon flight training, we examined as well the technical support and management of the pilots in these fleets, in some cases very detailed matters, such as checklist and procedure design.

Questionnaire data were collected in three phases:

Phase 1 — the first day of transition training

Phase 2 — approximately 3–4 months after transition training

Phase 3 — approximately 12–14 months after initial operating experience (IOE)

A total of 150 pilots who were entering 757 transition training volunteered for the study. Three were dropped during data analysis for the first stage due to incomplete data records. Of the remaining 147, 102 returned data forms in Phase II of the study, and of these, 99 pilot volunteers also completed the forms in the third phase.

Face-to-face and telephone interviews were conducted with a sample of 20 line pilots, as well as with flight instructors, check airmen, management pilots and ground school instructors.

As a side activity, at the request of the company, a sample of volunteers going through transition to the 737-300/500 was selected and given the questionnaires, before and after a change in the training program. The company wished to have an independent assessment of the effect of the change. This study will be reported in a subsequent publication authored by Rebecca Chute.

The 757 study found that, by and large, pilots transitioning to the B-757, most of whom were going to their first glass cockpit, had high morale, low levels of apprehension about the transition and a generally positive attitude toward their training and toward cockpit automation. They also shared some concerns, such as what they perceived as a potential for a loss of basic airmanship skills, and an apprehension about having sufficient time for extra-cockpit scanning ("head outside"). These concerns will be addressed in this report.

Start-up Transients

The program was hampered in the beginning by schedule problems due to uncertain aircraft deliveries, at times resulting in insufficient aircraft lines for the number of pilots in training. This in turn resulted in pilots having to return to their previous aircraft, or other aircraft, before they could later be assigned to the 757. At times, the opposite occurred — rapid acquisition of aircraft resulted in pilot shortages and an acceleration of the training schedule. There was also an unexpected bid off of the 757 due to what pilots considered undesirable flying schedules and their disappointment over the cancellation of the 767 order. The 767's extended two-engine operations (ETOPS) capabilities and the promise of transatlantic flying had been great motivators for bidding the 757-767 transition.

The Continental Airlines program differed from other programs in many ways, as discussed in the body of this report. One significant difference was that preparation for ETOPS operations and international flight were built right into the training syllabus. All 757 pilots emerged with ETOPS line-oriented flight training (LOFT) experience. First officers were type rated in the 757/767. The 757 was pressed into ETOPS service (with 180-minute certification) very soon after the program began. Service began with flights from Newark, New Jersey, United States, to Manchester, England, and later Newark to Lisbon, Portugal. In spite of doubts about the marketing issues raised by a single-aisle aircraft in transatlantic flight, the 757 was an immediate success, both with respect to marketing and flight. Ironically, the 757 flights to Europe were so successful that they were taken off the route and replaced by DC-10s.

Pilots entered the transition program with a far more positive attitude toward automation, and less apprehension about being able to make it through the program, than we saw in previous field studies. We believe that this is due in part to the fact that advanced automation, by the time of this study, no longer evoked emotions of uncertainty, and, with certain reservations, had proven itself to a skeptical pilot population. Other factors were the generally positive attitudes prevailing in an airline struggling to emerge from a stormy recent past, marked by bankruptcies, strikes, extremely rapid expansion through mergers and acquisitions, and mistrust between management and labor. By the time the first 757 arrived on the property, there was a "can do" spirit prevailing throughout the pilot ranks, and the rest of the airline. This spirit grew steadily during the years of the study, as we have noted elsewhere in this report. Finally, much of the positive attitude can be credited to the respect for and popularity of the two fleet managers of the 757/767 program and the fact that they were given a free hand to pick the initial cadre of training pilots.

The program made ample use of an advanced flight training device (FTD), computer-based training (CBT), and a full-flight simulator (FFS), modifying the training syllabus as they went. Fine-tuning of the training and the use of the devices took place as the program progressed. The program had the usual start-up transients. The loss of the 767 order was a severe blow.

A Clean Sheet of Paper

The terms "clean sheet of paper" and "free hand" emerged time and again to describe the extent to which the success of the program was the result of unswerving support from higher management. These phrases represented not only the all-important *perception* of support, but the practicalities — that fleet managers' requests were taken seriously and that management did not quibble or "nickel-dime" the managers of the training program. The fact that this support seemed unusual, and needed to be commented on, leads the authors to believe that the lot of a fleet manager had not always been a happy one. More will be said of this in Chapters VIII and IX.

I. Background to the Study

A. Continental Airlines — Summer of 1993

In August 1993, flight management from Continental Airlines (CAL), based in Houston, approached the first author and asked him to consult with them on transition training for pilots who would be transferring to the company's two new fleets of aircraft, the Boeing 757/767 and the Boeing 737-500. Two weeks later in Los Angeles, accompanied by Dr. Everett Palmer of the National Aeronautics and Space Administration (NASA) Ames Research Center, he made a presentation and proposal to company officials, resulting in this study, a cooperative project between NASA, CAL and the University of Miami. Capt. David Lynn, fleet manager for the 757/767 program, was named to be CAL's point of contact for the study. In 1996, Capt. Lynn took over the 737 program, and was replaced by Capt. David Sanctuary, who remained our point of contact to the end of the study.

The fleet at the time consisted of the DC-9, MD-80, DC-10, A300-2B (three-pilot, traditional instrumentation, not to be confused with the A300-600, a two-pilot EFIS [electronic flight instrument systems] aircraft), B-727, B-737-100/200/300 (non-EFIS), and B-747-100/200. In addition, CAL operated Continental Express, flying the ATR-42, ATR-72, EMB-120 and Beech 1900. The 737 was the largest fleet, and will remain so. The most advanced cockpit in the fleet was the B-737-300, with a flight management computer (FMC) but no EFIS, so CAL had no experience with EFIS ("glass cockpit") at that time. [A glossary of terms, mainly those dealing with flight-deck automation, can be found in Appendix B, page 110.] The fleet at CAL proper numbered about 460 [note: henceforth we shall consider only CAL, and ignore Continental Express and Continental Connection]. The A300 fleet has since been retired, and some B-727s have been retired. Older models of the B-737 are also being retired as the 500 models, as well as the "next generation" Boeing 737s, are added to the fleet.

Early in the next century, CAL will have an all-glass, all-Boeing fleet. In 1999 alone, CAL will take delivery of 58 new Boeing aircraft. The consolidation around Boeing aircraft will result in CAL's fleet having five, rather than the present nine, major model types, with predicted savings of $50 million per year (Proctor, 1998a).

Under the leadership of CEO Gordon Bethune, CAL will move in a very short time from an essentially obsolete fleet to one of the youngest in the industry.

B. A Brief History of Continental

Since this study was concentrated at one airline, and one with a turbulent financial and labor history through the 1980s and into this decade, it is necessary to understand some of the history of the company. The authors do not take sides in this discussion, but try to present a dispassionate discussion and understanding of how the company's background and culture developed and how it impacted the present study.

CAL, as we know it today, is the product of many tributaries, including the original CAL ("Old Continental" as it is called by pilots), Pioneer, Texas International, Frontier, New York Airways and People Express. CAL was founded in 1937 out of a Southern California company, Varney Speed Lines. The following year, Robert F. Six became president, and led the company for over 40 years. He built a California-based company concentrating on providing passenger service to the Southwest and later Hawaii. In 1953, CAL acquired Pioneer Airlines, with 16 destinations in the West. Six moved the company from El Paso to Denver, and in 1963, established the headquarters in Los Angeles. In 1968, CAL formed a subsidiary, Air Micronesia, to serve the islands of the Pacific. By 1980, CAL had 180 aircraft. Today it has earned its position in the "middle three" of U.S. air carriers (Northwest, CAL and US Airways), and is currently engaged in forging an alliance with Northwest.

The Airline Deregulation Act of 1978 ushered in a period of extreme turbulence in the airline industry. The experience at CAL was more than turbulent. These were the years of "merger mania." In 1981, the original CAL was purchased by Frank Lorenzo's holding company, Texas Air. CAL was later merged with Texas International Airline (formerly Trans-Texas), but kept the CAL name. It was called by many “New Continental.” The following year, Robert Six, at the age of 74, retired from the airline.

Lorenzo’s Texas Air Corporation (TAC), which already owned New York Airways, bought CAL, then acquired Frontier, New York Airways and People Express. In 1986, TAC purchased Eastern Airlines. In January 1987, TAC folded New York Air, Frontier and People Express into CAL, resulting in two companies of about the same size, CAL and Eastern.

In 1983 Lorenzo took CAL into bankruptcy. The conventional wisdom was that there was no financial justification for his move, that he was using the bankruptcy laws to defeat the unions. Lorenzo allegedly took advantage of the bankruptcy laws to abrogate labor contracts and impose lower wages and longer hours. In the case of pilots, this meant more flying time for less pay. The Air Line Pilots Association (ALPA) joined the machinists on strike. Later, Congress plugged that loophole in U.S. bankruptcy law.

The strike was not well disciplined. Many pilots crossed the picket lines after a brief gesture of supporting the strike. The strike ended in 1985, as the company emerged from bankruptcy. ALPA was decertified as CAL’s bargaining agent. Later, in a certification election, CAL pilots voted to create their own union, the Independent Association of Continental Pilots (IACP). This move has interesting implications for this study, and they will be discussed later.

In 1990, Lorenzo was forced to sell his holdings in CAL and relinquish control. Immediately following this, management again took the company into bankruptcy. In 1993, CAL again emerged from bankruptcy and began the process of rehabilitating the airline.

By 1993, when this study began, there was a spirit of rebuilding and a cautious optimism at CAL. A large fleet of glass aircraft was ordered from Boeing (737-500, 757, 767, and later, the 777), and they became not only the backbone of a new and modernized fleet, but also a symbol of optimism and hope for the airline. The first 737-500 arrived in January 1994, and the first of an initial order of 757s in May 1994. The 767 order was delayed, then canceled, and later reinstated. The impact of the off-and-on 767 order on the crews, the transition program, and this study, will be discussed later. In 1997, CAL and Boeing signed an agreement for CAL to become one of several “all Boeing” airlines. It placed a large order for the 737-700, and later became the domestic launch customer for the 737-800. The 767 order was reinstated. The first 777 delivery took place in September 1998. During the year of this writing (1998), CAL acquired 64 new Boeing transports.

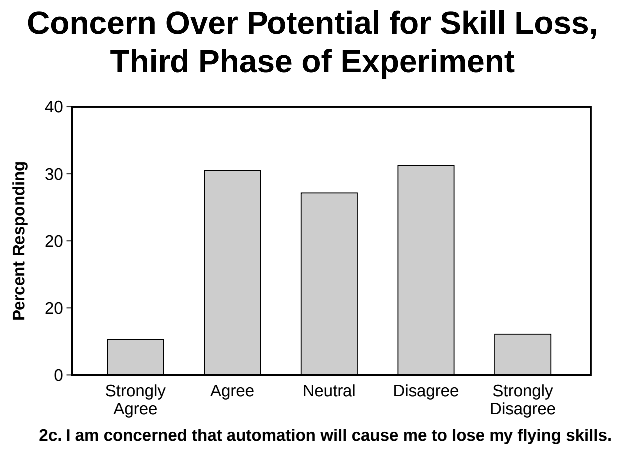
CAL, along with most of the larger airlines in the United States, was enjoying a period of prosperity and profits, high load factors, fleet modernization, and an expanding route structure (Shifrin, 1998). In 1996 and 1997, CAL was cited time and again by business publications and polls as one of the leading examples of a “turn around” company, both in its financial success and the quality of its passenger service. Much of the credit has been attributed to the leadership style of Gordon Bethune (Bethune and Huler, 1998).

C. The High-technology Cockpit

The last two decades have witnessed the rapid and widespread development of an entirely new cockpit technology, based on the capabilities of the microprocessor and color graphics. We will not attempt to review the literature, history or development of cockpit automation, as it is well reviewed elsewhere (see Sarter and Woods, 1994; Woods and Sarter, 1992; Rudisill, 1994; Flint, 1995; Billings, 1997; Wiener, 1988, 1989; Wiener and Nagel, 1988; U.S. Federal Aviation Administration (FAA), 1996). For all of automation’s astounding capabilities, doubts were expressed about the human factors issues raised by robotic flight. For an early version, see Wiener and Curry (1980), and for more recent writings, see Last (1997), Learmount (1996), and Foreman (1996).

Would the average pilot be able to manage the automation and its many modes? Would the hardware and software be able to live up to its claims for workload reduction, thus making it possible to eliminate the flight engineer’s position, and fly large jet aircraft, over oceans, with a two-pilot crew? Would automated flight invite operator “blunders” (large errors) as seen in other applications of automation? Would pilots “fall out of the loop” and not be able to keep up with the airplane? Would manual flying skills become degraded (see Figure I-1)? Some of the doubts harbored by pilots can be seen in the following report to the National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS).

[Note: throughout this report we include, for illustrative purposes, reports selected from a search of the NASA ASRS



Concern Over Potential for Skill Loss, Third Phase of Experiment

2c. I am concerned that automation will cause me to lose my flying skills.

Source: U.S. National Aeronautics and Space Administration

Figure I-1

database for cases dealing both with automation and training. The ASRS form does not ask for information about the employer of the reporter, or identify in any form the carrier(s) involved in the report. If the carrier were identified by the reporter, the information would not be stored in the database. Accordingly, the reports which are sampled and included in the text and in Appendix H are probably not from CAL, and they may or may not concern B-757 aircraft. We chose our cases strictly for their subject matter interest, and they should not be thought of as reports concerning CAL crews, or even necessarily B-757 aircraft.]

> **Narrative:** During IOE training en route PHL to CLE was given clearance to cross 10 miles east of YNG VORTAC at 24,000'. In discussion with check airman on best method to enter this info into FMC, I decided to start down and then work on FMC in descent. I inadvertently selected 10,000' into flight guidance system. Again we went heads down to concentrate on programming FMC for descent path. Moments later CLE center requested our altitude. We looked up as we were through 22,000', leveled out at 21,000'. We informed Center. Weather was clear and controller just said to maintain 21,000', apparently there was no conflicting traffic. This is not a new problem. Automation has taken over in the cockpit. Computers are not learned overnight and need hands on operating experience. It all comes back to “fly the airplane first!” (Accession Number: 116912)

Early Studies

As early as 1977, the first alarm was sounded by the late Elwyn Edwards (Edwards, 1977), who examined for the first time, the broad question of human factors of cockpit automation. At the same time, concerns were being expressed in the U.S. Congress. Two congressional reports identified automation as a safety problem for the coming decade (U.S. House of Representatives, 1977; U.S. Senate, 1980). There was much talk of “the automation problem,” but no person nor any agency was prepared to say with any certainty what “the problem” was. In 1979, NASA Ames Research Center was tasked with examining the safety implications and human factors in automated flight. The congressional subcommittees had no trouble recognizing the positive side; what they wanted to know was whether there was a “down side.” Quite simply, were there also adverse consequences of the new flight decks that the manufacturers, regulators and future operators were overlooking?

The project was assigned to Dr. Renwick Curry, then of NASA Ames, and Professor Earl Wiener, on leave at Ames from the University of Miami. Their collaboration produced a comprehensive report (Wiener and Curry, 1980) on the human factors of cockpit automation, proceeding beyond Edwards’ initial work (1977). They produced a list of 15 guidelines for the design and utilization of cockpit automation. Guidelines from other authors followed (see Billings, 1997). Following the publication of their 1980 paper, Wiener and Curry conducted three field studies of the adaptation of the new aircraft into the fleets of several airlines (Curry, 1985; Wiener, 1985b, 1989).

The Advance of the Glass Cockpit

The decade of the 1980s saw the appearance of the new, electronically sophisticated transport aircraft. The Boeing 767 was followed shortly by the 757, and later glass derivatives of the 737 and the MD-80. In the 1990s, a family of original aircraft was produced by Airbus Industrie: the A319-320-321, the A310, A330, A340, and the derivative A300-600. The A320 series took automation to a higher level than the first generation of glass aircraft, typified by the 757/767 and the A310, introducing fly-by-wire with the side-arm controller and other advanced capabilities. Douglas fielded the derivative MD-11, Fokker produced the F-100, and new models of Boeing’s best-selling 737 soon appeared. The long-haul market today is dominated by a glass derivative of the traditional 747, the 747-400, but the smaller A340 and the B-777 show promise of being the dominant long-haul aircraft of the next two decades (Proctor, 1988).

The new FMS and glass aircraft were considered a great success. The decision of the President’s Task Force on Aircraft Crew Complement (McLucus, Drinkwater, and Leaf, 1981) to allow two-pilot operation of the new jets proved to be wise. This, coupled with up to 180-minute ETOPS authority, brought a new era of economical transoceanic operations for two-engine, (generally) two-pilot glass cockpit aircraft. Under U.S. Federal Aviation Regulations (FARs), for two-engine aircraft, three-pilot crews are required for flights over eight hours, and four pilots when the flight is scheduled for over 12 hours. The success of ETOPS operations was summarized in a news item:

> **“ETOPS Record.** Boeing 767 transports have logged more than 1 million ETOPS flights with 57 airlines. According to Boeing statisticians, 767 operators now log more than 13,000 ETOPS flights a month, many of them across the North Atlantic … Through May [1998], Boeing-built twin-engine transports had accumulated more than 1.2 million ETOPS flights, according to the manufacturer.” (Proctor, 1998b).

Doubts and Reservations

Still, there were nagging doubts about human factors. Pilots were evenly divided on the workload issue; many interviewed by the authors remarked, “I’ve never been so busy in my life [flying the advanced cockpit].” We heard this comment over and over. There was genuine concern over not only workload, but also potential for skill degradation (“loss of scan,” as the pilots call it), though to this day there have been few data put forth to support claims of skill loss. In the single study that we are aware of, Patrick R. Veillette (Veillette, 1995) demonstrated a significant loss of manual skills in crews flying the automated cockpit. Veillette's work is a worthy beginning, but more investigation of this issue is needed, especially as longer and longer flights are anticipated. With 8,000-mile legs, and augmented crews, one can easily imagine flight schedules in which pilots will make as few as one takeoff and landing per month. If their captain is up for a check ride in the near future, it could be even less for the other crewmembers. Figure I-1 (page 6) displays the responses to the probe on skill loss. To see the responses during all three phases of the study, see page 86.

Two comments that we received in our open-ended questionnaire items (Chapter VI) were:

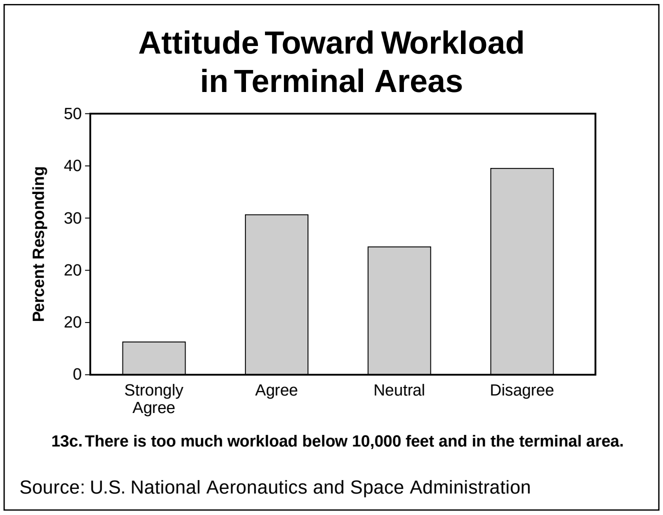
> "[Flying glass results in] more management and less hands-on. Because of the automation being almost fool proof, I tend to hand fly to 15,000 more often. The systems work well, but I need to keep basic flying skills in tune."
>
> "I bid off the 757 because of the automation and bad trips. The only thing I really miss about the 757 automation is the printer. The old technology is real flying, and it's fun. The old technology makes you a better pilot, by hand flying and using your brain."

The concern over skill loss and a variety of other factors on the part of one pilot can be seen in the following ASRS report.

> **Narrative:** Descent from FL200 to 12000', using FMC navigation and autopilot. Approx 15000' entered tops, encountered moderate to severe turbulence, heavy rain. Almost simultaneously ATC cleared to cross 40 southwest LRP, at 12000'. LRP not available immediately due not auto select on VOR, off screen on CRT. Captain (PNF) scrambled to find the runway chart to get the VOR frequency while I got engine anti-ice and ignition turned on. Then Captain began adjusting radar to find out why we were getting heavy rain and turbulence. When DME finally locked on LRP, it read 31 nm (SW of LRP). I deployed spoilers and turned off auto thrust. Rain and turbulence worsened in descent. As we approached 12000', I observed airspeed decreasing. Not immediately realizing, due to concern about the extreme turbulence, that the autopilot was leveling the aircraft at 12000' w/o auto thrust available, I disconnected the autopilot. The aircraft was trimmed nose down and continued descent below 12000'. The captain recognized the problem immediately and called out, "altitude." Flew the aircraft back to 12000' and re-engaged autopilot. Minimum altitude approx 11800'. Contributing factors: proficiency—I am junior on a wide body, have been mostly assigned for last 6 months as relief pilot (cruise only) or with restricted Captain. Consequently, flew 1 leg in Oct, 2 in Nov., 1 in Dec., none in Jan, 1 in Feb., none in Mar. This was only my sixth leg in 6 months. Crew shortage — I am in the middle of widebody transition training (completed FAA oral 3/29. Released from training due to a backed up simulator schedule). Due to crew shortage, sent out on wide body trip during transition training. ATC procedures—assignment of a crossing restriction only 10 nm from the crossing fix, using a navaid which is behind an aircraft using FMC equip, imposed an excessive workload on the crew with too little time to set it up. Fatigue—I was extremely fatigued after being unable to sleep in the hotel in Paris. Hotel is noisy during the day when crew is sleepy, stuffy at night. Company refuses to change hotel. (I do not smoke or drink alcohol.)
>
> Recommendations: The issue of proficiency of relief pilots on long range flights should be addressed. Captains in the widebody operation on our airline do not feel obligated to give legs to the relief pilot. Once having initiated transition training on new equip, a pilot should not be required to operate a previously qualified equipment type w/o at least one simulator refresher period. Constant crew shortages are destroying pilot personal lives. I am beginning to believe that scheduled airline pilot staffing levels need to be addressed by the FAR's. This is a complex subject, but our pilot group is experiencing intense turmoil over the effects of crew shortages. ATC should avoid short range crossing restrictions. Controllers should be trained on operational characteristics of FMC aircraft (e.g., navaids behind the aircraft are not readily accessible). Pilot working agreements do not provide adequate leverage to ensure that pilots are given suitable hotel accommodations. Unsuitable hotels are second only to crew shortages as the major problem in flight ops on our airline. Hotels are changed constantly to reduce costs, and many pilots are complaining about fatigue due to inadequate rest on layovers. (Accession Number: 108752)

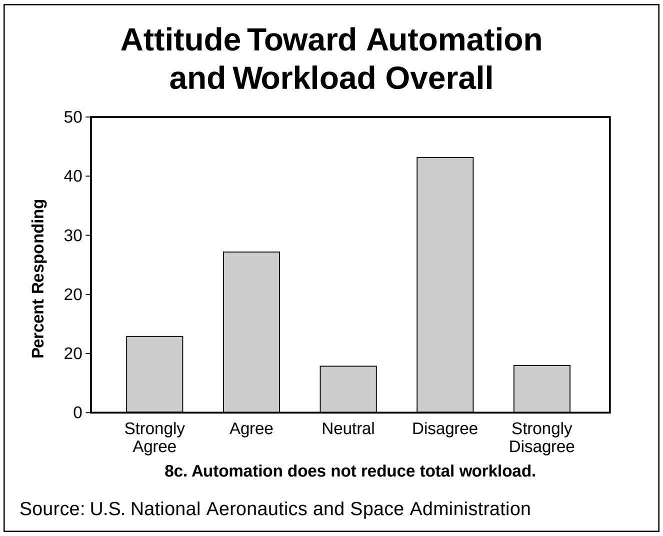
Likewise the question of relative workload in the automated cockpit is still open. For a review, see Wiener, 1993a. A simulator study by Wiener, Chidester, Kanki, Palmer, Curry, and Gregorich (1991) compared performance as well as pilot opinion of crews operating a DC-9 and its glass derivative, the MD-88, flying the same LOFT scenario. The perceived workload was greater for the MD-88 pilots. However, the mean differences were small, and this is but one study by which to judge a very complicated issue. Is the workload higher or lower in a glass cockpit or a traditional cockpit? This question remains to be answered. Responses to two of the attitude probes dealing with automation and workload are shown in Figures I-2 and I-3 (page 9). Graphs showing data for all three phases are on pages 98 and 93.

In a bit of irony, the FAA, citing concerns over the workload induced by automation on a short leg, stopped Mesa Airlines from flying from Fort Worth to Houston (*Aviation Week & Space Technology [AWST]*, May 5, 1997, p. 15). This prompted a letter from DC-9 pilot Bernie Harrigan, who comments



Source: U.S. National Aeronautics and Space Administration

Figure I-2



Source: U.S. National Aeronautics and Space Administration

Figure I-3

(*AWST*, June 30, 1997, p. 6), "I thought such equipment was designed to reduce workload. It would take me no more than 10 seconds to 'program' my DC-9 for such a flight. How far have we come, and where are we going?" Pilot Harrigan might be even more perplexed at an article in which the purchaser of the EMB-145 said that their models "will not be equipped with an FMS chiefly because those systems require too much head-down time in the cockpit and provide no 'payback' during short-haul flights" (Phillips, 1997). The industry had been told that automation would relieve cockpit workload. The question of excessive head-down time appears in all of the field studies and opinion polls that we have mentioned.

Students of glass cockpit human factors also have been concerned about human error rate and severity. Some (see Wiener, 1988, 1989; Woods and Sarter, 1995) have hypothesized that automated flight invites rare but large, high-consequence errors ("blunders") by the very nature of digital systems. Results from the LOFT study mentioned above did not support this view: the error severity was no different when comparing crew errors committed in the DC-9 and the MD-88.

The matter of mode errors appeared in the training programs to be vexing: Pilots transitioning to glass for the first time had difficulty understanding and properly utilizing the autoflight modes. "Mode error" is a broad term: it encompasses selecting an inappropriate mode, not understanding the implications of choice of mode, not realizing what mode was engaged, and failing to recognize that a change in mode had been made not by pilot selection, but by the FMS. Mode errors were to play a vital role in the series of glass cockpit accidents that was to follow (Degani, Shafto, and Kirlik, 1995; Degani, Shafto, and Kirlik, in press; Hughes and Dornheim, 1995; Hughes, 1995; Phillips, 1995).

Glass Cockpit Accidents

In June 1988, an Air France A320 crashed while making a low pass over the field at an air show in Germany. Misuse of automation modes was blamed. Less than two years later, another A320 crashed in Bangalore, India, due to mode mismanagement. Following this came a string of accidents and dramatic incidents involving first Airbus, then other manufacturers' high-technology aircraft (Sekigawa and Mecham, 1996).

With the situation appearing to be somewhat out of hand, *Aviation Week & Space Technology* published a two-part series on the automated cockpit, edited by David Hughes and Michael Dornheim (1995). We will not comment further on these accidents, as they are well covered elsewhere (Hughes and Dornheim, 1995; Billings, 1997), as well as by the official accident reports, most of which have been translated into English. For a detailed discussion of human error management, see Reason (1990) and Wiener (1993b). We do not cover in this study the expanding area of the effect of national and regional culture on accident rates, acceptance of modern technology and crew resource management (CRM) training. The reader wishing this is directed to Johnston (1993a), and to Helmreich and Merritt (1998).

Starting in December 1995, it was the Boeing 757's turn to be the center of attention. First, an American Airlines B-757 (Flight 965) crashed into a mountain while initiating an approach to Cali, Colombia (Aeronautica Civil of the Republic of Colombia, 1996 [in English]). This was the first hull loss accident involving a major, U.S.-operated glass airplane.

Two more 757 accidents followed in short order. The first was a Birgenair aircraft that crashed offshore near Puerto Plata, Dominican Republic (Phillips, 1996b). In October of that year, an Aeroperu 757 crashed offshore of Lima (McKenna, 1996b). The Cali accident is regarded by many as a turning point in the brief history of the glass cockpit: a flight crew without a clear picture of where they were or a clear plan for the approach once they accepted a runway change, and over-relying on automation, when hand flying and basic instruments would have been sufficient. The U.S. aviation establishment noted that heretofore the automation-induced accidents occurred exclusively on foreign soil, and were the work of foreign carriers, and mostly foreign (Airbus) manufactured. This time it was a U.S. carrier. (At the time of this writing there has never been a crash of a large glass cockpit passenger aircraft in the United States. There have been crashes of glass-equipped commuter aircraft.)

Although there was the inevitable disagreement about the causes of the individual accidents and the role that automation played, and considerable denial on the part of the manufacturers (see Hughes and Dornheim, 1995; Dornheim, 1995), more and more people in the industry were willing to admit that there were serious problems at the pilot-automation interface, as predicted by Edwards (1977) and Wiener and Curry (1980). One concern was the relatively weak role played by the FAA certification process in guaranteeing safe designs. In defense of the FAA, it must be recognized that certification standards simply did not exist. The certification requirements of FARs Part 25 were based on an earlier era of autoflight, when sophisticated FMSs were unknown. The FAA could not be expected to enforce what did not exist. FAA certification personnel were well versed in traditional areas: propulsion, aerodynamics, structures and guidance. They were not prepared for the flight management systems of the 1980s.

Recognizing the need to develop human factors certification standards for modern autoflight, the FAA appointed a committee, chaired by Dr. Kathy Abbott of NASA Langley, and Stephen Slotte and Donald Stimson of the FAA, to study the interface problem and make recommendations to the FAA for implementation of certification standards. Their report (FAA, 1996) contains a long list of recommendations that will form the blueprint for future design and certification of pilot-automation interfaces (North, 1998).

The FAA study in turn brought a flurry of activity in the United States and in Europe. The research community saw the report as a blueprint for studies that needed to be done to support the FAA's certification effort with timely human factors data. In the United States, the "alphabet" organizations also wanted their influence to be felt. For example, the Air Transport Association (ATA) appointed Capt. Frank Tullo (CAL) to head its Human Factors Committee. The Automation Subcommittee is chaired by Dr. Tom Chidester (American Airlines).

The inevitable question arising out of the accidents is whether glass aircraft are more or less safe than traditional models. Boeing produced data (Boeing, 1997; Daily, 1997) that showed the mean time between hull loss accidents to be considerably greater for glass than for conventionally instrumented aircraft. Confirmation of these results came from Airbus (Davis, 1997; Sparaco, 1998). An example of a classic controlled flight into terrain (CFIT) accident in an old technology aircraft (Boeing T-43, the military version of the B-737-200) occurred in Croatia (Phillips,1996a). The data provided by these two manufacturers are difficult to interpret, since the old technology planes flew more in earlier years, when many things were different — less safety equipment apart from the flight guidance systems, ATC control and weather information were less developed than in the recent 18 years of glass cockpit operations, and the warning and alerting devices that we know today are fairly recent. In addition, the glass aircraft are superior in many ways apart from instrumentation: better wings, better engines, and better cockpit procedures, perhaps even the CRM movement, to mention only a few.

The original Boeing data were computed before the 757 accidents. Later, the figures were recomputed, including the 757 accidents, and the new technology aircraft still had superior safety records.

Perhaps we are asking the wrong question. We should be focusing not on comparisons of glass and conventional aircraft, but on recognition of the fact that all new transport aircraft will soon be FMS equipped, and will probably be glass equipped. The question should be reworded and made more constructive. The question we propose is simply this: What can manufacturers, operators and governments do to maximize the reliability of human and machine performance of modern aircraft and enhance safety? (See McKenna, 1997).

In this report we shall concentrate on but one aspect of that question, pilot training, and in particular training for first-time transition to FMS and glass aircraft.

II. Transition to Glass

A. Introduction

In this chapter, we shall briefly outline the problems encountered when pilots transition from traditional cockpits to glass cockpits for the first time, the research issues, and the practical decisions facing the airline training community. We shall discuss later in the report possible intervention strategies for dealing with these problems.

Reviewing the literature in automation and training, Wiener noted (1993a) that very little has been written on the broad subject of training pilots to fly high-technology aircraft, and even less on the more limited topic of first-time transition to glass. The situation is still, six years later, about the same. A welcome addition is Sherman's dissertation (1997), in which he brings the general automation literature up to date. Also of great value are Billings' NASA report (1996) and book (1997) on cockpit automation. Billings remarks (1996, pp. 121–122): "Training must be considered during the design of *all* cockpit systems and should reflect that design in practice. Particular care should be given to documenting automated systems in such a way that pilots will be able to understand clearly *how they operate* and how they can best be exploited, as well as how to operate them."

By the late 1990s, the aviation community became more concerned about training for high-technology cockpits, largely as a result of a number of dramatic accidents and incidents occurring, first in Airbus, later in B-757 aircraft (Hughes and Dornheim, 1995). It is inevitable that following an accident, especially one in which the causes include lack of understanding of autoflight modes, that the method and adequacy of pilot training in the advanced cockpits will be questioned. The accident occurring in 1995 to American Airlines flight 965, a 757 on approach to Cali, Colombia, was particularly incomprehensible, perhaps because of the airline involved. American enjoys a reputation of leadership and uncompromising quality in its pilot training.

Over-use of Automation?

The Cali accident exposed to the public some of the hazards of autoflight, and much was written both in the human factors literature and the public press about the presumed over-use of automation. We will discuss over-use and under-use of automation elsewhere in this report. But the accident, and the reaction in the press, centered around training. Why were the pilots not better trained to use the proper autoflight modes, or to revert to manual flight? Why did they not make use of the information available (e.g., distance measuring equipment [DME])? We are mindful of Curry's (1985) plea for "turn-it-off training," made 10 years prior to the accident. Criticism of training that over-emphasized automation was coming from all directions.

Even the usually conservative *Aviation Week & Space Technology* spoke up editorially. In an editorial in early 1996 (*AWST*, Feb. 12, p. 66), immediately following the Cali accident, under the title "Failing grade for FMS training," the editors waded into the controversy in the first sentence, writing, "The training of airline pilots in the use of flight management systems (FMS) is clearly inadequate, and airlines, aircraft manufacturers and avionics suppliers should get together to pursue better solutions." Not the usual stuff that *Aviation Week & Space Technology* editorials are made of. Two months later, they carried an article by Morrocco (1996) in which he quotes Terry P. Newman, a senior test pilot in the U.K. Civil Aviation Authority and member of the FAA automation team (FAA, 1996) as complaining that pilots are being encouraged to make use of automation "at every possible opportunity, particularly the autopilot, because it can do a better job than you."

Newman said, "The effect of excessive confidence in automation has been noted in some accidents where the crews are turning to the autopilot in an attempt to resolve a deteriorating situation."

In September of the same year, the magazine again editorialized under the heading "Training is no band-aid for bad design" (*AWST*, Sept. 2, 1996, p. 228), stating, "Unfortunately automation has neither removed human error nor simplified the pilot's job. Instead, engineers have used the power of the computer revolution to cram more functions into smaller boxes, more information onto displays, and more options into flight management systems than the average pilot has any hope of mastering." A comprehensive report by Galante (1995), which included a field study of actual performance on the line, identified reasons why pilots "click off" the autopilot, or certain flight modes, and continue with a lower level of automation. She did not, however, relate these to training. The following NASA ASRS report illustrates the concern with over-reliance on automation.

> **Narrative:** Cruising at FL370 inbound to BDF VOR on J105 from the southwest. Kansas City Center gave us clearance to cross 70 nm south of BDF at FL330. I do not clearly recall how far from BDF we were at that time. But we immediately began to program our newly fully compliant flight management computer (FMC) for the descent. We twice attempted to set up the descent using the full FMC capabilities but were not successful, so we then reverted to the more basic FMC capabilities and were in the process of starting descent when the controller inquired if we were going to be able to make our crossing restriction. He added that we had only 9 miles to go. I immediately reverted to a manually controlled descent, i.e. throttles idle, speed brakes deployed and maximum rate of descent. We told the controller that we would try to make the crossing restriction. I believe that several factors contributed to this incident: 1) this was my second trip after being off this aircraft for four months. I had been to wide body recurrent training in Oct. and had renewed currency in the simulator. That simulator does not have the "full-up" FMC. 2) my copilot was a qualified Captain on wide body who was on his first trip after requalifying, 4 months since his last wide body trip. Both pilots are dual qualified, i.e. simultaneous qualification on other equip. 3) we were attempting to utilize the new full up features of the FMC, but neither of us were proficient in its use. Nor had we been given any hands on training on the new features. 4) we had earlier, with the help of a written text, programmed the FMC to cross BDF at FL240 and were not expecting the FL330 restriction. 5) we neglected to refuse the clearance when it appeared doubtful that we could not comply. 6) we both allowed ourselves to become "mesmerized" by the computer programming, which we were both trying to learn by doing. 7) I believe I suffer from, as I believe many pilots do, a reluctance to revert to basic skills and methods, abandoning the advanced technology in our modern aircraft. That technology seems to lure one into a dependence and therefore a state of unwillingness and unpreparedness to come to the realization that operating the equipment in the "real world" ATC environment is not the same as a sterile simulator. This impression seems to me to be reinforced by the "official" insistence that the technology be used as it is an integral and essential part of the two man crew concept. I feel that we have

> neglected to emphasize that the technology has its definite limitations in this real world. Had I been more prepared to override the automatic features of the flight guidance system I feel we would have had no problem complying with the clearance. (Accession Number: 59982)

So at least part of the training agenda has been defined as a result of the accidents and incidents of the first half of this decade, and the field studies that had uncovered the problems even earlier (Curry, 1985; Wiener, 1985b, 1988). It is now clear that training for autoflight must include not only proficiency in each autoflight mode, but also training on mode selection for the task at hand, and turn-it-off training as well. In order to achieve this, not only must training methods and curricula be modified, but administrative support for the pilot's right and duty to use or not use the automation as he/she sees fit must be clear.

Aviation automation practitioners and researchers should note that we are not alone in recognizing the potential problem of over-use of automation. The maritime world as well suffers from presumed over-reliance on automatic devices. A brief article in *Professional Mariner* magazine (December/January 1998, pp. 68–69) describes the grounding of the cruise ship *Royal Majesty* near Nantucket Island, Massachusetts, United States, in June 1995. The U.S. National Transportation Safety Board (NTSB) determined that the probable cause of the grounding was "over-reliance on the automated features of the integrated bridge system; Majesty Cruise Line's failure to ensure that its officers were adequately trained in the automated features of the integrated bridge system and in the implications of this automation for bridge resource management [an adaptation of CRM for ships]; the deficiencies in the design and implementation of the integrated bridge system and in the procedures for its operation; and the second officer's failure to take corrective action after several cues indicated the vessel was off course." All of this language should sound very familiar to those who have read aviation accident and incident reports involving high-tech aircraft.

Automation Philosophy

Relief came in the form of an "automation philosophy" statement (Wiener, 1985a), pioneered at Delta Air Lines, then CAL, then several others. The Delta statement appears in Wiener et al., 1991. The CAL statement and its development are discussed in Chapter VII of this volume, and the various forms of the automation statement are in Appendix F (page 130). The Delta and CAL statements, and imitators that followed, say essentially the same thing: The pilot must be proficient in all autoflight modes, but the selection of the mode or modes to be employed (including, presumably totally manual flight) rests with the crew. There are, to be sure, practical limitations on this. Federal Aviation Regulations (FARs) require the use of certain automatic features for low visibility approaches. Pilot discretion, except in an emergency, stops at the doorstep of the FARs.

Chidester, writing of American Airlines' approach to the question of authority to select modes (1994, p. 8), said:

> "What we are trying to establish in the classroom, and through this article, is to encourage our pilots to develop their judgment on how to use the automation on their aircraft. Many pilots report feeling pressured to always operate in the highest mode of automation available. We need to remove that perceived pressure and encourage pilots to choose among the modes in any given situation. To do that, we need to review what has been automated, some of the documented effects of automation, and some lessons learned."

All of this translates into a training requirement. It is incumbent on the training syllabus to ensure the first requirement, total proficiency in all modes, and to instruct as well on the tactics of mode selection. The first task is relatively easy — it is what flight training has been for years, only now with modern, extremely flexible, equipment. The second task is much more difficult. Not only must the pilot be taught discretionary use of autoflight modes, he also must be examined and graded on his choices. In a previous field study on the 757 (Wiener, 1989), during an interview, a captain had this to say regarding a simulator check ride: "All my life the FAA examiner has been turning things *off*; now they make us turn everything *on*." The problem of autopilot mode errors was first pointed out by Wiener and Curry (1980), and has been a popular subject for automation researchers (see for example, Degani, Shafto, and Kirlik, 1995; in press) as well as the operational community. As we have previously pointed out, autopilot modes and their potential for human error have been discussed by many authors, so we will not pursue this, except to say that this is a major area of concern for transition training, both in the pre-simulator and the simulator phase.

B. Research Methods in Flight Training

We shall note briefly here the various research methods that are available and appropriate for examination of pilot training for and transition to high-technology cockpits. A somewhat more detailed presentation can be found in Wiener (1993a).

Opinion Surveys

The opinion or attitude survey is widely used, due to its relative ease of administration and analysis. Wiener (1993a) listed 10 studies employing attitude measurement. Other pilot attitude studies have since been published, including Sherman, 1997; Sherman, Helmreich, Smith, Wiener, and Merritt, 1996; Gras, Moricot, and Poirot-Delpech, 1994; Rogers, Tenney, and Pew, 1995; Tenney, Rogers, and Pew, 1998; Sarter (1991); Sarter and Woods (1993, 1994, 1995); Woods and Sarter (1992); Madigan and Tsang, 1990; and the Australian Bureau of Air Safety Investigation [BASI] (1998).

Most experimenters have been content to display the results of each attitude probe by tabular or graphic means, and perhaps test certain hypotheses using attitude data (as in the present volume). These investigators are contrasted with those who have done extensive multivariate analyses on their data. Two examples of the latter approach are the work of McClumpha, James, Green, and Belyavin (1991), and Sherman (1997).

Attitude surveys have been criticized for being superficial, and not obtaining "real" data, hard performance measures that one would prefer in human factors work. A considerable literature has developed defending attitudes as measurements of performance; as reviewed by Sherman (1997). In the typical survey experiment, the sample sizes tend to run in the area of 100 to 200. Often the population being sampled is small by definition (e.g., MD-11 pilots going through transition training at a certain airline). McClumpha et al. (1991) defined a larger population, European pilots from a variety of aircraft, leading to a sample of 572, which is at the high end of sample sizes so far. Sherman (1997) made use of the vast database constructed by Helmreich and his colleagues at the University of Texas, with sub-populations in the thousands (see Helmreich and Merritt, 1998; and Sherman, Helmreich, and Merritt, submitted for publication).

The value of pilot opinion data, when hard data such as performance measures during a simulator run might be preferred, will never be fully resolved. Opinion surveys are above all easy to do and relatively inexpensive. In contrast, one simulator session can cost as much as US$2,400. The data from attitude surveys are valuable per se, for example in evaluating a hardware design or a training method, or a general belief such as the probe used in this study: "I have no trouble staying 'ahead of the plane.'" As many authors have asserted, attitude data can be taken as imperfect measures of system performance.

In-flight Observations

Observations taken from the jump seat during line operations are the ultimate in realism. Examples are Helmreich and Foushee, (1993); Helmreich and Merritt, (1998); Degani and Kirlik (1995); and an extensive study of mixed-line flying of various models of the B-737 by Lyall (1990).

In-flight observations are difficult to come by for a variety of reasons:

1. In-flight observation requires a trained observer, familiar with the aircraft systems, air traffic control, flight regulations, and flight-deck procedures. Human factors personnel with those qualifications are rare. Often this problem is overcome by using retired pilots as observers, which creates a training requirement of its own. Former pilots may be familiar with the environment, but are not necessarily good observers, and their expertise in human factors may be modest.

2. Observing, and especially taking notes or logging data, may be frowned upon by the crew. It is one thing to have a passive observer in the jump seat; it is quite another to have someone logging data. The airline cockpit is one of the most exclusive work environments known, outside of government, military, or law enforcement operations, and this is jealously guarded by those who work there. Exclusive or not, who among us would enjoy having someone observe our work day, occasionally writing something on a clipboard or punching keys on a digital device whenever we say or do something, or perhaps when we do nothing?

3. Cockpit observing is expensive and possibly inefficient. It is efficient in that the experimenter does not have to build or buy anything — the "laboratory" is furnished by the airline, air traffic control (ATC) and the FAA. The inefficiency comes from the paucity of occurrences of the events that the observer may be looking for, e.g., TCAS encounters, certain kinds of errors in using the automation, or perhaps CRM behaviors of a specified type. One can fly many legs and never see what it is that he is looking for, since it is usually low-probability events that are of interest.

4. There is the age-old problem of observation effects. The mere presence of an observer may alter the behavior of the crew. This is difficult to overcome, and can probably only be overcome by long-time exposure with the same crew.

Observation of Training in a Simulator or Flight Training Device

Both the simulator and the lower-fidelity FTD offer a highly valid platform from which to observe not only the behavior of the crew, but the device and the instructor as well. In our research on transition to glass, these observations were invaluable. Simulator training was observed in many field studies, including Curry, 1985; Wiener, 1985b, 1989; Wiener et al., 1991; Sarter, 1991; and Woods and Sarter, 1992.

This approach has some of the same problems as those encountered during in-flight observations, as described above. However there is clearly little or no observer effect: the instructor absorbs whatever anxiety there is about being observed. The human factors observer is insulated from the crew, stationed in the back of the simulator cab, out of sight, out of mind.

The same observations that we made with respect to cost and difficulty of in-flight observations apply to the simulator as a research tool: qualification of the observer, cost of the device, and rarity of event if the observation is looking for something specific. Usually in research into transition to a higher level of automation, the observer's scope is wide-angle. He/she is interested in almost anything that reveals what happens when pilots move from low-technology to high-technology cockpits.

Experiments in Simulators

The simulator offers the ideal compromise between the valid but uncontrolled real world of line flying, and the highly controlled, but far from valid, experimental booth. The simulator's validity is extremely close to the "real thing," but it still has drawbacks that the experimenter must consider.

1. For all its realism, the simulator scenario is still not line flying: No lives and no equipment are at risk. As absorbed as simulator pilots may be, they still know that they are in a box, on the ground, and no amount of simulated ATC chatter, weather, electronic visual scenes, or motion is going to change that.

2. For the human factors experiment, the extreme realism of the simulator comes at an extreme price. In one simulator study of automation effects, (Wiener, et al., 1991), the study had to buy simulator time (on two simulators — DC-9 and MD-88) and instructor time, and in addition pay for a pilot-observer. Fortunately pilot volunteers served as subjects without compensation.

3. Airline simulators are not equipped for human factors research. Additional equipment to record parameters, sample data, and record pilot inputs may be required. (The addition of closed-circuit TV cameras in the simulator cockpit, to facilitate LOFT debriefings, has been a boon to the human factors researcher.) More and more experimenters are turning to research simulators (such as those at NASA Ames and NASA Langley) for their work. These simulators are either built ab initio to provide for data collection, or they are retrofitted airline simulators.

4. Following a simulator study, the experimenter is left with a massive data-reduction task, long before statistical analyses can be performed. It may take several person-years to reduce the data to usable form, particularly if the variables under study are qualitative (e.g., quality of CRM behavior) rather than flight parameters.

As examples of simulator-based experimentation, we recommend Foushee, Lauber, Baetge, and Acomb, 1986; Wiener et al., 1991; T. Abbott, 1995; Sarter and Woods, 1995; and Veillette, 1995.

C. Difficulties in Transition Training Programs

The emergence of the glass cockpit brought a host of training problems and failure rates in transition training heretofore unknown. The typical failure rate that was reported in the early 1980s and mid-1980s was in the neighborhood of 15 to 17 percent. Dornheim (1992), describing the development of MD-11 training by Douglas, quotes an almost unbelievable figure of 40 percent failures in transition to the MD-11 in its early days. Typically the failure rate in transition training to various models with conventional cockpits has been less that 1 percent. Something was clearly amiss. After a complete redesign of training programs, and the investment in very expensive flight training devices, the rate was brought down to about 2 percent.

Before continuing, we should take note that the alarming rates no longer exist, and the failure rate for transition to glass is in the 1 percent range (Wiener, 1993a, Dornheim, 1996b). In the present study, only two pilots from the original sample of 148 failed the 757 transition course, and both were highly unusual cases where motivation and personality, not the pilots' ability, nor the quality of the training program, was the clear explanation.

We shall next discuss a few of the possible causes of the initially disastrous training situation encountered by most carriers in their early experience with transition to glass cockpit technology.

Misinformation and Misconceptions

Pilots arriving at transition training often came with a stock of misconceptions. There was a collection of bizarre accounts of glass aircraft taking over from helpless pilots. One such story that swept the airline community tells of an A320 that entered a holding pattern and could not get out, imprisoned by advanced electronics! It did not help the trainers that pilots arrived with such accounts, mythical as they were.

Defeatist Attitudes

The outrageous stories, along with rumors (some correct, unfortunately) of high failure rates, led to pilots arriving for training with attitudes of self defeat. They also had heard that the program was impossible — the popular saying that ground school for the transition to glass was like the proverbial "drinking from a fire hose." At other airlines where we had conducted field studies in the decade of the 1980s, it was said (in one form or another) that every pilot on his/her way to transition training had a neighbor who had a cousin who worked for a man who lived next door to a pilot who had washed out of glass transition training. It was also commonly stated that the older captains could not pass the course, due to their lack of computer familiarization, and perhaps due as well to the general prejudice about old dogs and new tricks. It is little wonder that some captains showed up at the training centers with an overpowering sense of impending defeat. Many withdrew their bids and returned to their traditional aircraft.

Dornheim (1992, p. 93) wrote of his own frustration with his introduction to the complex automation of the MD-11:

> "The simulator session gave me a rude awakening about the realities of modern glass-cockpit aircraft. I expected some takeoffs, landings, approaches to stalls, engine failures and other maneuvers. Instead, I received a frustrating walkthrough of the automatic flight control system and endless complexities of the flight management system (FMS). I was irritated at first, but then I realized that this was what it was all about — pushing buttons and memorizing FMS screen pages."

Dornheim continues in this article to trace the design and even the costs of the various training devices employed by Douglas for its MD-11 training. Costs of training are also discussed in Chapters VIII and IX.

Poor Curriculum Planning and Implementation

Much of the blame lay not on the rumor mill, but where it belonged, on those who designed the training syllabus. Most researchers who have examined this area agree that the basic problem was that the early curriculum planners were hidebound, attempting to design their programs as if they were training pilots for the 727.

The first author attended 757 ground school at two major airlines in 1986. At one, in the first session of the first day of ground school, the instructor taught the class control display unit (CDU) operations, including how to build "man-made" waypoints. There was virtually no introduction to the airplane, at a time when one might have had the opportunity to dispel some of the misconceptions and ease the minds of the students. They jumped immediately into the most difficult and unfamiliar parts of transition to glass.

Some airlines also were poorly equipped with respect to training hardware. At one airline, ground school instruction was slide projector based, but they did not have the customary cubical and projection screen. Projectors and pilots were lined up side-by-side, four to a table, with the projectors pointing toward the wall. At any given time there were four projected images, seldom the same, on the wall in front of the pilots, which they viewed in coordination with recorded instruction.

CRM Taught Separately

The 1980s and early 1990s initiated the era of CRM training (Wiener, Kanki, and Helmreich, 1993; Foushee and Helmreich, 1988); the later 1990s witnessed the integration of CRM with conventional flight training (systems, maneuvers, navigation, etc.) This concept, pioneered by Boeing's flight training group, was the result of earlier misdirected effort, leaving the student with the notion that "real" flight training and automation training were one area, CRM was another.

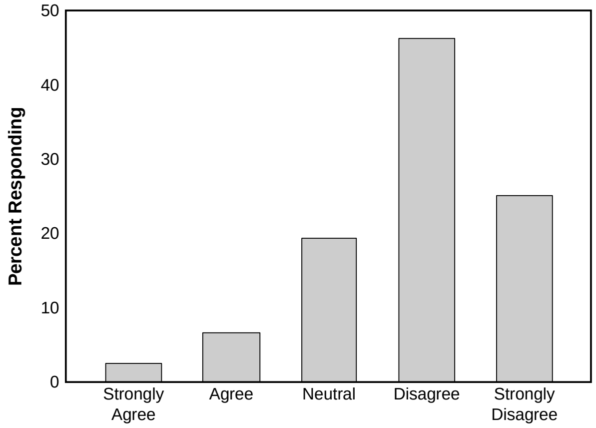
Boeing's contribution was to show that the two were inseparable parts of flight training, and that both went better when taught and practiced as an integrated whole. This integration of the two formed the basis for CAL's training program. [More is said of this in Chapter VII. See also the quotation at the bottom of page 64]. From the first day in the FTD to the final simulator session, procedures, actions and decisions in the cockpit were accompanied by communication training (CRM, briefings, etc.).

Achievements

One by one, the early problems of transition to glass have been solved. The misinformation has abated. Failure rates are virtually zero in the transition programs. Captains and older first officers no longer have distinguishable difficulties attributed to their age or computer skills. Training program curricula have been vastly improved — no more warmed-over 727 lesson plans. CRM has been integrated into flight training, and this is reflected in the carriers' advanced qualification program (AQP) applications. Those companies that offer introduction-to-automation courses early in ground school considered them a great success.

The data in Figure II-1 support the impression that much of the difficulty had been overcome. The data come from the first questionnaire, given the first day of transition training for the 757 pilots (n = 148). About 90 percent of the pilots either reject the probe or take a neutral position. About 10 percent accept the probe, expressing their apprehension about the transition program. We feel certain that in earlier days of glass cockpit transition programs far more apprehension would have been reported. And to our collective relief, there are as yet no documented cases of A320s (or anything else) getting stuck in a holding pattern, beyond the control of the flight crew, imprisoned by their automation, and destined to fly all turns

Self-report of Apprehension upon Entering B-757 Transition Program



8a. I am very apprehensive about going through this transition.

Source: U.S. National Aeronautics and Space Administration

Figure II-1

right, two-minute legs, until their fuel is exhausted and the law of gravity takes over. Such a story today would bring laughter where it once brought apprehension.

D. Training Considerations

In this section we shall discuss some of the factors that must be considered in designing and implementing a transition to glass program, whose ultimate worth will be measured on the line, not in a simulator. We will consider not only the formal design of the program, but various human factors problems encountered in automatic flight, such as the potential for skill loss. The list is by no means exhaustive. The factors that now must be taken into account, particularly when operating under an approved AQP plan, seem endless. This is one of the virtues of the AQP process: it forces the training department of an airline to state its goals, and to perform a detailed analysis of the subject matter, as well as the teaching and learning activities required to reach the specified goals.

Understanding Autoflight

How much does the line pilot need to know about the overall FMS of the 757? This is not an easy question. Should the pilot merely know how to perform the functions he wishes to use in flight, or should he have a larger understanding of the overall autoflight system? Sarter (1991) is critical of the present training methods, criticizing them for a "bottom-up" approach which tells them how to get the job done, but nothing about the overall plan and philosophy of the FMS ("top-down" approach). She argues that with top-down training, the pilot would be better equipped to solve unique problems, diagnose automation "glitches" and avoid illogical or dangerous mode errors, all of this because they would be able to *understand* the consequences of the modes selected, and other actions and selections in using the automation.

There is no simple answer to the problem raised by Sarter. The pilot must be trained to obtain the desired output as a function of his/her input to the automation, and this is bottom-up training by any standard. Is it necessary for the pilot to "understand" the system? Would the accidents that are discussed by Hughes and Dornheim (1995), for example, the A300-600 crash in Nagoya, Japan, have occurred had the pilots been trained under a more top-down philosophy, and the crews better understood the consequences of their choices?

Hopkins (1992) states, "Pilots are unanimous in their opinion that training for the 'glass cockpit' should not be based on the same assumptions which form the framework for conventional flight-deck training, yet it still is." He goes on to quote Capt. Steve Last, a highly experienced pilot and trainer, who said, "We should avoid FMS training with insufficient 'overview' at the start; trainees have difficulty later in synthesizing the detail to see the whole." J. Butler (1991) argues:

> "The principles of training for advanced technology cockpits are not dissimilar to those of older technology. One of the most important aspects remains to select the right people for the task and then to provide the necessary hardware … and training devices to enable a rapid and efficient acquisition of knowledge and skill … The fundamentals of the aircraft operation must be clearly established, understood and supported by all instructors and acquired and complied with by trainee pilots. Training courses, while necessarily concentrating on the acquisition of flying skills, must also place great emphasis upon the human factors aspects of teamwork, crew coordination, communication, leadership, judgment and decision making."

It is tempting to say that line pilots must not only be able to operate but also to understand the FMS. But our corporate memory of earlier generations of aircraft and flight training should disturb us. It was not too long ago that pilots were taught "everything," including details of how systems worked, specifications and limitations, detailed knowledge about systems over which the pilot had no control and were the concern only of maintenance workers. With the coming of the jet age, a new training doctrine arrived: Teach the pilot only what he/she needs to operate the plane, and leave the rest to maintenance.

Learning details of electrical, hydraulic and pneumatic systems, and how they work together, is not the same as understanding the inter-related autoflight modes and how they work together. It is only by research and observation of line experience, including accidents and incidents, that we might some day be able to answer the top-down vs. bottom-up question. In the meantime, the training departments of the world must strike a compromise in determining just what level of detail a pilot must master.

An editorial by *AWST* (Feb. 12, 1996, p. 66) titled somewhat provocatively, "Failing Grade for FMS Training" states, "The training of airline pilots in the use of flight management systems (FMS) is clearly inadequate…" The editorial goes on to discuss the fact that something of a "cottage industry" has grown up in the airline pilot community. This industry supplies unofficial manuals covering cockpit automation. The efforts are well meaning, but not welcomed by flight management, due to the fact that these manuals are not official, are not approved by the FAA or the customer's company. And they may contain errors.

Why do pilots buy these products? As Orlady (1991) pointed out, pilots are never satisfied — they will always say that they need more training. This was confirmed in earlier field studies and in our interviews and open-ended questions in the present study, even though the pilots expressed favorable views of the training program.

Skill Degradation

From our earliest field studies to the present, we have heard repeatedly from the pilots in training for glass, or in their first years of flying glass, of their fear of skill loss due to their dependence on autoflight (Curry, 1985; Wiener et al., 1991; Veillette, 1995). McClumpha, James, Green, and Belyavin (1991), in a large-scale survey of attitudes toward automation of European pilots, also found the same concern, and reported as well that older pilots (> 50 years) and those with more training hours showed less concern. Skill loss is a realistic issue. No pilot wants to stand by and watch the asset he values the most, his flying skill, deteriorate. At some companies, where policies required use of autoflight modes whenever possible, the concern multiplied. Pilots found some relief at those companies which developed automation guidelines such as those derived at Delta and CAL, allowing the pilots, under most circumstances, a choice of autopilot modes (including no autopilot — hand flying).

Many pilots adopted their own code of hand flying. For example, when they were pilot flying (PF), after takeoff they would hand fly to the first level-off altitude, then engage the autopilot; or perhaps hand fly to cruise altitude. Some would hand fly, with or without the flight director, at least one instrument landing system (ILS) approach per trip, weather permitting. The list is endless. The self-imposed rules were taken seriously, almost as if they were regulations. In a previous field study of B-757 pilots, Wiener (1989) reported that 90 percent of his questionnaire respondents stated that they tried to hand fly some portion of each trip, and if possible, some portion of each leg.

Veillette (1995) states four reasons why skill maintenance is important:

1. Manual flying skills are necessary to handle the critical flight regime of the jet;

2. Crews that become task-saturated in terminal areas often revert to manual flying. [This is a well established behavior that we have seen in other studies, both in interviews and questionnaires, as well as in jump seat observations on the line. It should be a discomfort to those who claim that automation implies workload reduction.];

3. Some ATC clearances require a high degree of manual skill, if they are not done using autopilot modes (e.g., “slam-dunk” approaches); and,

4. Manual handling of the aircraft provides information and situational awareness to the pilot. It enhances feedback from machine to pilot.

ETOPS operations also have had an impact on automation usage and the skills maintenance issue. Most companies that operated twin-engine (usually wide-body) jets such as the B-767 and the A310 on transoceanic flights also used the equipment for domestic legs. Some segregated the pilots who were flying the same aircraft into two sub-fleets, ETOPS and domestic. Those on the domestic flight had far less concern about skill loss. The ETOPS pilots expressed fear that they were losing not only manual skills, but automation skills as well, since almost all of their time was spent at cruise, with few opportunities to exercise automation skills, particularly CDU programming. Some ETOPS trips had a domestic leg at the end. Pilots welcomed this as an opportunity to practice automation skills. At the companies that allowed pilots to bid both types of trips, pilots who were concerned about skill loss would typically bid a line that contained two overseas trips and several days of domestic flying in a month. Again, they took this self-imposed discipline seriously. This may no longer be a problem. Most carriers that we are aware of allow mixing domestic and transoceanic trips. Further discussion of the role of company policies, procedures and implementation can be found in Orlady (1991), Chidester (1994), and Degani and Wiener (1994).

Unfortunately there has been almost no experimental work on the topic of skill loss in today’s automated aircraft, the one exception we are aware of being the study by Veillette (1995). What we know about the subject comes from interviews and questionnaires. Thus it is difficult to design an intervention if we do not know the magnitude or locus of the (presumed) problem. It would be difficult, even if a simulator were available, to plan and execute such an experiment.

Backward Transition

Backward transition refers to the transfer of a pilot from a glass environment to a traditional cockpit, and whatever problems this may present. Usually the backward transition requires only one or two days of formal training and a simulator check ride. The presumption is that a pilot who has been flying glass for some time may encounter difficulties if he/she returns to traditional instruments. Once again, we have little in the way of data: only interviews, attitude surveys and open-ended questions. (See Wiener, 1989, pp. 87–92.) We are not aware of any research that directly deals with backward transition. The general sense of what the pilots said was that they had trouble at first, but very quickly overcame it, and within a trip or two were up to the level of proficiency that they enjoyed prior to their 757 transition.

The biggest difficulty in the backward transition from the 757 appeared to be the loss of the HSI map mode display. Pilots in Wiener’s field study (1989) had expressed a great attachment to that instrument, and for better or worse, they had learned to depend heavily on it in the 757. The problem emerged in the need to integrate the information from various displays to determine one’s position. What pilot would not miss this display? While he was training to fly glass, it made navigation, planning and weather avoidance so simple and so precise.

Specifically, the pilots felt at a loss without the map and found it difficult to stay “ahead of the airplane” without this display. Many said that within a terminal area, either on takeoff or approach, if ATC turned them off of the published standard terminal arrival route (STAR) or standard instrument departure (SID), they had trouble taking into account the various navigation displays in the traditional aircraft and knowing where they were. It had been so easy in the 757! Also mentioned was the ease with which radar and navigational information could be combined and displayed on the 757 map. On the traditional displays, they had to extract radar information and then mentally combine it with HSI, DME, automatic direction finder (ADF) and very-high-frequency omnidirectional range (VOR) displays. Again, all of this was "done for them" by the glass displays.

In fact, newly transitioned pilots had to be told not to stare at the map, but to bring it into their scan like any other instrument. There should be little surprise that line pilots would find this to be the feature that they missed the most when they took backward transition to the 727s, the DC-9s and the 747s (Wiener, 1989).

Backward transition is a topic that is interesting to discuss, but probably not very important. Pilots generally do not see it as a problem, at least not after a day or so back in the traditional cockpit. Whatever problems are brought about by backward transition seem to vanish quickly, and problem or not, the whole issue will disappear in the years ahead, when there is no primitive cockpit to go back to. Were it not for the supernatural longevity of the B-727, many airlines would be all glass by now, or close to it.

We raise one more issue before leaving backward transition — the possible loss of automation skills during the period the pilot was re-assigned to traditional cockpits. At some point, this pilot would return to glass and would be expected to have lost some of his knowledge and skills in operating in an autoflight environment. The question for training departments is how much re-training, and what kind, is required to bring the pilot back, hopefully close to the level he had reached in his original glass training.

Ab Initio Training and Very-low-time New Hires

In the latter part of the decade of the 1980s airline service and aircraft began to expand, and military flight training began to diminish. The military service, the traditional source of airline pilots, looked to be insufficient for the years ahead, particularly in Europe and Asia. Other sources, such as flying academies, could not fill the gap. So major airlines in both European and Asian countries proposed *ab initio* (from the beginning) training, whereby young men and women, entering the program with zero flight time, would be trained, usually at airline expense, up to a point where they had their basic licenses (see Glines, 1990, and Telfer, 1993; this topic is also discussed in Chapter VIII). At this point, students would have approximately 200–300 flight hours and a large amount of jet simulator time. They would then go through type training and join the line. The type could be whatever the airline flew, including heavy jets and glass cockpits.

To the traditional pilot or instructor it may be difficult to accept that a low-time pilot trainee just out of "primary training" could occupy the right seat in an airliner. In the United States, there was concern about pilot shortages, but *ab initio* training was never a very attractive solution. One fleet manager told us that he doubted that CAL would ever have to hire *ab initio* pilots. CAL hired 880 pilots in 1998, and their mean total flying time was over 3,000 hours. Each had turbine time. CAL, like many carriers with their own commuter airlines, will draw most of their new hires from its commuter. In the short run, CAL will obtain 100 percent of its pilots from its commuter ranks. Later, there will be a mixture of backgrounds.

The anticipated pilot shortage never occurred, primarily because there are various ways in which a young pilot can qualify for an airline seat in the United States. A 300-hour pilot would have a difficult time finding employment at even the smallest airlines. Inexperienced pilots in the United States have a hard life: they must take any kind of flying job (usually instructing beginning students) in order to build up their hours. The next step is usually the FARs Part 135 charter operator, which serves as a "farm club" for the larger regional carriers and the major airlines. How long he/she stays at a farm club depends on the market. There is some movement toward the pilot applicant, not the airline, to carry the cost of primary training. Some carriers, such as Southwest Airlines, require new hires to have a type rating, in this case for a 737. The airline hiring the pilot may provide, at a price, the necessary training, or the candidate may go elsewhere to obtain his/her type rating.

Finally, let us consider the following question. Consider a low-time, zero-jet-time *ab initio* graduate who is recruited by an airline. If the airline has its choice, where should he/she be placed for the first line experience, the traditional cockpit or the automated model? The traditional cockpit is simpler and more like the aircraft the applicant had trained in. Remember, his/her exposure to autoflight is almost nil. The 737 or DC-9 sounds just right. On the other hand, it could be argued that the very-low-time pilot is best off in a highly automated plane, with a sophisticated autopilot and autothrottle supporting him. Only line experience and research will answer the question that we have posed.

Airline training departments may find it difficult to believe that they will ever hire *ab initio* or other very-low-time pilots. But who would ever have dreamed that over half of the graduating class from the U.S. Air Force Academy, due to the cutback in flying, will now go to non-flying jobs?

Advanced Maneuvers Training

Following a series of airline mishaps and close calls in the latter half of the 1990s, in which the aircraft became severely upset and had to be recovered from an abnormal attitude, some airlines instituted “advanced maneuvers” simulator training for all pilots. Military pilots for the most part had such training [traditionally called “unusual attitudes”], but those who came to the airlines from civilian sources often did not. This training is required at CAL. For a comment from a pilot, see the ASRS report at the end of this chapter. [Note: advanced maneuvers are not part of this study, as the program came after our work at CAL was complete.]

Training Devices

We shall mention training devices only briefly, as so much has been written on this subject. The last two decades have witnessed a rapid development of training devices, both at the high end, the FFS, and what will probably soon be the middle on the sophistication scale, the FTD. The FTD provides pilot trainers with a device with full systems and flight simulation, including autopilot and flight director modes and glass displays. In the interest of economy of both purchase price and maintenance, the FTD does not have a visual scene or a motion base. FTDs offer the pilot trainee an excellent platform upon which to obtain cockpit familiarization, including running checklists, cockpit procedures (normal and abnormal), flight maneuvers and autoflight modes. For a discussion of the importance of the FTD in one program (MD-11), see Dornheim (1992).

The biggest problem is that FTDs are coming at a steadily increasing price, due largely to the number and complexity of autoflight modes that they must simulate. One airline that participated in an earlier field study (Wiener, 1989) found that their FTD, a very elaborate model, was converging in price on the FFS. They canceled their order for a second FTD, preferring to put their funds toward a second FFS. Better to pay more up front in order to have the sophistication and regulatory status that only an FFS enjoys, they reasoned.

At CAL, the 757 FTD (Level 5 out of seven levels on the FAA’s rating scale at this writing) and the CBT were carefully integrated into a logical syllabus. The typical ground school day is: two hours instructor briefing, two hours FTD and four hours CBT. After two weeks of this, they move to the FFS. (At this writing, CAL’s FFS is Level C on the FAA scale, soon to be upgraded to Level D, the highest level). Training emphasizes not only the technical material that had to be mastered, but also checklists, procedures, communications, briefings and CRM.

What seems to be missing in the array of training devices would be a device so small and so inexpensive that it could be provided, along with the software, to each pilot, not only for transition training, but for recurrent, and for incorporation of new devices. One can recall the confusion that existed over the training for the traffic-alert and collision avoidance system (TCAS), and the argument about whether TCAS training had to be in a simulator. We asked in a previous field study (Wiener, 1989) why the personal computer, perhaps as a home study aid and motivator, could not be used to relieve the load on the training center, and particularly on the FTD. This subject is also discussed in Chapter VIII.

Recently there has been some developmental work on using an ordinary laptop computer as an FTD. Stephen Casner of NASA Ames has programmed a relatively inexpensive laptop as a B-737 CBT device, with highly attractive color graphic displays. Nordwall (1995) describes how the U.S. Navy is using laptops for pilot training. He writes (pp. 68–69), “The capability of the new CDNU (control display navigation unit) exceeded Navy expectations. Its use has broadened from a tutorial aid to something pilots can use for proficiency training and dynamic simulation.”

Clearly the potential exists for development of very sophisticated, low-cost personal-computer-based devices. The problem, as always, will be the cost of development and distribution of software. One could envision software upgrades being included in the pilots’ Jeppesen revision envelopes. Certification of PC-based training software is something that the FAA presently is not well-equipped to do. Presently there is also the beginning of a discussion of “Web-based training,” whereby software can be down-loaded from the World Wide Web (WWW) to a personal computer. This has two advantages over conventional personal-computer-based systems: the cost of delivering software is reduced and the uniformity of software is assured. Web-based learning combines the advances of personal-computer-based training with a highly efficient, quality-controlled means of delivering and updating software.

Cost of Training

We shall mention only briefly the matter of cost of training. See also Chapter VIII. We have previously discussed the rising cost of FTDs and simulators, but simulators, while dramatic, are only a part of the picture. Cost considerations in designing a training program cannot be ignored, in the highly competitive and cost-conscious economic environment of post-deregulation operations. Gone are the days when the word *training* was sacred and training departments could get anything they wanted by waving the flag of safety. Today every cost in the training process must be justified, and the justification may be a traditional one drawn from the corporate world, return on investment (ROI). Kelly, Graeber, and Fadden (1993) discuss the ROI principle in flight-deck design (p. 56): “While many operational features provided by a flight deck may be considered desirable, the market increasingly demands return on investment for capabilities as opposed to features.” The same statement could be made about training capabilities, though the direct connection to the marketplace is somewhat less visible. Cost figures are seldom published. An exception is Dornheim’s article (1992) on the MD-11 school at Douglas.

Orlady (1991, p. 2.6) cautions us about assuming that automation can reduce training requirements: “Unfortunately, one of the great myths of automation is that automation reduces training needs. One of the persuasive arguments for further use of automation has been that it reduces training costs. This assertion is patently false, particularly in the areas of manual skills, system knowledge, and the logic of the automatics."

On the other hand, Leonard (1993, p. 149) states that when CBT training for the advanced cockpit is combined with an FTD, "the results have been an overall cost reduction in flight crew transition training and an increase in successful training rates for advanced flight deck aircraft." He quotes failure rates of training for the glass cockpit, in 1984, as 40 percent. He describes the problem in economic terms, saying (p. 150), "This failure rate was unacceptable because extensive remedial training of flight crews was economically unacceptable. The high failure rate dramatically highlights the inadequacy of existing training strategies to develop the cognitive skills required by evolving aircraft technologies." Leonard goes on to describe the development of the MD-11 training package.

Crew Resource Management (CRM)

We will only mention CRM training briefly here, as Chapter VII is dedicated to CRM at CAL. Crew resource management, or alternatively *cockpit* resource management, was first explored by the airlines in the 1970s, and was developed as a commercial product and sold to other airlines by United Airlines. Not until the early 1980s was it widely used or explored (Cooper, White, and Lauber, 1979; Wiener, Kanki, and Helmreich, 1993). CRM training was not an FARs requirement, but its presence as an FAA advisory circular (AC 120-51B) is a clear signal to the air carriers that the FAA has more than a casual interest in this form of training. The AC is usually a precursor of an FAR. Under the AQP, CRM is part and parcel of the training and evaluation. Not only must CRM be included in the training proposal, but pilots will be evaluated on their CRM skills. CAL was one of the pioneers of CRM training; their training approach and materials have been widely imitated.

As we have mentioned elsewhere in this report, the trend today is toward integrating CRM training and technical flying training. This approach has been developed and encouraged by the airframe manufacturers, and was employed by the 757 planners at CAL in their design of the training syllabus. Under the new approach, no longer will pilots be exposed to stand-alone CRM training in the classroom. CRM will be taught in the FTDs, the simulator and in conversation with the instructors as a subject intermingled with traditional maneuver and procedure training. In each maneuver, or checklist, the CRM aspects will be taught along with the technical training. AQP programs also encourage this type of training. More will be said of this in Chapter VII. The importance of learning and practicing good CRM skills can be seen in the ASRS report below.

> **Narrative:** The problem began approx 100 nm south of DCA. The captain was flying. I obtained the ATIS, LDA-DME 18 was in use. That approach is not in our FMS's database so I started to build it. The captain told me not to do that. His explanation was that is one of our simulator scenarios, to check on CRM ability, and he wanted to practice it first. About 5 mins later I stated my concerns about not using all the equipment at our disposal. The navigation display is a great help and we were not going to use it. The captain restated his wishes and I dropped it. While being vectored for the approach, I idented the localizer, however we were not receiving the DME. As we were being turned onto final the captain instructed me to reconfigure my panel to get the DME. This leaves me with no localizer indication and no navigation display. By the time I did this, we received another turn and a descent, 3000 ft down to 2000 ft. Then I noticed the autopilot was not set to capture the localizer. I pointed this out. The captain armed the autopilot. He is new (3 months) to the airplane and was behind. As we descended Approach asked if we had final OK. The captain lied and said 'yes.' Just then we broke out. I saw the river to the right and pointed it out. Approach once again asked if we had the final approach course and gave us a turn to the right. That was very quickly changed to a left turn and climb to 3000 ft. We accomplished this, did the after takeoff checklist and followed more vectors. My situational awareness was shot. I offered once again to build the approach but the captain refused. We were once again vectored to final and I asked Approach what was our relationship to the localizer. We were already through it and getting worse. Approach Control broke us off once again for the VOR 18. We asked for time to review it and set it up. This approach was successful. There was no CRM. The equipment on board was not properly utilized and I was not properly utilized. No matter how much CRM training is given, some people don't get it at the most basic level. (Accession Number: 110413.)

E. Conclusions

What can we conclude at this point in the report? It is clear that many of the problems that were experienced in the early years of the glass cockpit have been overcome. As we noted, the failure rate today in first-time glass transition is about the same as in traditional aircraft, less than 1 percent. But pass/fail does not tell us the entire picture. We must certain that those 99+ percent who graduate and transition to glass do so with the training that will serve them well in their line flying. The line is the ultimate test.

The most striking criticism charges that flight training is not governed by any overall philosophy. Perhaps the final product is an amalgam of philosophies, some complementary, some antagonistic. It is essential today, and will be more essential in the future, that the training package for any aircraft be consistent not only with the best operation of the equipment, but with the objectives of the company and the training objectives of the entire fleet. With a variety of aircraft flown as a common fleet (e.g., the many models of the B-737 that are presently available and will soon be on the line), a unified training philosophy is essential.

As Degani and Wiener (1994) observed, procedures are not strictly determined by the hardware: The same piece of equipment is operated according to different procedures at different carriers. The procedures are governed only partly by the hardware, but also by the philosophy, background, mission, history, operations, and corporate culture of the company. Some differences are trivial (e.g., various ways to set up TCAS modes), some are dramatic. For example, at the beginning of the study, only one major U.S. airline that we are aware of employed QFE (height above field elevation) altimeter procedures. What was it about the flight culture of that company that they, and they alone, found it desirable to use QFE altimetry? In 1998, the company abandoned the use of the QFE altimeter (personal communication, T. Chidester, 1999).

Degani and Wiener interviewed top flight management, starting with the vice president for flight, at three major airlines on procedure development, and asked, "Why do you develop your own procedures? Why not just follow the Boeing (or any other airframer's) procedures?" The answer was always the same: "Boeing designs and assembles aircraft. We fly passengers."

We believe the Four Ps model of Degani and Wiener (Table II-1) could be used profitably in designing training: AQP may have already forced the issue. Their model states that *philosophy* determines *policies*, *policies* lead to *procedures* (or in the matter at hand, training packages), and *procedures* are compared to *practices* (what actually occurs). Without the unifying influence of the first two Ps, training programs are likely to be a hodgepodge. A philosophy-based training program could avoid this and meet the critics' charges that most training programs are based on anything but a unified philosophy. More likely, training programs are based on tradition, convenience, cost-containment and the whims of a dozen or more training directors, fleet managers and newly minted AQP specialists.

We end this chapter on a happy note, an ASRS report where the pilot claims to have saved the day and gives credit to his "advanced maneuvering" training.

Table II-1
Degani and Wiener's "Four Ps"

PHILOSOPHY

POLICIES

PROCEDURES

PRACTICES

Source: U.S. National Aeronautics and Space Administration

Narrative: Conducting a visual approach to runway 23L sidestep runway 23R at MEX. At about 3000 ft AGL aircraft encountered unexpected wake vortex. Aircraft rolled rapidly to right approximately 45–55 degrees. Recovery initiated in accordance with company training for advanced maneuvers. 2 minutes later we were told of a heavy Airbus landing on runway 23L. Had Mexican ATC warned of the Heavy, I could have flown above the glideslope. Callback conversation with reporter revealed the following: Report was used for structured callback and following information was obtained. Reporter had just completed the new program initiated by his company for advanced maneuvers training. The experience with the Airbus was almost identical to the simulator training he had completed. He said it was almost like a time warp where for a nano second he felt he was back in the simulator. He feels that is why he handled the situation so well and with very little stress. He feels strongly that all air carriers should institute such a program. (Accession Number: 307029)

III. Study Methodology

A. Basic Questions and Premises

Our basic premise in designing this study was that information on the detailed features, as well as an assessment of the quality of the training program, could be obtained by seeking data directly from the pilots involved. For example, information could be gained from questionnaires (attitudes, experiences, etc.), interviews, flight-deck observations and direct observation of the ground school training. All of these were essentially subjective measures; we would like to have more objective measures, but these do not exist, or cannot be obtained at a reasonable cost, in most training programs. Even instructors' evaluations of maneuvers, or overall simulator performance, are essentially subjective. The fundamental information upon which this report is based comes from pilot responses to questions (interviews) and questionnaire data, as well as the authors' observations. For a brief review of the attitude surveys related to cockpit automation, see Wiener, 1993a. The list of studies has grown since that writing.

Longitudinal Studies

This study is essentially anthropological. We did not manufacture conditions or manipulate independent variables, as the experimenters did in a previous automation study (Wiener et al., 1991). Like anthropologists, we accepted the "village" of transition training as we found it, attempted to learn something about the culture, and sought to be as unobtrusive as possible. With the exception of our interviews and three questionnaires, we generally achieved unobtrusiveness.

This experiment was designed as a *longitudinal* study. A longitudinal study is simply one in which two or more sets of measurements are taken over the *same sample* during the span of the experiment. This allows the analysis to include not only absolute levels, but to evaluate change, or the effect of time, or other interventions. This is to be contrasted with a *cross-sectional* design, in which each sample is observed only once.

The advantage of a longitudinal study is its sensitivity to change. In this and many other human factors studies of cockpit automation, the primary tool is the attitude scale. A more objective dependent variable, one that is a sensitive measure of the strength and weaknesses of automation, is desirable. Such measures are seldom available. Even in costly and time-consuming simulator studies, there are seldom any objective dependent variables to measure, and the experimenter again turns to subjective measures of automation effects. For an example, see Wiener et al., 1991. In that study, an attempt to measure the effect of automation on the communication of crews flying a LOFT scenario, the independent variable of automation was achieved by collecting data from crews flying the same LOFT in two models of the same aircraft: the traditionally configured DC-9-30 and its high-tech (glass cockpit) derivative, the MD-88. Even here, with full simulation, and a highly scripted LOFT, we ultimately had to rely on observers and simulator instructors to provide the raw data of the analysis. For a thorough discussion of this question, we recommend Gregorich and Wilhelm (1993).

While sensitivity to change over time is the strong point of longitudinal studies, there also are weak points and disadvantages. The more serious disadvantages are cost and loss of subjects from the original sample. The experiments are costly because they must be continued over time in order to obtain two or more data collection points (which we will refer to as “phases” in this study). In this experiment, there were three phases. The greatest hazard in longitudinal analysis is the steady and unavoidable loss of subjects. Subjects lose interest and drop out, simply do not fill out questionnaires, or fail to appear for interviews for a variety of reasons. They may retire, die or be reassigned, become medically disqualified, or most likely, change address and fail to notify the experimenters.

In some experiments (such as this), subjects who drop out for reasons of reassignment may be of particular value. In the present experiment, these were pilots who at least completed the B-757 transition program, and then were reassigned to other aircraft, for administrative reasons related to new aircraft delivery. We were eager to speak with these pilots because of the shortage of information on “reverse transition,” going from a modern aircraft back to a traditional cockpit (see previous chapter, pp. 17–18, for a discussion of “backward transitioning”).

The effect of a pilot receiving training and possibly line exposure to the glass cockpit and then returning to the traditional models is worthy of study: it happens every day, and we know little about it (Wiener, 1989). Questionnaires 2 and 3 (Q2 and Q3) contained a question specifically for pilots who had made a reverse transition (see Appendix D). Some pilots in the early days of the 757 program were sent back to their former planes to await available seats in the 757. As aircraft deliveries accelerated, pilots quickly moved back to the 757 line.

The human subject in a long-term experiment is not an inanimate object or a lab animal. There are inevitable changes in his/her existence that, quite apart from aircraft training and line experience, affect a pilot’s lifestyle, flying habits and certainly on-the-job attitudes. The volunteer in a longitudinal study, particularly a pilot in a highly dynamic industry, is a moving target.

Basic Design of the Study

This study was designed as a three-phase longitudinal experiment. The phases are data collection points, in time, which we designate as “P1,” “P2” and “P3.” The three phases are based on the pilot volunteer’s entry into the program, as follows:

P1: The first day of transition class (ground school);

P2: Approximately three to four months later, a time at which a pilot will have completed transition training, including ground school, simulator and initial operating experience (IOE), and will have started line flying. If there were no delays in assignment to the 757, the pilot should have a month or two of line flying following IOE before receiving his P2 questionnaire form (Q2); and,

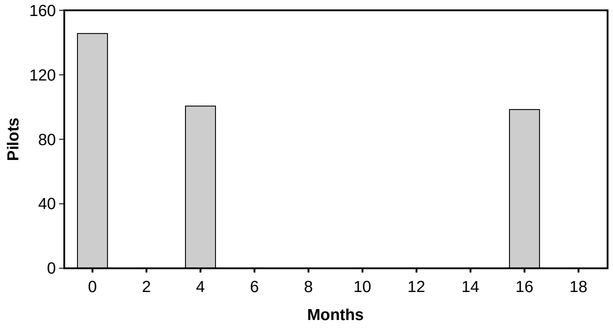
P3: Approximately 12 to 14 months after P2, when the pilot would have about 700–900 hours of line experience in the 757.

The location in time of P1 was fixed: the first day of transition training. A package consisting of the first questionnaire (Q1) was distributed by the 757 fleet manager at the beginning of the first day of ground school. He encouraged the pilots to sign up. The package included the first questionnaire, instructions on how to sign up, a sign-up sheet with informed consent form and a description of the confidentiality protection. The questionnaire can be found in Appendix D. Most pilots who signed up did so on the spot, filled out the questionnaire and mailed it to the authors at NASA Ames. The confidentiality system is discussed below. No effort was made to contact those who did not join the study at P1.

One hundred fifty pilots signed up for the study using the blank in Q1. Three who signed up were later dropped due to incomplete data. Pilot volunteers were considered members of the cohort when their Q1 arrived at NASA Ames. They were mailed Q2 approximately four months later, and Q3 approximately 12–14 months after that. Those who did not respond to Q2 were still sent the Q3 form.

It is possible that a pilot could fill out the forms in the wrong order. That is, he could store Q2 and not send it in until after Q3 had been filled out. Although there was considerable delay in some of the Q2 questionnaires arriving, we have no reason to believe that any were responded to out of order.

Participation (Number of Questionnaires Completed) by Phases of the Experiment



Source: U.S. National Aeronautics and Space Administration

Figure III-1

Thus the delivery of Q2 and Q3 was individually timed to each pilot's entry into the program. However, the time at which the form was filled out and mailed back to us at NASA Ames was completely under the pilot's control.

In summary, the basic experiment consisted of three applications of questionnaires, including among other questions, an attitude scale of 20 to 24 items ("probes"). A perfect record would be a pilot volunteer filling out all three and returning them in a timely manner for inclusion in the database.

Training Books: Data Discontinued

The most objective data that we had available were grades as recorded in what CAL calls training books. These are essentially grade books, with pages in the same order as the training syllabus. At the end of each graded session (e.g., simulator periods) the instructor would enter the grade. The pilot trainee retained his own book as he progressed through the program. When the training was completed, the necessary sign-offs were made in the book. When everything was complete and satisfactory, the pilot delivered the training book to his chief pilot, and at this point the pilot was ready for IOE and line qualification in the airplane. The training book was destroyed. No grades were kept — only the fact that the training was completed.

The training books were made available to the project. Unfortunately, they proved of little value, since nearly all of the grades recorded were the same. This was due to the fact that in airline training, the company is looking for standardization and conformity to a standard. It is not looking for unusual virtuosity. This is somewhat embedded in the nature of airline pilot training. A maneuver can be done satisfactorily or unsatisfactorily; it cannot be done "beautifully." If some grades were unsatisfactory, the maneuver was repeated. Given the skill and motivation of the trainees, and the instructional skills of the trainers, it is not surprising that nearly every grade was "satisfactory." Therefore, to our disappointment, the training books were of no value for statistical evaluation, and were destroyed.

CAL's grading system

1 Close to perfect

2 Excellent

3 Average

4 Satisfactory, but needed to be repeated

5 Unsatisfactory

B. Questionnaires: Attitude Scales, Demography and Flying Experience

Questionnaires

The questionnaires are included in Appendix D. Q1 and Q2 are reproduced in toto; Q3 is essentially the same as Q2, except for some demographic questions, which can be found on page 125. To conserve space, the parts of Q3 common to Q2 were not replicated in this report.

The questionnaires consisted of three parts:

1. A Likert-type attitude scale (see example below) dealing with opinions about flight safety, piloting and particularly cockpit automation. There are 20 items ("probes") in Q1 and 24 in Q2 and Q3. Certain items in Q2 and Q3 were inappropriate for Q1, since the pilots had not yet taken their 757 training;

2. Demographic data, mainly questions about past flying experience, but also questions about age, computer usage and aircraft preferences; and,

3. Open-ended questions which allowed pilot volunteers to express their beliefs and feelings in their own words. These were read and classified somewhat subjectively by the experimenters (see Chapter VI). No statistical treatment was performed on these data.

Q1 was both a recruiting and data-gathering instrument. It contained a description of the study, a sign-up sheet and an informed consent form. In addition it contained a 20-item

Likert scale, in order to measure pilots' attitudes as they entered 757 training. Demographic information also was obtained (see Chapter IV).

With the loss of the anticipated data from the training books, we had to rely more heavily on the questionnaires, interviews and direct observations. The raw data from the questionnaires were entered into a computer database at NASA Ames, and data files were sent to the University of Miami for analysis. Statistical analysis and graphics design were performed using the *SPSS for Windows 6.1(a)*™ package. Most of the demographic data are displayed graphically in Chapter IV.

Likert Scales

Likert scales for measurement of attitude are in wide use. They are easy to design, easy to administer, and the format is generally familiar to the population being sampled. In brief, an item consists of a statement ("probe") which can be positively or negatively stated. The respondent replies by accepting one choice of a multiple choice of items showing the agreement/disagreement with the probe and the degree of this sentiment. This is called an intensity scale: the respondent states not only whether he/she agrees or disagrees, but the intensity of this belief. Usually there is an odd number of choices, and the center is one of neutrality. The center choice is somewhat ambiguous: it could possibly mean "no opinion," "undecided," "don't care," or a truly neutral position on the content of the probe.

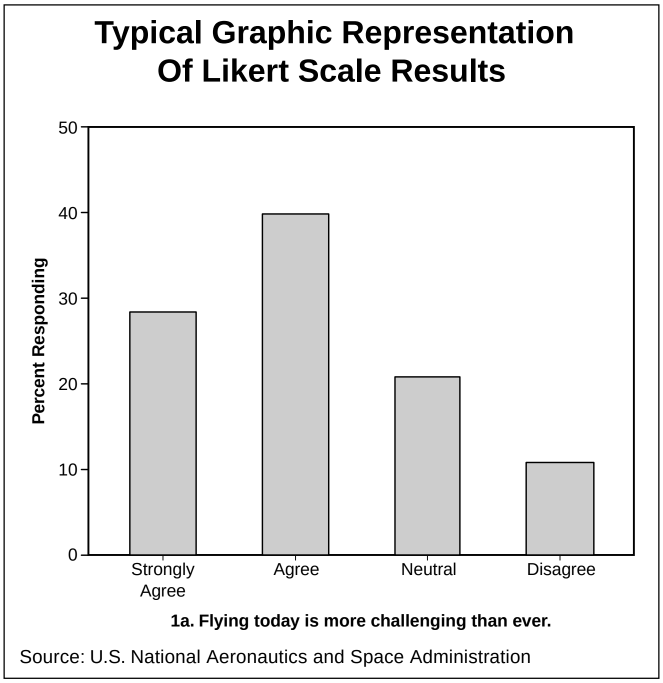
For a summary of the results of several studies employing this technique to measure attitudes toward cockpit automation, see Wiener (1993, pp. 216–220). Since the publication of the first review, there have been more such studies, including a large-scale sampling of U.S. air carrier pilots by Sherman (1997).

Likert data can be treated as coming from a *nominal scale* ("strongly agree" and "agree" are simply categories of response, having no ordinal or numerical relationship to each other, or as an *ordinal scale*, meaning that the responses to the probe could be put in a logical order: "strongly agree" is stronger endorsement of the probe than "agree," which is stronger than "neutral," etc. Many experimenters treat Likert responses as if they are from an *interval scale*, attaching numerical values to the responses. For example, "strongly agree" would be scored as a "1," "agree" as a "2," etc., and the results handling statistically as if interval scores had been generated. The problem here is that the numbers and intervals are entirely arbitrary: using 1,2,3,4,5 as numerical values treats the distance between responses as psychometrically equal: The distance in attitude intensity between "strongly agree" and "agree" would be assumed to be the same as between "agree" and "neutral," a questionable, though oft-made, assumption.

The Likert data are displayed as in the example below at various places in this report. The entire set of graphics is displayed three to a page (Q1, Q2 and Q3) so that the reader can view longitudinal differences. The graphs are found in Appendix A.

Demographic and Flying Experience Data

All three questionnaires contained questions of a demographic nature; most dealt with flying experience, at CAL and elsewhere. Most of these data are displayed graphically in the following chapter. Due to the attrition in the study, the sample sizes vary as shown previously. The demographic data are based on all of the questionnaires that we received. Thus some pilots may appear in Q2 or Q3 or both, in these displays. All pilots appear in the Q1 data — filling out that form was the entry path into the study.



Source: U.S. National Aeronautics and Space Administration

Figure III-2

Confidentiality

Volunteer pilots were assured of confidentiality. A method which was previously used in our studies was employed: for details, see Wiener (1989, p. 12). The confidentiality system was based on self-assigned combinations of letters and numerals to a maximum of six characters. In the portion of the Q1 form in which the pilot signs up to join the study (Appendix D-2), pilots were instructed to assign themselves a code which they could remember but would not identify them. They were also given a self-adhesive tag with a matrix of boxes into which they could enter their identification (ID) code; it was suggested that they keep it in a flight manual. The code was attached to the sign-up page. When we received the Q1, we set up a separate computer file with the ID code and the pilot's name and address, so that we could contact the pilot if need be. For example, we occasionally received a form with an entire page inadvertently left blank. No other record could link the pilot to his code, and this record has since been destroyed. Q2 and Q3 contained only the ID code, no names or addresses.

Prior to recruiting pilot volunteers, we met with the Safety Committee of the IACP to outline the study and discuss the confidentiality plan. No concerns about confidentiality were raised by the IACP representatives, and they readily agreed to support the study. The investigators offered to brief IACP on the progress of the study, or to hold joint management-IACP briefings. Several of these meetings have been held, and cooperation with IACP was excellent.

In other contacts with the pilots, confidentiality was also preserved by whatever means necessary. For example, in the face-to-face and telephone interviews (next section), we could not pretend that we did not know whom we were talking to. We simply explained this and assured the pilot that we would not record any names or identification codes with the interview notes. The pilots were satisfied with this; in fact no question about confidentiality was ever raised. On jump seat observations, no record was kept of crew names or flight numbers, dates, origins or destinations. We feel safe in saying that confidentiality was simply not an issue in this study.

C. Other Sources of Information

Interviews

Two sets of interviews were conducted. The first was at the initial period of the study, before 757 school had begun. The interviewees were flight management personnel, beginning with the vice president for flight operations. Following him were flight standards pilots, the 757/767 fleet manager and assistant fleet manager, and others in the management hierarchy. These interviews were face to face, and were conducted mostly one on one, with a few being one on two.

The purpose of these interviews was to determine management attitudes toward automation, training methods and standardization, and what problems they anticipated. The experimenter asked prepared questions, but allowed the interviewee ample room to discuss anything he wished. The information gleaned from the interviews was not treated as data, but as background material.

The interviews with the management pilots yielded the following information:

1. A strong confidence in the choice of the 757/767 and the important role of these aircraft in the modernization of CAL's fleet and its route plans;

2. A strong approval of the training plans and syllabi being drawn up by the fleet managers and their staffs;

3. Concern about safety problems in highly automated aircraft and the ability of management to ensure, through training and other support, that automation would not be a problem; and,

4. Concern about standardization in general and the ability of flight management to standardize the 757/767 fleet to harmonize with the other fleets at CAL. The question of cross-fleet standardization and the desire not to make the automated aircraft "oddballs" permeated every discussion. [These interviews were completed nearly three years before the company made the decision to buy the fleet of Boeing jets.]

Jump Seat Observations

The three authors and one graduate student assigned to the project made a number of jump seat observations of line trips on the 757. This was for familiarization; no data were collected on these flights.

Ground Schools

Two of the authors attended ground school on the 757, including the program on human-centered automation training (H-CAT), and the international qualification class. Both authors had a CBT access code and worked on this instruction while in ground school.

Standardization Meetings

Two of the authors attended some of the 757 standardization committee meetings for instructional purposes and at times were called on for advice on matters of checklists and procedures. The study team made several presentations on the progress of the study in standardization meetings.

IV. Characteristics of the Volunteer Cohort

A. Overview

In this chapter, we provide in graphic and tabular form certain demographic information provided about themselves by the pilot volunteers. Most of the information deals with flying time and experience in various cockpits; a minor portion of the chapter covers such variables as the volunteers' age, computer usage and preferences for aircraft. The chapter is organized along the three longitudinal phases of the study and the questionnaire data collected at each phase.

Representativeness of the Sample

As we noted in a previous NASA report (Wiener et al., 1991), an experimenter can never be certain that the sample of volunteers is truly representative of the overall population (all pilots in some circumscribed group). We asked ourselves the following question: Are people who volunteer for a project, who are willing to give their time for no direct gain, attitudinally different from those who do not respond to the call for volunteers? This problem is known in statistical sampling as "non-response bias."

We have no ready answer to this question — the possibility of non-response bias plagues any study based on volunteers. It is generally supposed, but seldom proven, that volunteers for a study such as this may be the "sharper," more capable, more motivated end of the continuum of aptitudes among the population from which they are drawn. If this is true, it may be extended to assume that the attitudes expressed are more positive toward fleet modernization and the role of automation. It might follow from this that the sample would contain proportionally more young pilots than the population, but this is speculation also.

Why does a pilot volunteer to serve in such a study? We feel that we know the answer to this from interviews and open-ended questions. First, many are curious about the study, and many feel that volunteering for a study is the professional thing to do. Others may be attracted by the technological reputation and mystique of NASA. Finally, we feel that many, perhaps most, of the volunteers were drawn to the study by the persuasion of a popular fleet manager who personally called for volunteers at the first meeting of each new transition training class.

We have not answered the question of non-response bias. We have found no obvious bias in our sample. We have every reason to believe that these responses can be generalized to the population of CAL pilots who bid the 757 in those years. This may present a bias in itself: who among the CAL pilots leaves a comfortable position in a traditional aircraft, and for no monetary gain (see below) accepts the trouble and the risk of a transition to a modern aircraft? We have some answers to that question: in previous studies we asked volunteers why they bid the glass aircraft. The answer was usually framed in terms of seeing glass as the future of commercial aviation, and their desire to be on the leading edge of that trend. A number of the attitude probes (see page 89) are aimed at pilots' motivation to bid the new aircraft.

Migration Patterns

At the time of our study, CAL, unlike nearly every other airline in the United States, did not pay pilots according to a "weight differential." Pay was based on longevity at the company, and not on the weight of the aircraft flown. Longevity affected bidding for aircraft seats, trips and bases, as it does at other airlines. This fact has implications throughout the company, as well as for this study. One of the things that the non-differential system does is to discourage "seat hopping," a practice which is costly for a training department and generally wasteful of pilot talent. In other airlines, pilots bid from plane to plane in order to move up the path of weight differential and higher pay. Most pilot contracts attempt to limit seat hopping, due to its impact on training cost and flight proficiency. Some pilots seat hop in order to collect type ratings, as a hedge against possible job loss and re-entry into the market.

At CAL, pilots tend to move around until they find a plane, a base and a schedule that serves their needs, and stay put for what seems, by standards of other airlines, a long stand. The recent base closings and reductions, with Newark and Houston, Texas, expanding, have shattered some pilots' plans, which were based on location rather than aircraft. With no weight differential, pilots based their bids on their own convenience, and did not particularly care which aircraft they flew. Bids reflected desires for bases, schedules, long periods off, etc., and not so much for aircraft type.

Non-differential pay schedules, though financially efficient for the company, can lead to some peculiar results, e.g., senior captains flying low-end aircraft (DC-9, B-737-200), while junior captains were flying DC-10s over the Pacific. We once rode jump seat in a DC-9 with a captain who was one of the most senior in the airline. With his seniority, why was he flying a DC-9, when "heavy metal" (DC-10s and B-747s) and international schedules were available to him? His reply was that he was tired of hotel living, and with his seniority could consistently bid out-and-back trips from Houston (IAH). He boasted that in the last five years, he had spent only one or two nights a month in a hotel.

We found in our early interviews that one of the motivators for a 757 bid was the anticipated fleet of 767s, which was on order for ETOPS operations across the North Atlantic, a highly desirable route. This turned out to have its negative side for this study. When, for economic reasons, the company decided to cancel its 767 order, there was widespread dissatisfaction among the 757 pilots, due to both the reduction of the ETOPs flights and the 757 schedule in general. At CAL, the 757 and 767 are in the same fleet. Because the company could not make good on the 767 lines, they agreed to waive the two-year rule (training freeze) and allow the crews to bid off of the 757. This resulted in a serious loss of pilots in our cohort, one of the hazards of longitudinal studies, as noted previously. The 757 program proceeded, and a new fleet of 777s and 767s is now being delivered.

Thus, a combination of the loss of the 767 fleet, the generally undesirable schedules (in terms of the effort required to earn flight hours), and the assignment of more and more 757 time to Newark (EWR) and less to IAH led to heavy out-migration from the program in the first year of our field study. 757 time scheduled at the Guam base remained unchanged. The situation has now stabilized, and the promise of the 767s, with first deliveries scheduled for 1999, has once again made this a desirable fleet. [Deliveries of 26 767-400s will begin in July 2000.]

In June 1998, after data collection on this study had been completed, a new contract changed all of this and put CAL pilots on a traditional seniority and weight differential basis.

The entire airline had a "flush bid," meaning that every pilot could bid any plane in the fleet. The bidding at CAL was simplified somewhat by a contract that created only three weight classes:

Narrow-body	DC-9, 737-300/500/700;
Mid-body	727, MD-80, 737-800, 757; and,
Wide-body	DC-10, 767, 777.

B. Phase 1 Data

Repeating what was said previously, the first questionnaire (Q1) was attached to the invitation to join the study. To sign up, the pilot filled out the questionnaire, which included the questions whose results are presented in this chapter, as well as a 20-item Likert attitude scale. There was one page that dealt with the confidentiality and self-assignment of the ID code, and an informed consent sign-off. The completed forms were then sent to us at NASA Ames Research Center in an addressed, stamped envelope provided with the invitation and questionnaire.

One attitude probe which appeared on Q1 that was not appropriate in the later phases: No. 8a, "I am very apprehensive about going through this transition" (see Figure III-2, page 24). The results of the Likert probes are shown in Appendix A.

Miscellaneous Information

Of the 101 volunteer pilots who submitted all three questionnaires, all but one were males. One other female pilot filled out Q1, but we never received data from her again. Accordingly, we use principally the male gender in this report. Volunteers were asked to give their age to the closest month. We converted this to years for graphic purposes (see Figure IV-1). The age distribution is consistent with what we have seen in other field studies: the 757 tends to be a mid-career choice. At other airlines with weight differentials in their contracts, bidding the 757 represented something of a stepping stone, from lighter (and therefore less lucrative) aircraft such as the B-737 and DC-9/MD-80 to the "heavy metal." At CAL, with no weight differential, and various reasons for bidding the 757, we still see mid-career pilots making this transition.

We were astonished at the number of "older" (with respect to a mandatory retirement at age 60) pilots bidding the 757 (see Figure IV-1). About one-third of the pilots were within 10 years of retirement when they filled out Q1. With nothing to gain monetarily, this bid probably represented a desire to fly a modern aircraft before retirement. Many reported to us that even with only five to 10 years left, they saw the company rapidly expanding with a glass fleet and wanted to be part of that movement. We will look at where (what aircraft) these pilots arrived from. Professional pride played a big part in the bidding.

Source: U.S. National Aeronautics and Space Administration

Figure IV-1

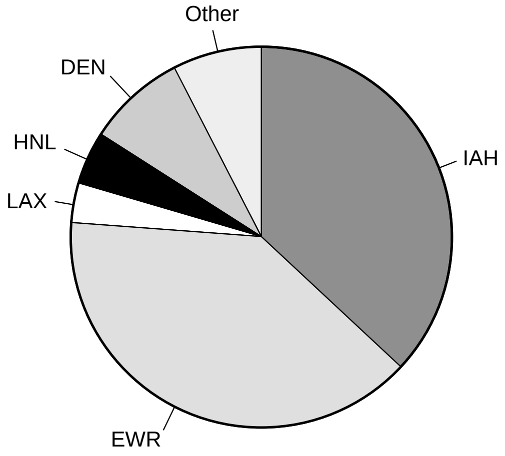
We have said little so far about first officers. Much of what we already have said of captains applies as well to the first officers, and as we will see, their attitudes are remarkably similar. Our first officers tended to be mid-career in that seat, and jockeying for position as a captain of a smaller aircraft. Some senior first officers remained in the right seat of the 757, awaiting an opportunity to bid 757 captain. For most first officers, unless they are very senior, a more inviting route is to bid captain in the expanding fleet of B-737-500s and next-generation 737s. Here they will find the opportunity to utilize glass cockpit knowledge and skills learned on the 757. As seniority builds, there is always a future in the expanding 757/767 fleet.

The present base to which the volunteer was assigned, and his expected post-transition base, were also asked on Q1. The present base is displayed in the pie chart, Figure IV-2 (page 28). The anticipated future bases are easily summarized:

Base	Number	Percent
Houston, Texas	64	43.5
Newark, New Jersey	78	53.1
Other	5	3.4

Note that these are pilots' expectations; the reality of assignments is where the company chose to base its 757 fleet. As it turned out, these were fairly realistic estimates in the aggregate. One can easily see the influence of CAL's two primary bases, Houston and Newark. During the course of the study there was considerable base realignment and closing, including the once powerful and highly desired Denver, Colorado, base. Presently, 757s are based only at Houston, Guam and Newark. This report essentially ignores the Guam base, which even now is a small, somewhat remote part of the

Base of Volunteers at The Time of 757 Transition



DEN = Denver, Colorado   EWR = Newark, New Jersey
HNL = Honolulu, Hawaii   IAH = Houston, Texas
LAX = Los Angeles, California

Source: U.S. National Aeronautics and Space Administration

Figure IV-2

757 operation. The concentration of 757s at Newark has turned CAL 757 pilots into a tribe of commuters, many continuing to live near formerly thriving bases such as Denver and Los Angeles, California, locations of reduced importance at CAL, but still considered desirable places to live.

Computer Experience

In a previous study (Wiener et al., 1991), the authors were curious about the pilot's computer experience, and hoped to relate this to performance in the cockpit. Unfortunately, we asked the question the wrong way, asking merely was there a computer in the home? We should have asked who used it. We sought to remedy that problem in this questionnaire by asking if there was a personal computer in his home, and if so, how often did he (the pilot) use it? For the exact format, see pages 120–121, questions 10 and 11.

The answer to the first question (see Table IV-1), "do you use a personal computer in your home," yielded the following results:

Yes	76%
No	23%

Table IV-1
Computer Usage by Seat

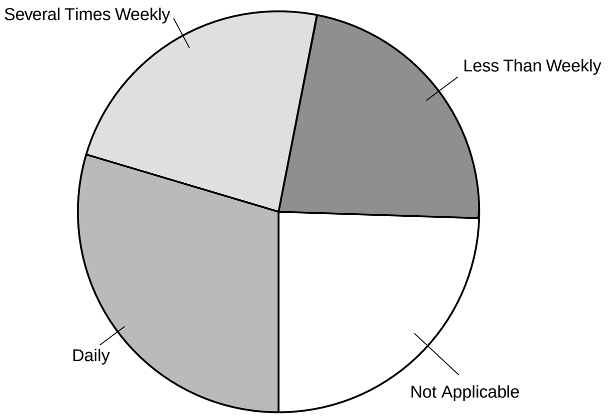
	Do you use a personal computer at home?		
	Yes	**No**	**Total**
Captain	67	17	84
First Officer	45	17	62
Total	112	34	146

Source: U.S. National Aeronautics and Space Administration

It is often assumed that first officers, being younger than captains and therefore educated in the era of digital computers, are more likely to be intrigued by and competent in computers. One might expect to find a higher proportion of first officers with home computers. This is argumentative: one could advance the position that captains can more easily afford computers. First officers may not have the cash to put into computers. We examined this by casting the data into a two-by-two table and performing a chi-square test of row/column independence. This resulted in a chi-square of 1.03, (*df* = 1), indicating that the difference in home computer usage between captains and first officers (80 percent vs. 73 percent) was not statistically significant.

For the roughly three-fourths of the sample that responded positively, the breakdown by level of usage is given in Figure IV-3. Well over half of the sample reported usage daily or several times weekly. We again examined computer usage by captains and first officers, casting the data into a two-by-four matrix (Table IV-1a, page 29). Again the result was not significant: chi-square = 2.04 (*df* = 3).

Frequency of Usage of Home Computer



Source: U.S. National Aeronautics and Space Administration

Figure IV-3

In summary, we find that in our sample of 146 pilots, about three-fourths report having and using a personal computer, with fairly uniform distribution of cases over the four levels of usage. We find no difference between captains and first officers in the availability or usage of the home computer. We shall next attempt to correlate these data with attitude items. We are unable to do what we had originally planned (using the training

Table IV-1a
Frequency of Usage of Home Computer by Seat in 757

	Daily	Several Times per Week	Less than Weekly	Not Applicable	Total
Captain	26	22	19	17	84
First Officer	15	19	11	17	62
Total	41	41	30	34	146

Source: U.S. National Aeronautics and Space Administration

books): attempt to correlate computer usage with proficiency measures.

In Table IV-1a, we have displayed frequency of computer usage by the crewmembers as a two-by-four contingency table. We will discuss the outcome of statistical tests on this and other tables in the next chapter.

The only other experimenter that we are aware of who has gathered statistics on computer usage by high-tech crewmembers is Orlady (1991), who asked pilots of high-tech cockpits how many *had* home computers. The group was about evenly split. Note that if his report is taken literally, he made the same mistake as Wiener et al. did in their 1991 study. The proper question is not ownership, but usage. Orlady took it a step further and asked the group that responded that they did have computers whether they felt their computer experience made any difference in transition to glass. The group was about evenly split (Orlady, 1991, p. 2.12).

Choice of Aircraft

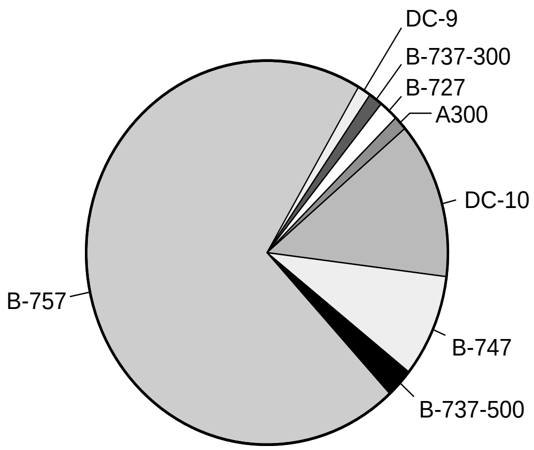
We asked a question we have asked before, requiring the volunteer to pick from his company's fleet the plane that he would most want to fly, quality of trips and pay being equal (see page 121, question 14, for exact wording). The results are displayed in Figure IV-4. The results indicate a strong loyalty for the 757, accounting for nearly three-fourths of the votes. The DC-10 and the B-747 accounted for most of the rest, the remaining aircraft, narrow bodies with one exception, obtained few votes.

Total Flying Time

The two bar charts (Figure IV-5 and Figure IV-6, page 30) showing total flying time and flying time at CAL reinforce what we have said about mid-career pilots, those in a range of perhaps 10,000–16,000 hours. We have made a distinction in the two flying time charts between total time and time at CAL. These disparities exist because, as explained early in this report, CAL is not a "purebred" airline, but one composed of many tributaries (see Chapter I). A large number of the pilots came to CAL in recent years, as a result of the airline mergers and acquisitions engineered during the reign of Frank Lorenzo. Thus the difference between the hours of flying time depicted in the two figures is considerable.

Pilots' Choice of Aircraft In CAL Fleet

First Choice of Aircraft Type Regardless of Money, Base, Etc.

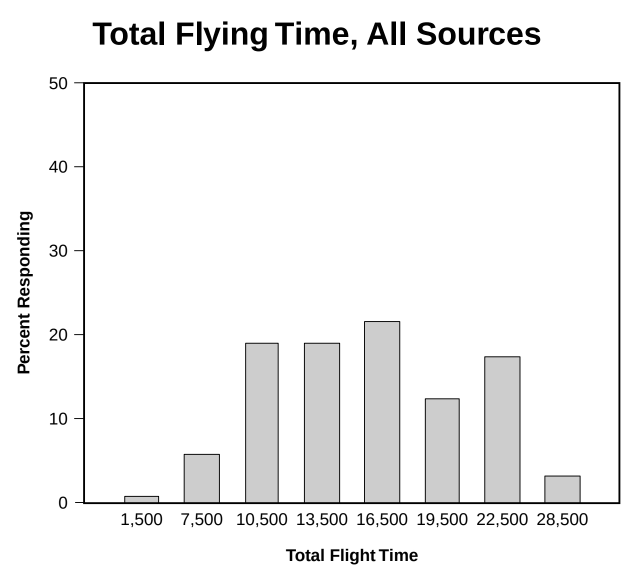


Source: U.S. National Aeronautics and Space Administration

Figure IV-4

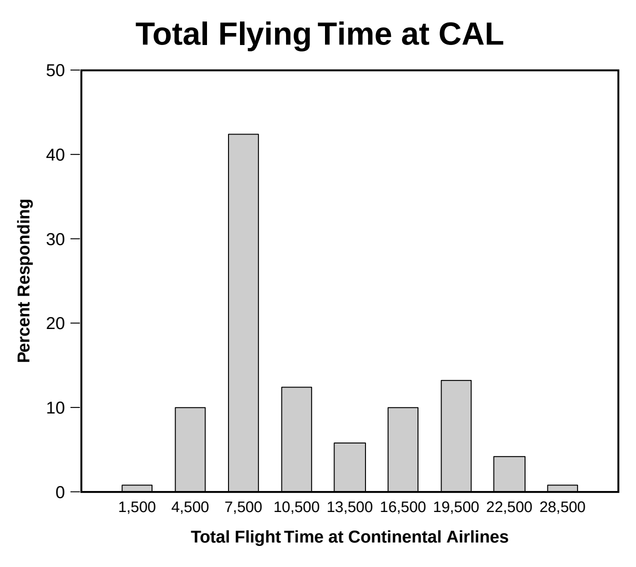
The typical CAL pilot in the 757 program, at the time we collected data (mid-1990s) had about 8,000–13,000 total hours, including pre-merger companies, military, general aviation, etc., about half of which was with CAL. Like the pilots whom we have studied in other projects (Wiener, 1989; Wiener et al., 1991), the B-727 predominates. At every airline we have studied, this is the case. We call the 727 the "prep school for 757." Table IV-2 (page 30) illustrates the importance of the 727 in the migration patterns of the 757 pilot.

Transition from the 727 (or the DC-9 for that matter) to the 757 is a turning point in a pilot's career: a sweeping technological change, and a challenging training program. At most of the airlines we have studied, we have encountered the "25-year 727 pilot." Every airline has a collection of them. He (or she) has spent an entire career in the three seats of the 727 and has little interest in moving. What it takes is a new-technology aircraft, not just a heavier one, and perhaps a subtle threat that the 727 is going to soon be retired. One thing that makes the 25-year 727 pilot somewhat apprehensive about bidding the 757 is that he



Source: U.S. National Aeronautics and Space Administration

Figure IV-5



Source: U.S. National Aeronautics and Space Administration

Figure IV-6

has been to school so little during his career on the 727, compared to pilots who have migrated all over the fleet. And at CAL, with no weight differential, why bother?

Previous Cockpit Positions

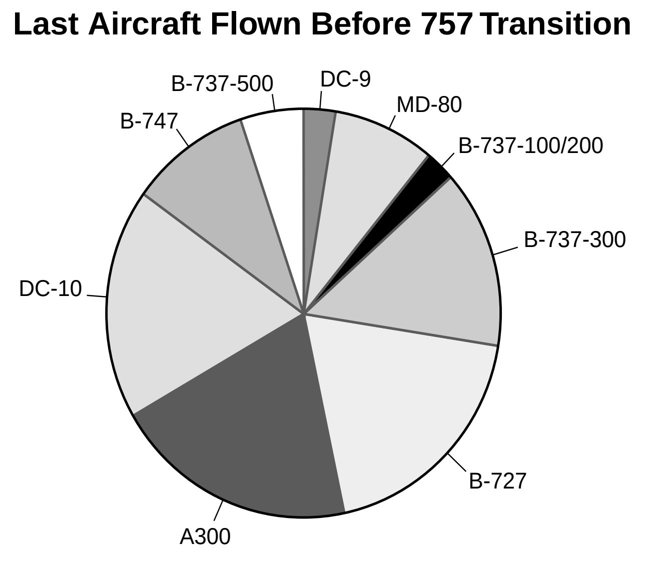
Pilots were asked to fill in a matrix similar to Table IV-2, simply checking each cockpit position they had held at CAL. They were instructed not to include flying time in each seat, only a check that they had at least once held this seat at CAL. Some interesting facts come from this table. We again observe the importance of the 727 in the migration of pilots. Pilots came from a variety of seats, including captains who had flown the three wide-body (“heavy”) jets that were in operation by CAL when the study began (A300, B-747, DC-10). The A300 has since been retired. Again turning to our discussion of the lack of weight differential pay scales at CAL, it is probable that such a bid would not have occurred at other U.S. airlines. The 757 is a mid-weight aircraft, somewhat heavier than the other narrow-bodies, far lighter than the wide-bodies. At an airline with weight differentials, it would be a significant financial sacrifice for a wide-body pilot to bid the 757, whatever his motive.

Table IV-2
Previous Seats Held at CAL
By Pilots in the Cohort

Aircraft Type	Captain	First Officer	Second Officer	Totals
DC-9	25	38	—	63
MD-80	15	17	—	32
737-100/200	9	6	—	15
737-300	23	22	—	45
727	52	64	57	173
A-300	21	9	2	32
707/720	4	19	22	45
DC-10	26	37	23	86
747	14	14	6	34

Source: U.S. National Aeronautics and Space Administration

We next asked the pilots what was their last aircraft before embarking on their 757 transition. Figure IV-7 shows the results. It is noteworthy that they came from so many aircraft, with a sizable number coming from the three wide-bodies. We have not attempted to scale these results to the number of



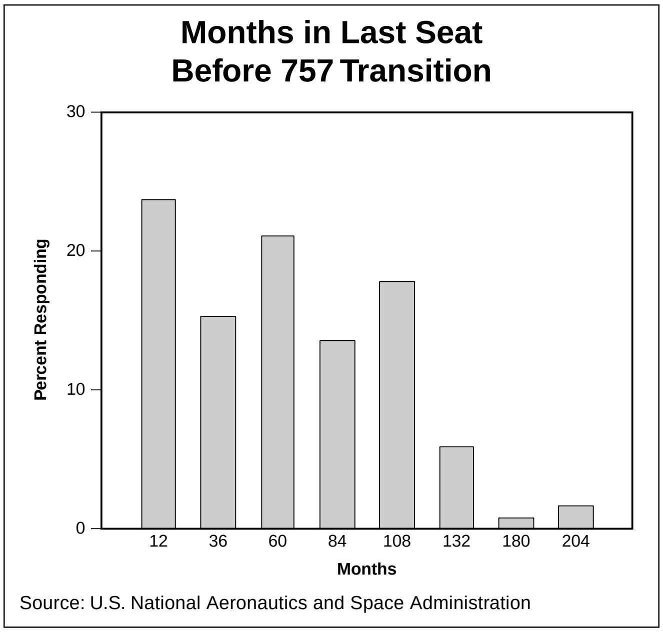
Source: U.S. National Aeronautics and Space Administration

Figure IV-7

aircraft (and crews) in each fleet. The DC-10, A300, 737 and 727 are about equal in their contribution, and the four account for almost three-fourths of the pilots in the cohort. At the time the first 757 classes were being formed, the A300 was on the way out of the company's fleet; their pilots were scrambling for the best deal they could find. The 737-300 at the time was the company's most modern cockpit. CAL's models had the FMS, but not the glass cockpit. This configuration is often called the B-737-300-non-EFIS. At this time, the fleet of glass B-737-500s began arriving.

For the 737-300 pilots, familiar as they were with FMS functionality and Boeing terminology, this was a relatively easy transition.

In order to determine the stability of assignment of the pilots who bid the 757, we asked the number of months in the model flown before transition. These data are displayed in Figure IV-8. Examination of the figure shows that a sizable group (27 percent) resided in the left-most bar (zero to 24 months). Following them were three roughly equal subgroups (25–96 months) accounting for about 55 percent of the sample. Four small subgroups of those with a large number of years accounted for less that 20 percent of the total.



Source: U.S. National Aeronautics and Space Administration

Figure IV-8

How many of the transitioning 757 pilots had previous glass experience at CAL or elsewhere? Pilots were asked merely to list any glass cockpit of any type in which they had been assigned. Table IV-3 displays the results. About three-fourths were 737-500, the rest being a scattering of military and executive jet cockpits. Thus, if we exclude for the moment previous 737-500 crews, it can be said that the vast majority in the cohort had not been exposed to glass prior to 757 transition.

Table IV-3
Glass Aircraft Flown by Cohort Prior to 757 Transition

Aircraft Type	Responses
Northrop Grumman F-14A	1
Boeing 737-500	27
Gulfstream G4	2
Beech C-90B King Air	1
Lockheed Martin F-16	1
Boeing 747-400	1
Embraer EMB-120	3
Falcon 50/Learjet 55	1
Boeing 737-500/Mitsubishi MU-300	1
Saab 340	1
ATR 42	1
Total	**40**

Source: U.S. National Aeronautics and Space Administration

Glass or not, we wished to know the most advanced cockpit that the pilot had flown at any time during his career. The exact meaning of "most advanced" was left to the pilots' discretion. These data are shown in Table IV-4 (page 32). The table indicates a wide variety of airline, military and executive jet cockpits in the experience of the cohort. There are some discrepancies between these data and the previous question about glass experience, probably due to misunderstanding the question.

For example, we cannot explain the fact that 10 pilots claimed to have 757 experience, but this is not reflected in the previous question about glass experience. Also there is a minor discrepancy: 31 pilots claim 737-500 experience, but only 27 listed the -500 in response to the question about past glass cockpits. With the rapid fleet expansion at CAL, with large orders from Boeing for 757, 767, 777, 737-500 and recently for next-generation 737s, and the retirement of the older model aircraft, the figures will change dramatically in the next five years. If these questions were asked five years from now, undoubtedly most pilots would have glass experience, most would list some new model of Boeing aircraft as their most advanced cockpit, and they would not be going through glass transition for the first time. Early in the next century, CAL's fleet will be all Boeing and all glass.

Recent Experience with Various Instrument Approaches

In past field studies, we have asked the volunteer pilots to estimate how many times in the previous 12 months they have flown, either as PF or pilot not flying (PNF), various instrument approaches. [Currently at CAL, the PNF is called the "pilot monitoring" (PM).] The results are displayed in the next five figures. The data must be regarded as estimates, based on the pilots' memory of the previous year. These data

Table IV-4
The Most Advanced Aircraft Flown Prior to 757 Transition

Aircraft Type	Total
Boeing 727	6
Boeing 737-200	1
Boeing 737-300	17
Boeing 737-500	31
Boeing 747	4
Boeing 757	10
Airbus A300	12
Douglas DC-10	20
McDonnell Douglas MD-80	21
Saab 340	1
ATR 42	1
McDonnell Douglas F-4	2
McDonnell Douglas F-15	1
Lockheed Martin F-16	3
Dassault Falcon 50	1
Lockheed C-141	2
Lockheed 53-A Viking	1
IAI Westwind 1124	1
Gulfstream G3	1
Gulfstream G4	1

Seven responses each involving two aircraft were not included in the table: 1. DC-10/A-300 2. DC-10/L-1011 3. DC-10/C-141 4. DC-10/737-300 5. 757/767 6. 757/767 7. DC-9/727

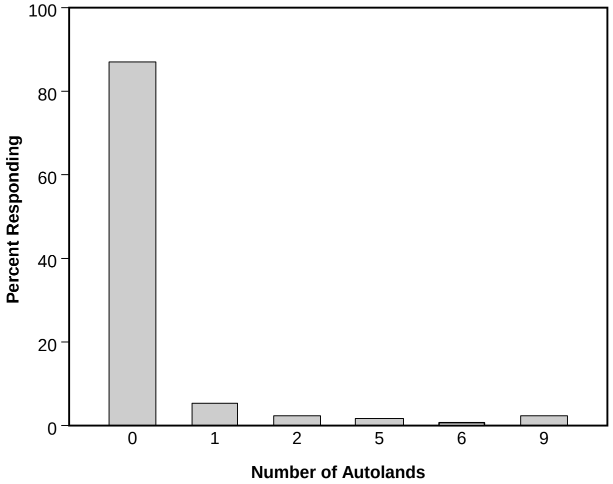
Source: U.S. National Aeronautics and Space Administration

have been deemed valuable in planning training for the less-frequently used approaches. Such data may be particularly useful in planning training syllabi and schedules for the AQP.

The question sometimes arises during an accident investigation, when the pilots fly an infrequently used approach and an accident results. Such was the case in the crash of the U.S. Air Force B-737 (T-43A) in Croatia (Phillips, 1996a). It is not unusual in these cases to find that the pilot has made few, if any, of the less-often employed nonprecision approaches in the last 12 months.

The data on autolands present a special case. Some of the pilots would have spent the last year flying older aircraft not configured for autoland, or possibly configured but not maintained for autoland (see Figure IV-7). Be that as it may, the frequency of autolands in the pre-1994 CAL line experience of the early 757 cohort was virtually zero. Close to 90 percent of our volunteers reported no autolands, and the remaining frequencies are minimal (see Figure IV-9). The following CAL aircraft were equipped and authorized for autoland at the time of our study: B-737-300/500 and B-757. The MD-80 was equipped but not used.

Frequency of Autolands In Previous Year



Source: U.S. National Aeronautics and Space Administration

Figure IV-9

Figures IV-10, IV-11 and IV-12 (page 33) demonstrate that the frequency of various nonprecision approaches is quite small. About 55 percent of the pilots report no ADF (more correctly, nondirectional beacon [NDB]) approaches during the previous year, and the frequency is very low for the remaining pilots. The frequency of localizer and VOR approaches is also quite low: about 30 percent of the pilots report having flown none of these two approaches during the previous year.

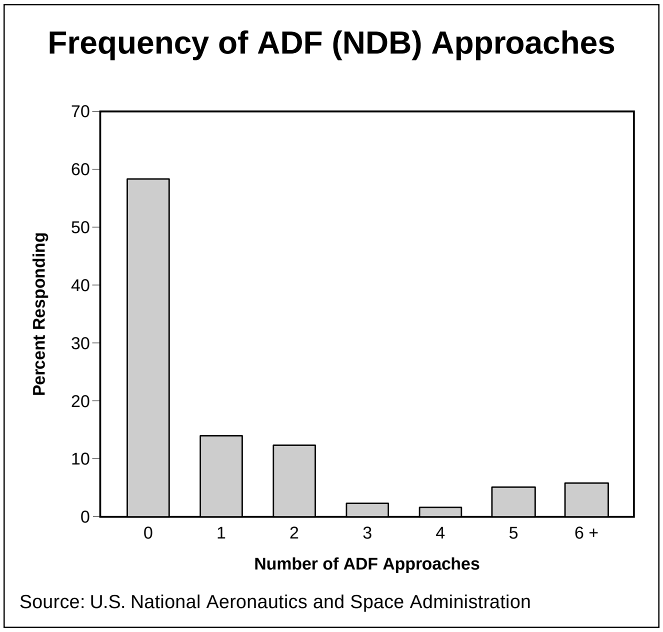
We were somewhat surprised by the low usage of Category II ILS approaches [Figure IV-13, page 33]. About 45 percent of the pilots reported zero Cat II approaches. All of CAL's fleets were qualified for Cat II. The following were qualified for Cat III at the time of the study: 737-500, 757, MD-80 and 737-300. Now the 777 and 737NG can be added to the list, and the MD-80 is Cat III qualified.

C. Phase 2 Data

In this section we shall discuss the demographic data of Phase 2. This phase was timed to be after the end of training and IOE. Volunteer pilots were sent Q2 forms approximately three to four months after they entered the study. This period allowed time for transition training (ground school and simulator), IOE, vacation time and at worst about two months back in their previous seat while awaiting a 757 seat (see Figure IV-14 and IV-15, page 34).

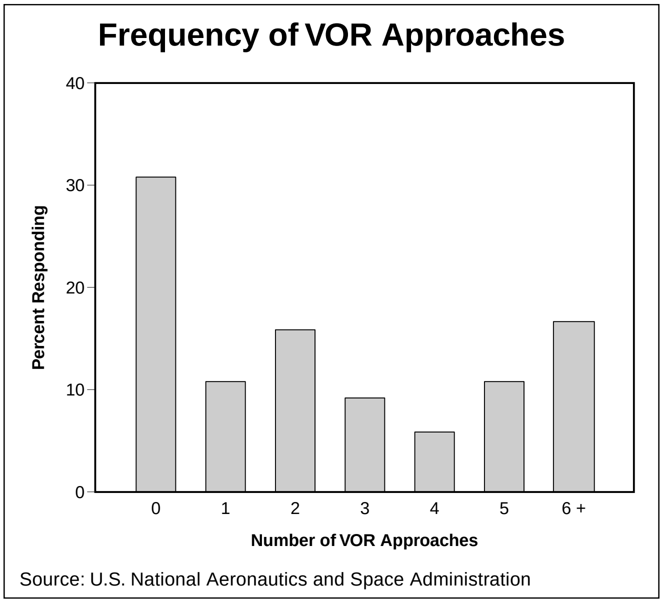
As the study moved on into the latter half of the 1990s, this became less of a factor. Pilots went straight through the program and joined the line without interruption.

Thus, if our timing was right, and if the pilots filled out the Q2 form promptly, one may think of the second phase



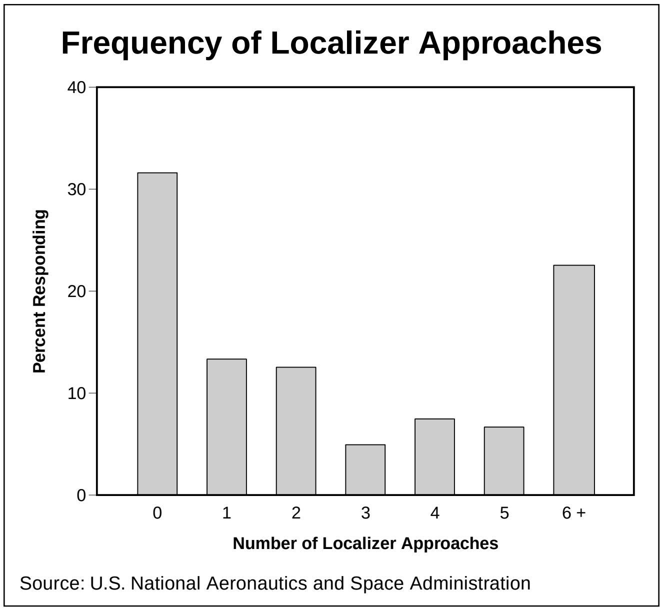
Source: U.S. National Aeronautics and Space Administration

Figure IV-10



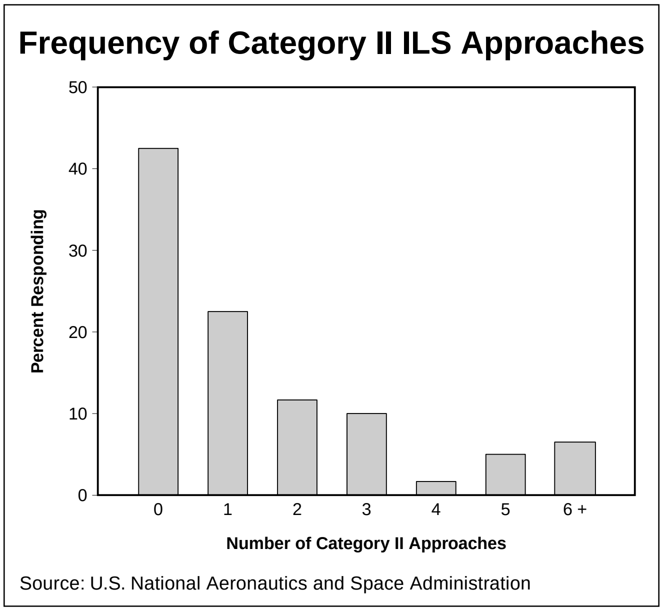
Source: U.S. National Aeronautics and Space Administration

Figure IV-11



Source: U.S. National Aeronautics and Space Administration

Figure IV-12



Source: U.S. National Aeronautics and Space Administration

Figure IV-13

questionnaire as being close to the initial point of a pilot's line experience. His formal training was complete, and he would now be learning through on-the-job training. We should also note that this is the point, early in our study, at which our sample size diminished, due to the bid-off of the 757, due largely to what were perceived as poor schedules.

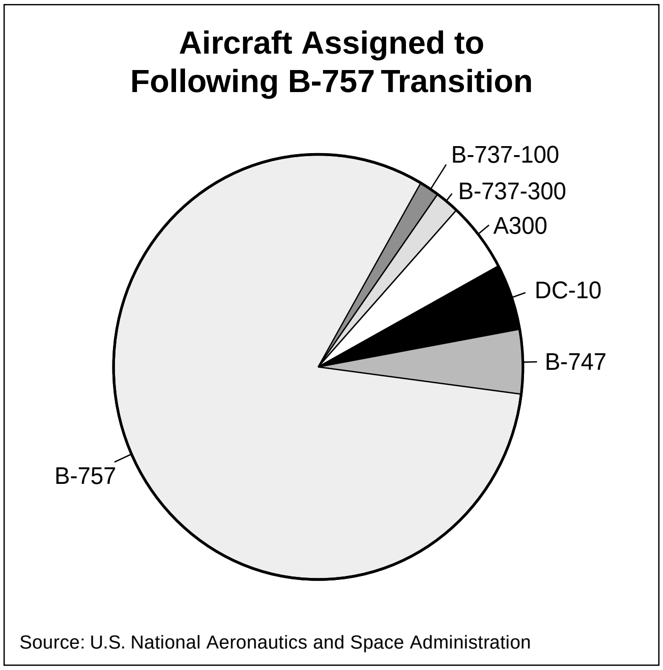
Post-training Assignment

In the first year of this study, many pilots completed training, and in some cases IOE, and then had to be assigned to their former aircraft for typically two months until a 757 seat was available. One question simply asked if they were assigned after training to a 757 or their former plane. The results of this question are tabulated below.

B-757:	84%
Former plane:	16%

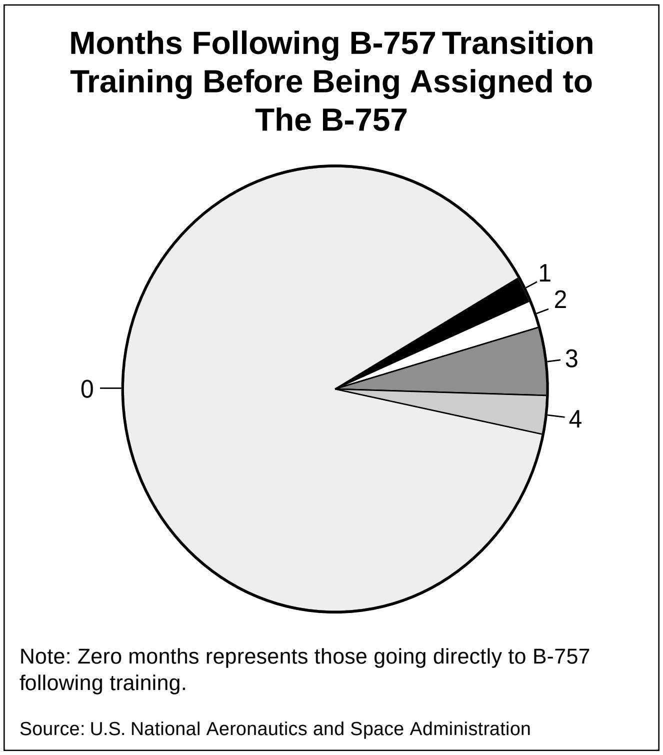
The cockpit they returned to is summarized in Figure IV-14, page 34.

For those who did not go the 757 immediately, the number of months of reassignment to their former plane, before


Aircraft Assigned to Following B-757 Transition

Source: U.S. National Aeronautics and Space Administration

Figure IV-14


Months Following B-757 Transition Training Before Being Assigned to The B-757

Note: Zero months represents those going directly to B-757 following training.

Source: U.S. National Aeronautics and Space Administration

Figure IV-15

moving to the 757, is shown graphically in Figure IV-15. This was in part due to the difficulty of balancing training through-put with new aircraft arrivals, during a period of rapid fleet expansion. No fleet manager wants to get caught short of flight crews with new aircraft on the tarmac. The obvious solution is to absorb some costs and train to inventory, hoping to make use of the excess pilots in their old plane until a 757 billet is available. They did not do badly: Figure IV-14 and the data on the previous page show that the vast majority of pilots went directly from 757 training to the 757 line, and the maximum delay for those who did not was three months. The following ASRS report addresses this issue:

> **Narrative:** Finished checkout F/O 6/89. No position until 10/89. Flew simulator in 9/89 for 90-day landing currency. You could say the find points of working the FMC had escaped my memory. We were cruising at FL390 and received clearance to FL410. Captain loaded in MCP glare shield altitude — at which point I asked how he input the data for the climb, neither monitoring to confirm the climb to FL410. Several mins later Center asked if we had climbed. “No, still at 390.” The altitude had not been put in the FMC, and we were navigating with VNAV and LNAV. Both crewmembers low experience levels in type contributory to the altitude oversight. Factors affecting performance: 1) supervision management practice of putting 2 inexperienced crewmembers together, or 2) just not monitoring/keeping track of crews’ levels of experience; and 3) after training crewmember on advanced/automated cockpit, waiting an extended period before assignment to aircraft. Fly the aircraft. (Accession Number: 124912)

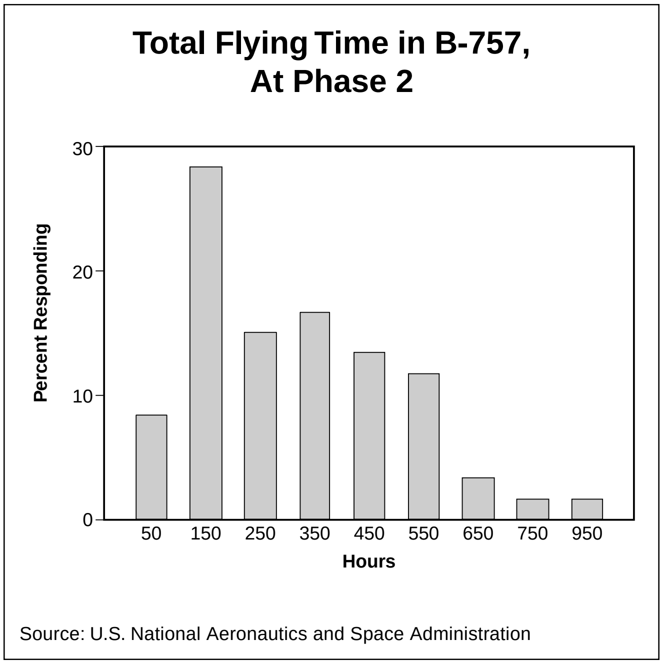
Flying Experience

Pilots were asked to estimate their total 757 flying time. These data are displayed in Figure IV-16, page 35. It was expected that at this point, the 757 time would be quite low. We estimated that the pilot would have, at best, 200–300 hours. Some pilots had as much as 500 hours. The very high times shown in Figure IV-16 can only be from pilots who did not send the form back promptly and amassed flying time before filling out at least that question. This graphic will be displayed again in this chapter, when data from P3 are presented, in order that it may be compared to the flying time of the pilots in P3 (over a year later).

On the following page we have two bar charts (Figure IV-16 and Figure IV-17, page 35) showing 757 flying time at Phase 2 and Phase 3. Note that the plots are on different scales. On the top graph (Phase 2), the bars are 100 hours apart; on the lower they are 200 hours apart.

D. Phase 3 Data

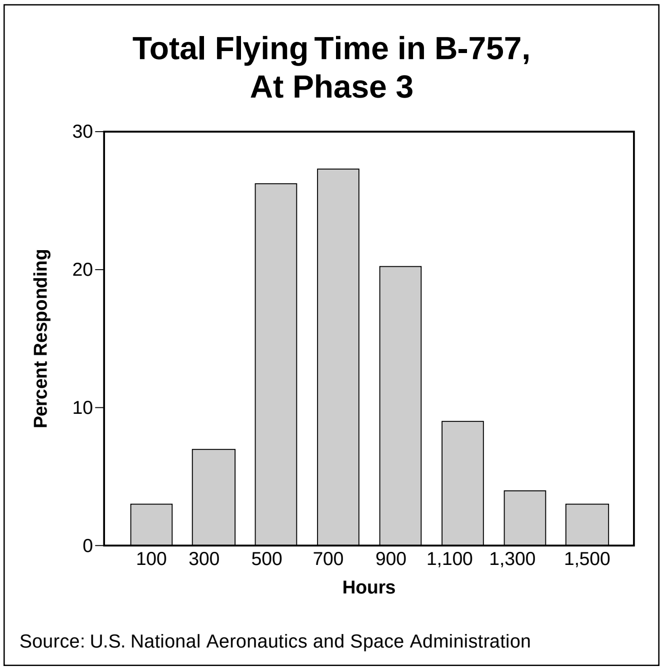
The third and final phase of the experiment (P3) was designed to be approximately one year after IOE. In other field studies that we have conducted, this time is usually found to be a turning point at which the pilot starts to “feel comfortable.” Although there is always more to be learned, at this time, with a year’s line experience behind him, the pilot new to the glass cockpit has mastered the FMS functionality, autopilot modes,



Total Flying Time in B-757, At Phase 2

Source: U.S. National Aeronautics and Space Administration

Figure IV-16



Total Flying Time in B-757, At Phase 3

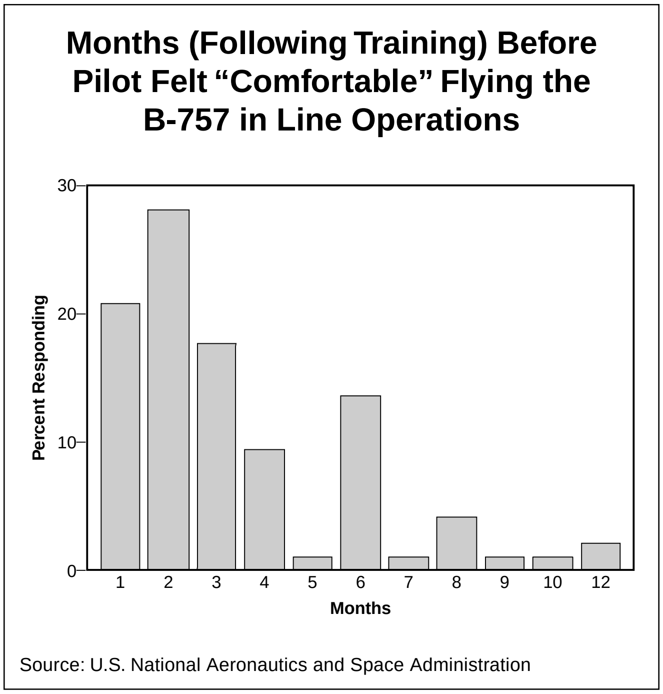
Source: U.S. National Aeronautics and Space Administration

Figure IV-17

display modes, etc., and has probably also mastered the "tricks" of line flying a glass aircraft.

Comfort with the Aircraft

In this study the pilots appeared to "feel comfortable" (a phrase widely used by pilots) much earlier than our previous work would forecast. Figure IV-18 shows the results of the compound question in Q3: "Do you feel 'comfortable' in the 757 now? (Y/N). If yes, how long after you went on the line did it take (months)?" As to the first question, 97 percent reported "yes," they felt comfortable. The durations on the line are shown in Figure IV-18. Almost half of the respondents reported two months or fewer, and a very small percentage offered replies of over six months. Such favorable results are probably due to the user-friendliness of the training program. The high confidence and high regard that this cohort had for the transition training program emerges in many places in this report: e.g., attitude probes, interviews and the open-ended questions in Q2 and Q3.



Months (Following Training) Before Pilot Felt "Comfortable" Flying the B-757 in Line Operations

Source: U.S. National Aeronautics and Space Administration

Figure IV-18

Flying Time, Phase 2 and Phase 3

The total hours of 757 flying time at Phase 2 (actually whenever the respondent filled out his questionnaire) is depicted in Figure IV-16. Figure IV-17, the 757 time at Phase 3, is displayed on the same page for comparison. Phase 2 was designed to be approximately three to four months after transition training. Again, the calculation of the intervals between phases is at the mercy of the pilot volunteer and when he fills out this questionnaire. For P1 and P2, we tailored the delivery of Q2 and Q3 to each pilot, attempting to deliver the questionnaires to him based on the nominal time of the phases. Viewing the two figures together allows one to see the growth in 757 flying time during the (nominal) year, from IOE to the point at which he filled out the Q3 form.

In the following narrative, we see a captain who has only been on the aircraft one month, who handles a very difficult emergency and attributes his success to the training he received, as well as the competence of the first officer. We believe the reader will agree that this is a good example of airmanship by a captain with an extremely low time in type. Note that it is obvious that this report is from an Airbus, as the term *ECAM* (electronic centralized aircraft monitor) is used.

> **Narrative:** Aircraft was in Cruise at FL290 due to the prior shutting down of the number-two pack for overhead. We were just preparing to descend to cross Bradford intersection at FL240 when we heard a possible compressor stall and the aircraft shook and yawed. We got confirmation of the number-two engine failure in the electronic controlled aircraft monitoring ECAM [an Airbus term which is the counterpart of Boeing's EICAS]. ECAM procedures were followed. The first-officer was flying and I allowed him to continue to do so. I did not elect to do a restart as the EGT was climbing rapidly. I shut down the engine according to ECAM and used the fire bottle due to high and rising EGT. Started APU, declared emergency with ATC, notified Dispatch, made public-announcement to passenger, subsequently lost APU before landing, wouldn't restart. Elected not to prepare cabin for evacuation and weather was VFR. Landed without incident at Chicago and taxied back to gate as all hydraulic systems were operating normally. The number-two engine compressor section had failed completely and broken up. The engine was replaced by maintenance. I was fortunate to have along a very competent first-officer, and although I had only been on the aircraft a month, training had prepared me very well to handle the problem. (Accession Number: 284470)

V. Analysis of Questionnaire Data

A. Methods of Analysis

Because most of the variables examined in this study were categorical (e.g., captain vs. first officer; or previous glass experience vs. none), the data collected are best suited to nonparametric analysis. Where possible, these methods were employed, and interval data (such as age and flying hours) were divided into categories (see Chapter IV). In this chapter, we shall report and comment on those data that were analyzed and subjected to statistical tests. Much of the data are reported in Chapter IV as merely descriptive data, not suited to statistical analysis (e.g., choice of favorite aircraft in company's fleet). In some cases, for statistical convenience, the data are treated as being on an interval scale, when more correctly they are on an ordinal scale. For example, the intercorrelation matrices were computed using the Pearson product moment method, which properly requires interval data, but is widely used for ordinal data, such as responses on a Likert scale.

Other data were subjected to cross-tabulation tests (contingency tables) using the chi-square distribution. An example would be determining if there is a relationship between a variable which we have called "SEAT" (captain vs. first officer) and some other categorical variable such as computer usage (yes/no). Unfortunately, our sample size is small for the number of variables examined, and some compromises with statistical purity were made. In the case of contingency tables, there were often low frequencies at the extreme points (corners of the matrix), so the results may be inexact.

In the case of the intercorrelations of the Likert variables, each pair taken together potentially produced a five-by-five matrix. In some cases, there were no responses at all for a given response category, thereby reducing the matrix. Usually those cases involved one or both of the two extremes where the respondent could "*strongly* agree" or "*strongly* disagree." We have seen in this study, and in previous ones, a tendency on the part of the pilot volunteers to avoid the extremes, for example, the graphs on page 96. No pilot responded in the "strongly disagree" category in response to that probe. There are no cases in our data where there were fewer than four non-zero categories. Eleven tests involved reduced matrices due to one extreme (either "strongly agree" or "strongly disagree") yielding no responses.

Throughout this report, we use the conventional value of .05 for the statistical significance level (alpha, or probability of a type-1 error). In interpreting the correlation matrices, an absolute value of Pearson's $r > .163$ is significant for $n = 147$ for two-tailed null hypotheses. For $n = 146$, where the data from one volunteer may be missing, the critical value is very slightly higher in the third decimal place.

B. Phase 1

Intercorrelations

For each of the three questionnaires (Q1, Q2 and Q3), an intercorrelation matrix of the responses to the Likert probes was computed as described above. Additionally 10 selected demographic variables were included in the original matrix, but are not included in the matrices reported here, due to the fact that their inclusion would result in a vastly expanded matrix. A copy of any of the entire intercorrelation matrices mentioned in this report is available to the qualified requester. [Contact John H. Moses, Ames Research Center, MS 262-6, Moffett Field, CA, United States 94035-1000.]

> The size of the entire square, symmetric intercorrelation matrix is a function of the square of the number of variables included; a single echelon of the symmetric matrix would contain, for N variables, $N(N-1)/2$ correlations. If the computer program prints the entire square matrix, there are N^2 correlations.

The Q1 questionnaire included 20 Likert scale probes, resulting in 190 correlations. Had we included the 10 demographic variables, there would be 465 correlations. With our statistical software, the resulting matrix would require 18 printed pages. Accordingly, the correlations between the demographic variables and the Likerts were examined separately. Some of the terms were obvious in their correlation and hence are not reported; for example, the positive correlations between total flying time and flying time at CAL, or some of the obvious correlations of variables (e.g., AGE, or total flying time — TFTALL) with "SEAT" (captain vs. first officer). We chose from the list of 11, six variables to be included in the correlation matrix for Q1. There were originally 10 variables. We later derived GLASSNU (see Table V-1).

Table V-1
Demographic Variables on Questionnaire 1

AGE	pilot's age (months)
SEAT	position on 757 ("1" = captain, "2" = first officer)
PCUSE	does pilot use personal computer at home at all ("1" = yes, "2" = no)
TFTALL	total flying time, CAL and elsewhere (hours)
TFTCAL	total flying time at CAL (hours)
GLASSNU	had the pilot, previous to 757 transition, flown any glass cockpit? ("0" = no, "1" = yes)

The following are demographic variables not included in the analysis. See Chapter IV for descriptive statistics of these variables.

CHOICE	Pilot's first choice of aircraft in company's fleet
LASTACFT	Last aircraft flown before 757 transition
LASTMOS	Months on last aircraft before 757 transition
LASTSEAT	Seat occupied before 757 transition (captain vs. first officer)

Source: U.S. National Aeronautics and Space Administration

We shall now examine some of the variables and their relationships.

Pilots' Age

There has been considerable interest in both the airline community and the research community on the effect of chronological age of the pilot going through his first glass transition. Much of what was said was based on unsupported, usually negative stereotypes of older workers — that the senior captains were not abreast of technology, since they did not grow up in the computer age, and that they were mentally unadaptable to the high-tech cockpit. We do not know of any research on the topic of age and transition to glass. There has been considerable interest in pilot age in the last three decades due to the legal requirement that pilots flying under FARs Part 121 retire at age 60 (the "age 60 rule"). But the research to support that rule pre-dated the era of the FMS cockpits.

Training personnel spoke of apprehension borne by older pilots. In our interviews at other airlines with pilots in glass transition for the first time, there was frequent expression of apprehension concerning the demands of the transition training, particularly with respect to their lack of computer skills. These concerns always seem to come from captains: investigators did not encounter, in previous studies, apprehension on the part of the first officers making the transition. In our interviews with pilots and instructors in the current study, we have heard less of this. The graph (8A) from Questionnaire 1 may be instructive. It is shown as Figure II-1. Only about 10 percent of the respondents expressed agreement with the probe. We see in this graph a rather strong rejection of the opinion that pilots arrive at their transition training filled with apprehension. This subject is also discussed in Chapter II.

Chi-square tests of the 20 contingency tables of attitude response vs. seat (captain and first officer) all resulted in negative findings. We have found no difference between captains and first officers in replies to this or any other attitude probes, in any of the three questionnaires, or on questions about computer usage. In brief, we have found no differences between captains and first officers in the 757 program, except obvious factors such as age and flying experience. Therefore, in further analyses, we have aggregated the data of the two positions into one.

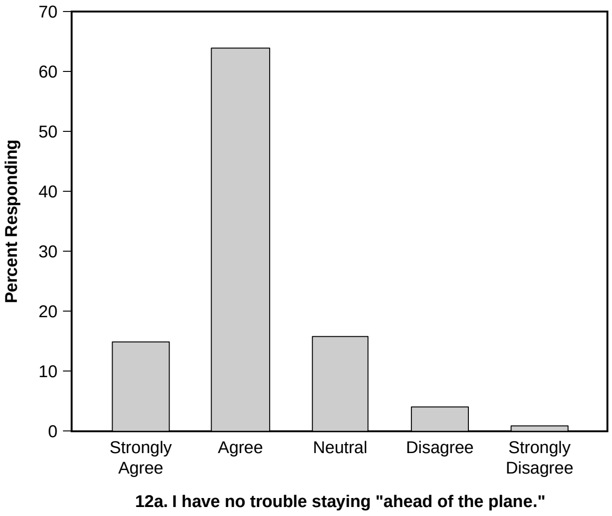
Our inquiries in previous studies (Wiener, 1989) into the influence of age revealed that if there is any reliable generalization, it is that the older pilots seemed to get off to a slow start in early days of ground school, having a slight amount of trouble mastering some of the new concepts, compared to the younger first officers, who were presumed to be "techies," skilled in digital concepts and operations. After this initial period, the captains, drawing on their vast experience and airmanship, caught up and by the time they reached the simulator, were performing at a high level. It was unfortunate that the training book data did not work out. They might have provided somewhat objective information on the effect of age during training.

AGE correlated significantly with one Likert probe, No. A12, "I have no trouble staying 'ahead of the plane'" (see Figure V-1, page 38). Since the Likert scale, when treated as an interval scale, goes from 1 to 5 as it goes from strongly agree to strongly disagree, a negative correlation means that high age goes with low Likert values (approval of the probe). In this case, the older the pilot, the more approving he is of the statement that he can easily stay ahead of the plane. The younger pilots may have some reservations about their own abilities.

For obvious reasons, the variable SEAT (captain vs. first officer) is highly (negatively) correlated with AGE ($r = -.54$). In SEAT, as we have indicated, captains are coded as "1"s and first officers as "2"s. The lower index number (captains) is associated with higher age. For this reason, SEAT also is positively correlated with A12.

In summary, we have not produced any evidence on differences due to the trainees' age. One significant Likert, and somewhat

Example of Generally Accepted Probe That Correlated with Age of Pilot



Source: U.S. National Aeronautics and Space Administration

Figure V-1

obvious correlations, is the best we can offer. The age question will have to await perhaps a simulator study in which dependent variables can be carefully measured and examined with respect to the pilots' ages.

Seat

The variable SEAT refers to the seat that was bid for 757 training, "1" for captain. In most cases, the seat in the 757 bid was the same as that held at the time of bid. A few senior first officers bid for 757 captain seats and made the transition and upgrade at the same time. SEAT is highly (negatively) correlated with AGE (r = -.54) due to seniority considerations. SEAT also is correlated with A12 (r = .17), possibly through its correlation with AGE. It also correlates (r = .18) with A10 ("I am not concerned about making errors, as long as we follow procedures and checklists"). This indicates that the captains are more accepting of the probe than the first officers. This finding, and the one indicating a positive correlation between age and A12, suggest a degree of caution and conservatism on the part of the first officers, and self-confidence on the part of the captains. This runs counter to the popularly held stereotype of the ultraconservative captain.

The relationship between seat and attitude was also tested by forming a two-by-five contingency table (two-by-four in those cases where an extreme [SA or SD] had zero entries), with attitude choice as a column variable and seat as a row variable. The chi-square contingency coefficient was computed and tested for all 20 probes. None resulted in a rejection of the null hypothesis of row/column independence.

Flying Experience

The two measures of flying time, TFTALL and TFTCAL naturally correlate highly with each other (r = .81). This correlation is obvious, since the pilot's total flying time, TFTALL, contains the value of the variable TFTCAL, his flying time at CAL. They also correlate, as one would expect, with SEAT and AGE.

TFTALL correlates (r = .16) with A18 ("CAL's CRM training has been helpful to me"), positive correlation indicating that pilots with high flying hours tend to take a less favorable view of the CRM training. This is probably due to the correlation with rank: it would indicate that low-time pilots (mostly first officers) are more accepting of CRM than captains, which is the experience at most airlines. It is interesting, and not easily explained, that the correlation of TFTCAL with this probe was very small. Total flying time appears not to be a particularly fruitful variable. In the discussion to follow, of Questionnaires 2 and 3, the interest will shift to 757 flying time as a predictor variable.

GLASSNU was a derived variable, based on the question about prior glass experience. We created this variable to test hypotheses about attitudes as a function of having flown or not flown glass aircraft before 757 transition. The variable we created was a "(0, 1)" variable: it recorded only yes (1) or no (0), did the pilot have prior glass experience?, and does not reflect the amount of glass flying time.

The influence of past glass experience was tested by forming a contingency table for each probe (as in the SEAT variable above), and performing a chi-square test on each. This resulted in three rejections of the null hypothesis of row/column independence. The contingency tables for the three are displayed below.

The interpretation of the entries in the matrix is up to the reader. It would appear that in probe A7 the glass-experienced pilots had a narrow range of opinion, mostly agreeing with the sense of the probe, and a small number neutral. Those without glass experience showed more variability, though the distributions were centered at about the same place. There was very high

Probe A7
"In the aircraft that I am presently flying, it is easy for the captain to monitor and supervise the first officer."

	SA	A	N	D	SD
No Glass	13	69	23	4	—
Glass	0	32	6	0	—

Chi-square = 8.12, df = 3, p < .05

SA = Strongly agree A = Agree N = Neutral D = Disagree
SD = Strongly disagree

Source: U.S. National Aeronautics and Space Administration

Probe A16
“I am concerned about the reliability of some of the automation equipment.”

	SA	A	N	D	SD
No Glass	6	33	27	41	2
Glass	1	4	4	23	6

Chi-square = 21.05, $df = 4$, $p < .001$

SA = Strongly agree A = Agree N = Neutral D = Disagree
SD = Strongly disagree

Source: U.S. National Aeronautics and Space Administration

Probe A17
“I am concerned about the lack of time to look outside the cockpit for other aircraft.”

	SA	A	N	D	SD
Glass	8	4	32	28	1
No Glass	2	14	3	18	1

Chi-square = 10.47, $df = 4$, $p < .05$

SA = Strongly agree A = Agree N = Neutral D = Disagree
SD = Strongly disagree

Source: U.S. National Aeronautics and Space Administration

agreement by the non-glass group — only four out of 109 disagreed with the probe.

In A16, the non-glass pilots showed a fairly symmetrical distribution, while the glass-experienced pilots had rather strong disagreement with the probe, with 29 on the disagree side and five on the agree side. Perhaps their experience with glass cockpits had relieved some of the apprehension of those making their first transition to glass.

In A17, the glass group was symmetrically divided over the range, with most responding agree or disagree, and few extreme or neutral. The non-glass showed somewhat the same pattern, but more neutral choices. It would appear that the non-glass pilots were somewhat more concerned about heads-up time than the glass pilots.

Home Computer Usage

Since the introduction of the FMS into airline fleets, there has been a persistent belief that pilots who own a home computer profit from this experience. It was further assumed that it is first officers who have this exposure, giving the “computer literate” first officer, if not an advantage, at least some compensation for the captain’s greater aviation experience. We again state that this entire line of reasoning has been based on assumptions and beliefs, not on empirical data.

In an earlier NASA report (Wiener et al., 1991, p. 25), the question of ownership of home computers was raised. Of the captains, 71 percent responded yes, and for the first officers it was 50 percent. For this sample size ($n = 73$), the difference was not statistically significant.

In this study, we corrected the mistake we had made in earlier studies by asking not about ownership, but usage: “Do you use a personal computer at home?” (PCUSE). The second question (PCFREQ) dealt with how often it was used. The statistical test involved a two-by-four contingency table (see Table IV-1a). Once again, we found no difference between the responses of the captains and first officers. Thus we are convinced that the myth of the computer-literate first officer and the computer-naive captain is unsupported. Whatever problems captains may have in transition to glass, compared to the first officers, they are probably not due to differences in home computer experience.

There were two significant correlations to report. PCFREQ correlated significantly with probe A1 (“Flying today is more challenging than ever”) ($r = -.18$). Since the correlation coefficient is negative, it indicates that frequent personal computer users (low index numbers) tended to have low approval (high Likert scale response values) of this probe. We find it difficult to interpret this result.

Likewise, PCUSE correlated significantly with probe A16 (“I am concerned about the reliability of some of the automation equipment”) ($r = -.19$). Here the result may be more clear. The correlation coefficient is negative, indicating that personal computer users (“1”) tended to give higher Likert responses (disapproval of the probe). Personal computer users may indeed be more accepting of automation technology, even its faults, than non-users (“2”).

Summary

These data, and the descriptive data presented in Chapter IV have not produced any startling results, but together paint a mosaic of the pilots’ attitudes toward transition training in a new technology aircraft. Further details will be found in crewmembers’ responses to the open-ended questions, presented in Chapter VI. This completes the discussion of Phase 1 by itself. We now turn to Phase 2 and to comparisons between Phase 1 and Phase 2.

C. Phase 2

The second phase of the experimental design was timed to be about four months after ground school, following all training including IOE, and assignment to a base to fly the 757 line.

Much of the data is summarized graphically in Chapter IV. The second phase questionnaire, Q2, included a small number of demographic variables, four open-ended questions (which are analyzed in Chapter VI), and a 24-item attitude scale. The

24 items included the 20 utilized in P1, plus four new items (21–24). The following demographic variables were included:

TIME757	Total hours 757 time
CBASE	Current base
ACASSIGN	The plane that the pilot was assigned to after training (757 or otherwise)
MORTRN	The number of months assigned to plane other than 757, following transition training, prior to assignment to 757 line
PROB757	This variable sought to measure problems encountered by pilots returning to their old aircraft to await a 757 assignment. Since so few fell into this category (see Figure IV-14), we have not used this variable.

Intercorrelations

The intercorrelation matrix of the 24 Likert scale variables, as well as the demographic variable TIME757, was computed. The intercorrelation matrix is too large to include in this report; it is available on request.

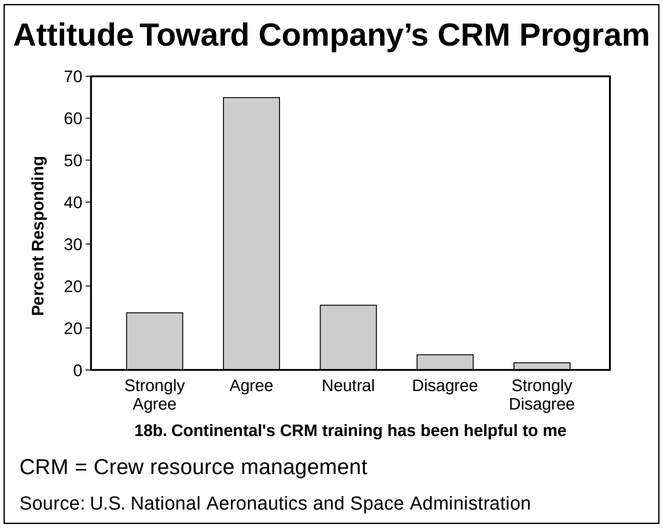
ACASSIGN and MORTRN

These variables are discussed and graphics depicting the variables are displayed in this chapter. The graphics of ACASSIGN (Figure IV-14) and MORTRN (Figure IV-15) indicate that only about 12 percent of the sample was unable to move directly into 757 line assignments. In the first few classes the figure was somewhat greater, as deliveries did not keep up with pilot training. Later the opposite was true: deliveries ran ahead of pilot training, training was accelerated, and new 757 pilots went to the line without delay.

TIME757

The variable TIME757, the number of hours of 757 time accumulated up to the completion of the P2 questionnaire, is displayed graphically in Chapter IV as Figure IV-16. It is displayed again in the next sub-chapter of this chapter along with the same question for P3, so that the growth in flying time accumulated in P2 and P3, over a 12–14 month period can be compared (Figures IV-16 and IV-17).

It would be interesting if this variable correlated with various attitude scale scores. The correlation between TIME757 and each of the 24 Likert scale variables was computed, and only one was significant: the correlation with probe A18 (“Continental’s CRM program has been helpful to me”) was 0.22 ($p < .025$). (Under the null hypothesis of zero correlation between two variables, for $n = 102$, an absolute value of Pearson’s r greater than .196 significant at the .05 level, two-tailed test.) Since the correlation is positive, this indicates that pilots with higher flying time in the 757 tend somewhat more to reject the probe. This is consistent with the finding from P1 that there was likewise a significant correlation between total flying time (TFTALL) and the A18 (CRM) probe (see page 38). The history, background and theoretical foundations of CAL’s CRM program are discussed in Chapter VII.



CRM = Crew resource management

Source: U.S. National Aeronautics and Space Administration

Figure V-2

PROB757

On Q2, there were questions about what plane the pilot returned to after 757 transition, if he could not be assigned to the 757. As we indicated previously, only about 16 percent of the sample returned to their previous plane rather than the 757, and this sub-sample was too small to be worthy of statistical testing. For confirmation, see Figure IV-14.

GLASSNU

24 contingency tables were formed, using the derived index GLASSNU and each attitude probe. These resulted in mostly two-by-five tables, in a few cases two-by-four. Each was tested using the chi-square test. None was significant. We can conclude that pilots who had formerly flown glass cockpits did not differ in attitude toward training and automation from those who had not.

SEAT

Contingency tables two-by-five (or two-by-four) were formed to test the variable SEAT (captain vs. first officer) against the 24 Likert attitude probes. None was significant. We again see that the attitude of captains and first officers did not differ in this sample.

Summary

The attitude and demographic data from Phase 2 have been analyzed in the foregoing sub-chapter. We now turn to comparisons of the attitude data between P1 and P2. This is the longitudinal analysis. Out of this analysis will come a comparison of responses in the two phases, which will tell us whether attitudes *shifted* between examination during Phase 1 (sign-up) and Phase 2 (post-IOE).

D. Comparison of Phase 1 and Phase 2 Attitude Results

In this sub-chapter we examine the attitude results from P1 and P2, to determine whether there has been an attitude shift during the three to four-month period between the times when the pilots filled out Q1 and Q2. We are particularly looking for shifts in attitudes toward training and toward automation in general. A shift would be indicated by finding differences in a pilot's responses to the same question asked during the two periods, that is, an inconsistency between responses on P2 and P3.

P1 vs. P2 Comparisons: Corresponding Questions

The following adjustment was made in numbering of Q1 and Q2 probes. Q1 no. 8 ("I am very apprehensive about going through this transition") was inappropriate for Q2 and Q3, so no comparison with it was possible. Q1 no. 14 was moved to take its place. On page 93, the probes 14a, 8b and 8c are shown graphically. Although the numbers are different, the probes are the same. Otherwise, each of the first 20 pages of Appendix A shows the three graphs representing the three phases in proper order (Probes 1–13, and 15–20). Pages 106–109 display, two to a page, the results of the four probes used on Q2 and Q3, but not Q1.

The Test Statistic: Marginal Homogeneity

Since the test statistic may not be familiar to all of the readers, we shall describe it briefly. The statistical measure is called the *marginal homogeneity* test. It is an extension and generalization of the familiar McNemar repeated measures test with two response categories (2-by-2). The McNemar problem is generalized to K-by-K matrix for K response categories. There is also a K-by-K categories test attributed to Bowker, used in a previous field study (Wiener, 1989). For the mathematical development of the marginal homogeneity test, see Agresti (1990).

The data must be categorical and ordered. Arbitrarily, the first phase (P1) responses are assigned to rows, the second phase (P2) to columns. Thus for the attitude data, a five-by-five matrix (or in some cases smaller) is produced, with cell ij representing a response of l to the first application of the probe (P1), and j to the second (P2). If the pilot responds the same on both applications of the probe, the tally will go in the main diagonal ($l = j$). If there is a shift in opinion, more cases will fall off the main diagonal.

Page 111 is repeated on page 42. The probe is no. 1, "Flying today is more challenging than ever." Looking at the main diagonal, 15 pilots chose the "strongly agree" response category on both Q1 and Q2, 21 chose "agree," etc. The off-diagonal tallies indicate shifts in attitude between the first to the second polling. Using the same example, nine pilots changed their response from "strongly agree" to "agree." If there were no changes, the entire tally would be contained in the main diagonal. The greater the change in attitude, the further the tally would fall from the main diagonal. In the example, four pilots changed their attitude response from "strongly agree" to "disagree." These were large defections from the initial (P2) position, but no full-scale changes (from "strongly agree" to "strongly disagree," or vice versa.

Results: P1 vs. P2

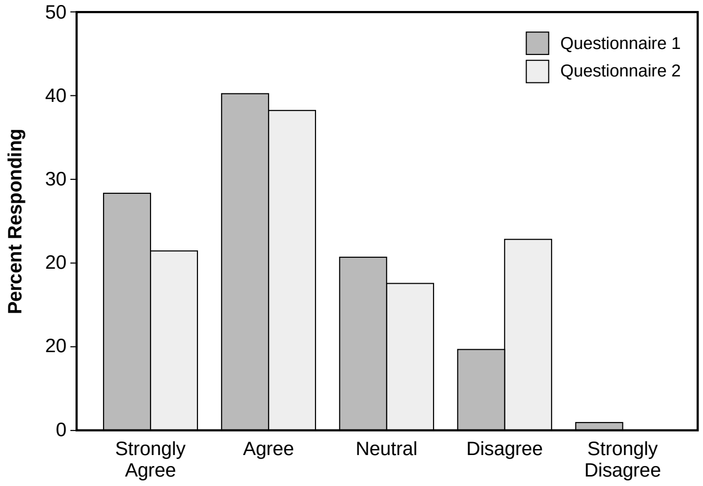
Under the two-tail null hypothesis of no change in attitude, the responses should be clustered on or near the main diagonal. A large number of off-diagonal entries (in either direction under a two-tail null hypothesis) would lead to a rejection. For a one-tail hypothesis, the direction of deviation from the first phase to the second is specified. We used the test on the 20 probes in common to P1 and P2, and the 24 probes in P2 and P3. In Appendix C, we have provided the matrix for only those probes that were statistically significant. Along with the response matrix, we have provided a graphic displaying the frequency of response for each of the five response categories. These two figures, although they use the same data, do not display the same information. The bar graph shows trends of groups, not the choices of individual pilots.

Table V-3 (page 42) lists the eight significant marginal homogeneity tests from Phase 1 compared to Phase 2, and indicates the nature of the change. The full text of the probes can be found in Appendix D. The movement of response from Phase 1 to Phase 2 in the attitude questionnaires can be seen graphically in Appendix C.

There is no consistent pattern in the movement toward disagreement with the probes, charted from P1 to P2. Some of the probes are positively stated toward automation (e.g., no. 3), and some are negative (e.g., no. 2). As the pilots repeat the questionnaire in P2, approximately three to four months after the first set of responses in P1, a movement toward less agreement with the probes does not portray a consistent attitude toward automation. The pilot changes his choice toward less agreement with no. 11, looking forward to more automation, and likewise changes toward less agreement with the more negative no. 13.

Perhaps we will find the next set of marginal homogeneity tests, for P2 vs. P3, more instructive. In those tests, the pilots will have had some flying experience in the 757, limited to a few months in P2, and over a year's worth in P3. In any event, it is interesting to note the volatility of opinion in P1 vs. P2, that eight out of 20 probes should result in statistically significant changes of opinion, even if we cannot find a

Probe C-1
"Flying today is more challenging than ever."



Phase 2

Phase 1	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Row Total
Strongly Agree	**15**	9	1	4		**29**
Agree	6	**21**	6	8		**41**
Neutral	1	8	**8**	4		**21**
Disagree		1	3	**6**		**10**
Strongly Disagree				1	**0**	**1**
Column Total	**22**	**39**	**18**	**23**	**0**	**102**

Source: U.S. National Aeronautics and Space Administration

Table V-3
Statistically Significant Marginal Homogeneity Tests

Probe	Abbreviated Text	Movement: P1 to P2
1	Flying is more challenging than ever	Toward disagreement
2	Concerned that automation will cause skill loss	Toward disagreement
3	Automation leads to safer operations	Toward disagreement
7	Easy for captain to monitor first officer	Toward disagreement
11	Look forward to more automation	Toward disagreement
13	Too much workload in terminal area	Toward disagreement
15	Easy to bust altitude in today's environment	Toward disagreement
17	Concerned about time to look outside	Toward disagreement

Source: U.S. National Aeronautics and Space Administration

consistency or an underlying meaning in these opinion shifts. When we compare opinions in P2 and P3, we would expect more stability of opinion, that is, fewer significant changes.

E. Phase 3

Phase 3, the final phase of the longitudinal study, was designed to collect data from the remaining volunteers at a time when they had about one year of line experience, or about 16–18 months after initially joining the study on the first day of ground school for 757 transition. We felt, based on past experience in field studies, that at this time, opinions would have solidified, and would probably not change appreciably if the interval between P2 and P3 were extended. Also, we would expect that at this time, the pilots would feel "comfortable," a word widely used by pilots to describe their feelings at some experience level after transitioning to a new aircraft. To be "comfortable" in the new aircraft would mean that the pilot was free of apprehensions about his ability to manage the cockpit and particularly the automated features, to be able to respond appropriately to abnormal situations, and in brief to feel at home, relaxed, self-confident and in command of his own abilities.

Phase 3 was designed mainly to obtain the final data on the 24 attitude probes. There are a minimal amount of demographic data sought on the questionnaire (see Appendix D), and a minimal number of hypotheses to be tested. Most of the data are merely descriptive.

Miscellaneous Questions

As to the "comfort" dimension, 91 of the 94 valid answers were "yes" to the question "Do you feel 'comfortable' in the 757 now?"

The data for the pilots' current base are tabulated below. The number of responses to this question of IAH and EWR are about proportional to the 757 flying time assigned to those two bases. The desirability, from the pilots' view, of CAL's various bases is discussed elsewhere. The Guam 757 base was essentially ignored in this study, since it was formed after the study began.

IAH (Houston)	33
EWR (Newark)	56
LAX (Los Angeles)	1
Other	6
Total	96

Cockpit Positions Held

The cockpit positions held by the volunteer pilots are shown in Table V-4. Note that of the 96 pilots represented by this table, the largest group (79 pilots, or 82 percent) were still flying the 757; the remainder were flying other aircraft. As a percentage of the 149 original volunteers, this group is probably under-represented due to the fact that many pilots, after bidding off the 757, dropped out of the study and did not send in Q3.

Contingency Tests

To test the null hypothesis that attitudes, as measured by our Likert scales, are not related to SEAT (position in the cockpit), two-by-five (in some cases two-by-four) contingency tables were cast, as in Phase 2. Chi-square tests were performed on the 24 resulting tables (one for each attitude probe). None was significant. We must again conclude that captains and first officers in this sample saw things alike.

Similar tables were set up using the derived variable GLASSNU (previous glass experience, or none) as one variable, responses on the Likert scales the other. None was significant. We conclude that pilots with past experience on glass aircraft and those with no such experience held similar attitudes as measured by our scales.

Table V-4
Current Aircraft and Seat of 96 Pilots

Current Aircraft	Captain	First Officer	Total
DC-9	1	0	1
MD-80	1	0	1
B-737-100	1	0	1
B-737-300	2	1	3
B-727	2	2	4
DC-10	4	2	6
Other	1	0	1
B-757	46	33	79
Total	**58**	**38**	**96**

Source: U.S. National Aeronautics and Space Administration

Intercorrelations

An intercorrelation matrix containing responses on the 24 attitude scales was formed, but was not examined statistically.

F. Comparison of Phase 2 and Phase 3 Attitude Results

As in sub-chapter D, we shall now examine the 24 attitude scales for possible shifts in attitude from P2 to P3, using the marginal homogeneity tests.

Of the 24 attitude scale items, three showed significant changes from P2 to P3, as summarized in Table V-5 (page 44).

As Table V-5 and the figures in Appendix E indicate, there was a significant shift of opinion in the pilots in the roughly 14 months between Phases 2 and 3. Numbers 17 and 24 indicate movement favorable to the 757 flight guidance system, and perhaps toward automated flight in general. In previous field studies, these are common worries of the new FMS aircraft pilots: sufficient time for extra-cockpit scanning; and mode confusion, as it has come to be called.

We observed also an increasingly favorable view toward the company's CRM program. We can only speculate as to the reason for this. It is most likely due to the emphasis put on CRM throughout the 757 transition training. Both fleet managers insisted that CRM be taught and included as part and parcel of the flight training, not as a separate block of instruction (see quotation, page 64). Some authors have stated previously (Wiener, 1989) that good CRM practices are even more essential in the automated than in the traditional cockpits. This point was emphasized from the first day (H-CAT training). Much of the credit for the emphasis on blending CRM with flight training goes to instructors at Boeing. It was there that the early cadres of CAL instructors first encountered this method of training. Typically flight training and CRM are taught as two worlds apart. Seeing the merit of the Boeing approach, it was transported back to Houston and made part of the flight training program.

Table V-5
Statistically Significant Marginal Homogeneity Tests, P2 vs. P3.

Probe	Z	Text	Movement P2 to P3
17	–2.3	I am concerned about the lack of time look outside the cockpit for other aircraft	Toward agreement
18	–2.7	Continental's CRM program has been helpful	Toward agreement
24	3.0	There are still modes and features of the 757 that I do not understand	Toward disagreement

Source: U.S. National Aeronautics and Space Administration

Presumably, over the period between filling out Q1 and Q2, a space of over a year, the pilots had an opportunity to practice their CRM skills in a demanding, automated environment. This perhaps accounts for the shift toward a more positive response to probe number 18.

Usage of HSI Modes

At the request of CAL flight management, we included a question in the third (final) questionnaire (Q3), asking the 757 pilots the percentage of time they used, in flight, the four HSI modes (map, expanded VOR, expanded ILS, and compass rose). See Page 125.

The map mode was used about 95 percent of the time, and the remaining 5 percent was about evenly split between the other three modes. As we have noted in previous studies (e.g., Wiener, 1989), most pilots will, if unimpeded, fly an entire trip with the HSI in map mode. Why not? It is a spectacular example of what can be done using glass displays. Only a non-precision approach would move the crew to select a different mode.

VI. Open-ended Questions and Responses

A. Introduction

The intent of this chapter is to take the reader into the "details" of CAL's B-757 training program. The open-ended responses and summaries which follow are an attempt to capture the experiences and comments, in their own words, of pilots progressing through their transition training and IOE, and eventually flying the line. No attempt has been made to place judgment on the responses with respect to appropriateness, quality or significance, but only to categorize them for descriptive analyses. The groupings and summaries are presented in the context of the training program with an emphasis on topics such as problematic areas, recommendations for improvement, effectiveness of the training aids and the implications for pilots in transition training. In this way, the reader can make his or her own judgments on the responses.

B. Methodology

The challenge of collecting qualitative data is to reduce them into a manageable and meaningful format, and then make sense of it, especially when it comes in voluminous amounts. This study was no exception, particularly when one considers that a set of open-ended questions was asked of each pilot just after his B-757 training, and then again after approximately one year of flying the line. This resulted in querying over 100 pilots twice on the following four topics: (1) training for the B-757, (2) errors observed or committed on the line, (3) crew coordination and procedures, and (4) cockpit workload. In addition, there was a question for those who left the B-757 pertaining to their reactions on having left the B-757. These five topics provided the initial structure for presenting the responses.

Once the data were organized and placed in a coherent structure, the task of identifying trends and regularities proceeded. There are many ways to identify regularities in qualitative data, but the method chosen for this study was to further characterize the responses by conducting an inductive analysis. In this way, the data defined themselves by having the patterns and characteristics emerge out of the chaotic responses. This was felt to be the most appropriate approach rather than imposing structure upon the data, especially with respect to identifying training problems as well as making recommendations and proposing intervention strategies.

As previously mentioned, one of the initial difficulties encountered in this study was the voluminous amount of open-ended data collected. This was further compounded by the somewhat arbitrary nature of some of the responses and the applicability to multiple categories (e.g., cockpit workload and CRM). Another consideration was the longitudinal nature of the study. An attempt was made to look at each questionnaire individually and then summarize the topic as a whole. We felt that this approach would capture any specific patterns after the initial transition training in Questionnaire 2 (Q2) and then once again after flying the line for approximately one year in Questionnaire 3 (Q3). In addition, Q2 and Q3 topics were summarized together at the end of each major question section.

Initially, the responses were transcribed from the individual questionnaires into an electronic format for ease of manipulation. The quotations are as close to verbatim as practical, with some minor editing of punctuation and spelling, and improvement to the flow of the wording. Several responses contain editorial insertions by the authors and are enclosed by these symbols < >. In addition, exclamation marks, question marks and words [italicized] for emphasis are the work of the respondent and not the authors.

Once the responses were electronically transcribed, they were grouped according to questionnaire number (Q2 or Q3) and placed in the appropriate topic: (1) training, (2) error, (3) CRM, (4) cockpit workload and, for a select few, (5) initial reaction having left the B-757. After grouping, an attempt was made to analyze the responses with a computerized narrative analysis tool called Quantitative, Objective, Representative, Unambiguous Modeler (QUORUM; see McGreevey, 1995, 1996, 1997). For a further description of the QUORUM method, see Appendix I. The QUORUM results on the open-ended responses were inconclusive, due to the short length and minimal narration in the pilots' responses.

Due to the inconclusive results of QUORUM, a manual sort was undertaken to develop the character of the responses. The four main topics were further decomposed into the individual question components as follows:

1.0 Training

Questionnaire 2

1.2.1 What did you think of your training for the 757?

1.2.2 Did you have trouble with anything?

1.2.3 What topics should receive more or less emphasis?

1.2.4 Please comment on the training aids and devices.

Questionnaire 3

1.3.1 What did you think of the training you received for the 757?

1.3.2 Is there any way you would recommend it to be changed?

3.3.3 Did the training program (including IOE, LOFT, etc.) prepare you to fly the line?

2.0 Error

Questionnaires 2 and 3

2.1 Describe in detail an error which you have made, or have seen someone else make, with the automation, that might have led to some undesirable consequence. How could it have been avoided? (equipment design, training, CRM, procedures?)

3.0 CRM

Questionnaires 2 and 3

3.1 What can you say about crew coordination and procedures in the 757?

3.2 In what way are they different from previous planes you have flown?

3.3 What areas can use improvement?

4.0 Workload

Questionnaires 2 and 3

4.1 How would you compare the overall workload in the 757 compared to your previous plane?

4.2 Please mention anything that you feel should be changed to help you manage workload (procedures, ATC, training, etc?).

5.0 Departed the 757

Questionnaire 3 (only)

5.1 After you left the 757 and went to another aircraft, what was your reaction?

5.2 What did you miss about the 757 avionics and automation?

5.3 What did you like better about the older technology planes?

5.4 Plane and seat you went to: Aircraft ________ Seat ________

Responses to each question were entered into tables according to a major keyword in the response (e.g., for error: "procedures"). Some responses required another entry according to a minor keyword in the response, if applicable (e.g., "procedures" and "not following"). With this "keyword" method, it was a matter of cutting and pasting the responses into the appropriate categories and then observing the patterns which emerged.

C. Open-ended Responses

Introduction

Each open-ended response topic — (1) training, (2) error, (3) CRM, (4) workload and (5) departed the B-757 (if applicable) — was examined individually according to the questionnaire number (Q2 or Q3) and then again, in a combination of both questionnaires (Q2 and Q3). Since the authors wish not to burden the readers by presenting all of the comments and responses received, only those comments which are typical, contrary or unusual in nature will be presented. However, all of the comments and responses are available for qualified researchers by contacting the authors.

1.0 Training

1.2.1 and 1.3.1 What did you think of your training for the 757?

Questionnaire 2

Of the 84 pilots who specifically stated their reaction to their training experience, the overwhelming majority stated that the training program was excellent. In addition, there was no mention of dissatisfied trainees or any dislike of the program.

- Excellent/best training I've had/outstanding/great. (45)*
- Good/very good/effective. (29)
- Adequate. (4)
- Inconsistent. (6)

*Number in parenthesis indicates similar responses. If none is present, then the reader may assume only one response of that type.

Questionnaire 3

Again, of the 62 pilots who specifically responded to the question, the vast majority felt the training program was good or excellent.

- Excellent/best training I've had/outstanding/great. (39)
- Good/very good/effective. (20)
- Adequate. (3)
- Inconsistent. (0)

Q2 and Q3 Summary

It is a commendable achievement for CAL's training department to receive such high accolades for the B-757 training program. There was not a single pilot who stated that he was dissatisfied or felt the program was inferior, which is in contrast to prior reports on automation and training programs (see Wiener 1989, BASI 1998). Even after approximately a year on the line, the pilots were exceedingly satisfied with their training program.

1.2.2 Did you have trouble with anything?

Questionnaire 2

There were few direct responses to this question. Most pilots addressed what should be improved or which topics needed more emphasis. The following three characteristics emerged from those who responded:

Felt rushed, intimidated or uncomfortable (8)

- I felt rushed. (5)
- I felt uncomfortable the whole ground school.
- There was so much material in so short of time that I am reviewing my manuals to re-learn all that I missed. Note: re-learning is different than reviewing.
- Difficult and intimidating.

Autoflight mode confusion (3)

- I had trouble adjusting to the use of different auto flight modes and some confusion as to which button to push and which mode to use for different aspects of flight.
- VNAV path is an area that rarely operates as I think it should, probably because I do not fully understand what it is using to make its decisions.
- I didn't understand a few things initially with LNAV and VNAV, but didn't quite know just what I should know or ask.

Oral exam (2)

- I had problems preparing for my oral exam. (2)

No problems or troubles (so stated). (9)

Questionnaire 3

Once again, there were few direct responses to this question. Of those who responded, the topics were as follows:

Felt rushed or intimidated (6)

- The company tried to squeeze a lot of new aircraft, new technology, and procedures in to too short of a time span for a rating ride.
- Fast paced and intense.
- Very difficult and frustrating. Too much, too soon, and too fast.
- Too rushed.
- Felt intimidated by the automation.
- I have not received "training" only what is required to fill the FAA requirements for training.

LOFT and IOE (2)

- Most problems during IOE and LOFT seemed to occur with the pilots who did not read the manual.

- My only LOFT was an Atlantic crossing, which I have never done in an aircraft. I would have benefited from a domestic LOFT.

Q2 and Q3 Summary

As previously stated, few pilots responded directly to this question. Most of those who replied to this question had suggestions or ideas to improve the program (see next section). Of those who did, the feeling was that the training program was rushed and contained too much information for such a short period of time. This seems especially true of those with no previous glass experience.

1.2.3 What topics should receive more or less emphasis or should be changed?

Questionnaire 2

There were numerous pilot responses to this question.

Instructors (4)

- Outside instructors <non-CAL personnel> need to be pilots or trained on our standard procedures.
- There needs to be some scheduled time with an instructor every day just on systems.
- Instructors lacked confidence.
- Instructors applied pressure to learn procedures.

“On-the-line” learning (5)

- Too much emphasis on OJT <on the job training>. (2)
- The expectation of the training department that minimal exposure received in training should be adequate is wrong.
- I noticed that other students with no FMC background having a harder time with line operations.
- It <training> generally came together on the line with lots of practice using the equipment.

Instructional topics (16)

- I am still not up to speed on programming the FMC. (2)
- I would like more in depth systems knowledge. (2)
- Windshear training verged on overkill.
- Training on the CDU was almost non-existent.
- More emphasis should be placed on the aircraft flight manuals.
- The FBS was over utilized in my case (5 years on the B-737-300).
- A more in depth explanation of the IRS’s function could have been a help.
- The training was lacking nuts and bolts.
- Instruction in Long Range Navigation was too deep, the experienced pilots knew better and the domestic pilots were “in shock” — teach the basics and keep it simple!
- There needs to be a greater emphasis on CRM and the greater need for the crew to interact with the automation (FMC) and each other to preclude mistakes.
- Human-automation interface training would have been more meaningful to me if it had been given after the sim training instead of before ground school.
- Exposure to automation should be done before training for those without prior experience.
- The FMC training needs to be focused on “real” operational situations.
- Being computer literate made the FMC a breeze to understand.

Questionnaire 3

Instructors (5)

- Need a higher level of experience on the part of the simulator instructors.
- Good instructors and check airmen. They are out to help rather than “grade” the pilot.
- Everyone involved was visible, available, and helpful, but certain once the program is fully integrated into our IAH facility, that will unfortunately change.
- The captains, simulators, and instructor teaching was excellent.

“On-the-line” learning (5)

- Training gave us the push-button knowledge, but flying the line was the teacher. (3)
- For the most part the training prepared me for line flying, but actually being on the line in everyday operations and utilizing all of the information brings it all together.

- More CDU training and operation as it took 3 months on the line to feel comfortable with the various modes and automation.

Instructional topics (6)

- More time with the automation.
- Specify strict procedures for only one pilot to program the FMC/MCP below 10,000.
- More preparation for the oral.
- Need more time spent on VNAV operation and profiles.
- Too much emphasis on FMC programming.
- IOE should be after 100 hours <on the line> especially if this is your first glass cockpit.

Q2 and Q3 Summary

This section is where one starts to see some divergence in pilots' responses with respect to the FMS and the automation in general. The FMS training seems to be either insufficient or excessive in some cases. Whether this is related to any prior glass cockpit experience or not is unknown. However, some respondents state that they have had prior automation experiences with aircraft such as the B-737-300/400. Of some concern are the responses which refer to "on-the-line" or on-the-job training (OJT) and "outside" or non-Continental (non-CAL) instructors who were not practiced in company SOPs. These two situations, OJT and non-CAL instructors, might leave a pilot with some ambiguity in certain situations, and, as a result, pilots may reinforce erroneous actions or faulty assumptions.

1.2.4 Please comment on the training aids and devices

Questionnaire 2

Positive comments (39)

- CBT is excellent/very effective. (13)
- The CBT allowed students to progress at their own pace, and review material. (9)
- Training aids were good/very good. (5)
- The CBT along with the FBS was very exciting/impressive. (4)
- Training aids and devices were adequate. (4)
- CBT and training devices in a building block approach is quite effective.
- The CBT was the best I ever received.
- The training aids and devices were state of the art.
- The CBT was better for not having to listen to an instructor ramble or go off on a tangent.

Negative comments (58)

- We need a FMC/CDU training aid for practice. (28)
- The CBT aids were inconsistent and/or had errors. (17)
- One needs to be able to go directly to a specific item instead of listening to a large portion of a system to answer one question. (3)
- I did not like the CBT, very impersonal and boring. (3)
- There needs to be more questions and answers on the CBT.
- The CBT is not the best way to learn an airplane.
- CBT was slow and frustrating to use.
- The CBT training is linear oriented and does not encompass the complete scope of the automated systems.
- At times, I had to "figure out" what the computer answer was rather than the system comprehension understanding in order to progress, which is negative learning.
- The CBT lulled one into a false sense of confidence.
- The FBS should not be used as a substitute for a real sim.

Questionnaire 3

Positive comments (5)

- The CBT was excellent. (3)
- CBT, FBS, and then the full sim was a logical progression.
- The CBT was the best of my career.

Negative comments (19)

- There needs to be an operating CDU/FMC trainer. (13)
- The CBT was distracting in several areas because it had errors. (2)
- The CBT could be improved to allow for more realistic FMC operations.

- CBT (in lieu of instructor-led ground school) is sheer drudgery. I'm sure that my retention of systems and overall understanding of systems operations is significantly lower on the B-757 due to CBT.

- Very dull in the personal computer trainer.

- The fixed-base simulator looked like an expensive make-work government project. It is not a simulator, but treated as a simulator, and graded as one, to the detriment of the student.

Q2 and Q3 Summary

Many of the pilots responded that the CBT was a good or excellent training device. However, some pilots mentioned that the CBT contained errors or that they had experienced frustration by having to retrace their steps in order to review a particular topic. In addition, many pilots mentioned a desire for a workable FMS trainer that would enable them to practice building FMC programming skills and techniques outside of the simulators (fixed base and full motion).

These last three issues — (1) CBT errors, (2) wading through prior CBT material in order to review previous topics and (3) the need for an operational FMS trainer — raise some concerns with the authors. Errors in the CBT are inappropriate for pilots undergoing transition training or any other type of airline training, for that matter. In addition, one can empathize with a pilot's frustration by having to navigate through prior material in order to review a previous topic only one or two frames away. Finally, we suspect the requests for the FMS trainer may be predominantly from pilots without prior glass experience.

1.3.3 Did the training program (IOE, LOFT, etc.) prepare you to fly the line?

Questionnaire 3 (only)

Twenty-eight pilots responded that the training they received adequately prepared them for flying on the line. There were no negative responses to this question and many without a response indicated.

General Comments on B-757 Training Program

Questionnaire 2

Style of instruction

- Felt the training was "bought cheap" and not kept up to date with changes or new information.

Curriculum development and implementation

- Coming off the B-737-500/300 made the training easy. (3)

- Coming from the B-737-300/500, it seemed more like transition training.

- I came from the B-737-300/500 and was bored with some simulator sessions — I should have had a "short course."

- Previous experience on the B-737-300/500 made the transition extremely easy. My only negative comment would be the length of training seemed a little long.

- Coming from the B-737-300/500, I had the advantage of being familiar with the glass cockpit and FMS computer which helped me a lot and made the B-757 training much easier.

- I was a Captain on the B-737 and went to FO position on the B-757. The change of seats was more trouble than the aircraft change.

- For pilots that have never had an FMS aircraft prior to the B-757, it requires a lot of hands on training.

- The transition from the B-727 was a quantum leap.

- I noticed students with no prior FMC background had a more difficult time with training.

Administration and scheduling

- The 14 hour day needs to be reduced. 4 to 6 hours training/day with study time would equal an 8–10 hour day.

- I wish I could have obtained my manuals sooner for studying.

- Being paired with the same FO throughout the training sessions was helpful. We lived together, studied together and flew together. Big benefit.

- They did not give us enough (almost none) information about training before-hand.

- ETOPS training should be given after IOE.

Questionnaire 3

Style of instruction

- Would like to see a group class.

- Bring back the classroom environment to create the question/answer exchanges from other pilots.

- If the line environment was as exciting as the training, I would have stayed on the aircraft.

- The LOFT training was invaluable. It all came together in those sessions.

- We need a LOFT program for training (had only one after PC) and more recurrent training (we have none).

- The B-757 training was a self-taught course with too much verbiage in the supplemental training guide.

Curriculum development and implementation

- Solicit feedback from the pilots.

- I came off the B-737-300 which is also automated. I thought the transition to the B-757 was easy.

- No complaints except a shorter course should be offered for pilots who transition from B-737-300/500.

- Training was well standardized and positive in nature.

- The simulator and LOFT sessions were very good.

Administration and scheduling

- The <oral> exam would have been more relaxed somewhat if some of the FMC work was saved until after the oral.

- Providing the study manual and flight manual before beginning training to give the pilots a chance to prepare ahead of time.

- I feel that training someone on any equipment, then letting them sit for three months is extremely dangerous and stupid. I lost currency twice before I logged 100 hours. Floundering around in an unfamiliar cockpit, trying to take in the finer points of long range navigation and skirting 23,000' mountains on the backside of the clock is not my idea of a good time.

Training Summary

Once again, CAL's training department receives accolades for such a positive response to their B-757 training program. Certainly some areas could use improvement, but the majority of the pilots felt their training gave them the skills and information necessary to fly the line. However, it is in this training section that one starts to see a dichotomy between those pilots with no prior glass experience and those with previous glass experience. This dichotomy is especially prevalent in section *1.3.3 General comments on B-757 training program*. In these general comments, one finds pilots with prior glass experience (mostly B-737-300/500 aircraft) commenting that the training was easy or in one instance, "boring." On the other hand, one can sense some pilots struggling with learning a whole new concept of flying and learning the FMS associated with glass cockpits.

2.0 Error

Introduction

The responses to this question were read, sorted and then categorized according to the type of error. While many responses indicated that the error had been committed by the respondent, some responses were instances in which the pilot observed an error either from the cockpit or jump seat. Several of the responses were complaints or irrelevant comments, and these were discarded from the categorization. In addition, an error was placed in only one category with no multiple entries.

2.1 Describe in detail an error which you have made, or have seen someone else make, with the automation that might have led to some undesirable consequence.

This topic was handled differently from the other open-ended responses, in that all the responses from questionnaires 2 and 3 were merged to derive the error topics. Once the errors were sorted and categorized, the responses were placed back into their respective questionnaires (Q2 or Q3). A total of 12 error types emerged from the response sort and analysis with the following topics emerging [see table on page 51].

The following pilot responses are typical of the errors or incidents that were either committed or observed. All the error responses are not included so as not to burden the reader with repetition. Any suggestions of how the error could have been prevented (e.g., via equipment design, training, CRM or procedures) took precedence and appear in the transcribed responses below.

2.1.1 Programming CDU/MCP (52)

Questionnaire 2

- Wrong fixes entered into the computer. However, <errors> are easier to see in the glass cockpit.

- A mistake that is being made by all in programming the route. If you are cleared EWR to LAX on Route 006, and you try to install Route 006, but a message appears "Route does not exist." Instead of going to the "Route Page" and manually placing the route in, everyone is trying Route 001, Route 002, Route 003, etc. until they found a route that matches 006.

- The speed knob is often mistaken for the heading knob and vice versa. On take-off and climb-out this can cause a decrease in airspeed at a critical time, or the start of a turn when it is not desired. This is an equipment design problem; they (knobs) are too close and too similar in appearance.

	Error Type	Total = (Q2 + Q3)	
2.1.1	Programming CDU/MCP (incorrect, incomplete, neglecting or not cross-checking)	52	(29 + 23)
2.1.2	Energy management (altitude bust, not meeting speed or crossing restriction)	24	(16 + 8)
2.1.3	Automation (over-reliance, surprise, or loss of situational awareness)	23	(8 + 15)
2.1.4	Action (out of sequence, neglected or incorrect)	19	(6 + 13)
2.1.5	LNAV (setup/confusion)	14	(6 + 8)
2.1.6	Mode switching (confusion with switching between modes or current mode state)	14	(9 + 5)
2.1.7	Procedures (incorrect, incomplete or neglecting)	14	(8 + 6)
2.1.8	Workload (time for scan, distractions or excessive heads-down)	13	(5 + 8)
2.1.9	VNAV (setup/confusion)	12	(8 + 4)
2.1.10	Approach (setup/confusion)	10	(7 + 3)
2.1.11	Equipment (aircraft systems configuration or NAV displays)	8	(6 + 2)
2.1.12	Training (negative transfer)	6	(4 + 2)

- We loaded the FMC manually, then the CDU kept flashing that it wanted to be loaded automatically by uplink causing difficulty for the flight. We were concerned we had loaded it manually and didn't know what the consequences would be.

Questionnaire 3

- Most common error for all pilots is not checking the FMA after selections or <after> engaging a mode selected on the MCP. This error can be avoided by making sure that what you have selected is enunciated correctly on the FMA.

- Captain entered the holding course incorrectly! He used the radial verses the inbound course. He was a little weak on the FMC.

- Setting the wrong altitude in the window <MCP panel>.

2.1.2 Energy management (24)

Questionnaire 2

- Depending on the aircraft to ensure meeting restrictions have twice resulted in potential violations.

- In LVL change with 315 knots below 10,000.

- I have never been involved in an "altitude bust" in 23 years of aviation. I was involved in one excursion and one trip later, almost another excursion for the same reason. The captain was flying both times. He decided to hand fly in VFR conditions out of a high density airport. He failed to brief his actions and responsibilities. We were advised several times on climb-out of VFR traffic. After performing my duties inside the aircraft, I turned to the outside to look for traffic and failed to cross-check the captain who I had never flown with before, but was an instructor and at least a check airman. I assumed he was flying the airplane. Unfortunately, he was "outside" the airplane and had such a high rate of ascent that he "busted" the altitude level-off by more than 800'. My very next trip was with a different captain but almost the same scenario except I called 500' before level-off and again with a high rate of ascent. The captain thanked me for the notification. There is a very big need for more communication in these high workload areas. I have learned from these mistakes. I only hope the captains, who set the CRM pace in the cockpit, also learn from their mistakes.

Questionnaire 3

- Relying on VNAV path to accomplish required altitudes at certain waypoints. VNAV is improperly programmed for the B-757 engines that CAL uses.

- Altitude busts. This A/C is so geared to smoothness for level off that if intermediate altitude is quickly selected, it is time to disconnect.

- LAX CIVET arrival. I set hard altitudes for numerous step-downs <while> operating on LNAV. Busted 1,000' below altitude at one VOR. First time in 22 years of flying that I had to file a NASA report.

2.1.3 Automation (23)

Questionnaire 2

- We were cleared for a visual approach to a parallel runway while on a base leg (FO flying). The FO should have disconnected the automation and turned into the runway. Instead, he stayed on the base leg course and intercepted the ILS at an 80 degree angle. We flew near the approach course for the parallel runway. The FO was too dependent on the automation.

- When I programmed in an approach, the path depicted for the IAF turn was not what I expected or could believe, nor did I feel the A/C would comply with the descent profile.

Questionnaire 3

- I flew one flight with the autothrottles inoperative. While encountering a mountain wave, airspeed blew off to a value near top bug. We were at FL 410 and airplane could have stalled. The autopilot kicked off for some reason, which is what got our attention. Extra engine power of B-757 allowed A/C to recover without having to trade altitude for speed. Dependence on the autothrottle system took away a set of flight parameters that I would normally monitor without this kind of system and which I seldom pay attention <to anymore>. My throttle techniques are rusty.

- After arriving at the LAX terminal area, ATC, due to excessive traffic and their inability to deal with increased traffic, asked us to turn and intercept the final course for rwy 24R in the north complex. This would have simply consisted of dialing the corresponding ILS freq and land on the corresponding and assigned rwy. The FO felt compelled to reprogram the FMC for the ILS approach to that <new> rwy. All crew interactions were suspended until he accomplished "the task" of reprogramming the computer. I repeatedly asked <him> to dial in the ILS freq to the assigned rwy. He became "hypnotized" and would not acknowledge my requests. His concentration on "pushing the right buttons" caused a breakdown of crew communications, loss of situational awareness and left me to fly the A/C, talk on the radio, set the flaps, etc. I have flow with this individual on other A/C and his behavior, I feel, is unique to this A/C. He seemed surprised that after he came back we were so close to landing. Training must emphasize a threshold of priority in order to fully maintain an integral crew during last minute changes.

2.1.4 Action (19)

Questionnaire 2

- The one I have to work on is select LNAV after having been on an assigned heading after cleared direct to a fix. I've missed that on a couple of times.

Questionnaire 3

- Multiple instances of failing to engage LNAV after programming a direct track and slow to recognize that the AC is in HDG mode.

- I was given a direct to a fix after being given a vector. After inputting the fix to which I was given the "direct to," I failed to select LNAV. After about 5 minutes, I noticed the A/C on the map display was deviating from the displayed route.

- Captain forgot to activate and execute a route in the FMS. I did not notice until ready for take-off. Could have been avoided if one of us had cross-checked the other's work.

2.1.5 LNAV (14)

Questionnaire 2

- Twice, since I have been in the B-757, I have been surprised to see which lateral mode is <displayed> in the flight mode annunciator.

Questionnaire 3

- Entering a waypoint way too close to or just past the fix and having the aircraft start a 360 degree turn. <I> switched to heading select.

2.1.6 Mode switching (14)

Questionnaire 2

- VNAV switched to FLCH. I did not realize it had done so and I was not watching the step downs. I was contacting the company and expected the automation not to miss a beat.

- Even with my experience, it is very easy to forget to cross-check that the aircraft is in LNAV and not heading select or VNAV speed and not path. VNAV is more critical than LNAV. An aural warning when VNAV changes to SPD from path would be nice. Constant cross-checking is imperative.

Questionnaire 3

- I have seen multiple occasions when the VNAV system defaults from VNAV path to VNAV speed. This is so subtle that it is many times unobserved. On previous FMC aircraft that I have flown (B-737-300), the FMC gave a message "unable path descent," which gave the pilot much better info compared to the subtle FMA change in the B-757.

2.1.7 Procedures (14)

Questionnaire 2

- The opposite pilot executing the CDU without the knowledge of the other pilot.

- Checklist items missed.

Questionnaire 3

- Not briefing a contingency approach for airport with low visibility (below 1,200 RVR). <Suggestion:> brief multiple approaches and do not allow approach control to give unrealistic commands.

2.1.8 Workload (13)

Questionnaire 2

- During TO and LND phases, as well as VFR, few pilots look outside. Specifically when ATC assigns "Turn left to…" the first action should be to glance to the left in the direction of the intended turn. Most pilots reach for the MCP or CDU first.

Questionnaire 3

- <We> had a runway incursion at SFO. <I> had a new FO and <he was> new to the automated A/C. A chime with ACARS sounded at the same time <a> clearance to cross 28L and hold short of 28R <was received>. As captain, I heard to position and hold 28R. FO read back hold short and became engaged in inserting a delay code in ACRS (which was not working) while I taxied into position. Tower said nothing. <Another> A/C was on 5 mile final and had to go around (NASA report filed).

2.1.9 VNAV (12)

Questionnaire 2

- In the VNAV descent mode the automation does not control the airspeed very well.

- I saw a pilot try to use the cruise page to initiate a descent in VNAV and get confused because it did not present the expected information.

Questionnaire 3

No responses.

2.1.10 Approach (10)

Questionnaire 2

- ILS capture problems in Mexico City and Bogota Colombia.

- After selecting approach mode to ILS 25L, LAX approach controller changed approach to ILS 24R with a heading intercept. We had not practiced an approach change after all three autopilots were engaged. We went HDG SEL with no reaction from the aircraft. It took both of us about 5 seconds to finally disconnect the autopilots and hand fly the AC to the other runway and reconfigure for the approach. Also, when we were told to change runways, we were told to maintain 4,000' until intercept, but GS had been captured. If we had not disconnected the AP, we would have busted the 4,000' restriction which is not good! So, I suggest more emphasis on runway changes after APP mode is selected.

Questionnaire 3

No responses.

2.1.11 Equipment (8)

Questionnaire 2

- Problems with several different pilots having confusion with heading up verses track up (map mode).

- I accidentally turned on the APU [auxiliary power unit] in heavy rain on short final because the two switches (APU and wiper) are identical and too close together.

- I arrived at the runway with the flaps up (for take off). The <unextended> flaps <were> discovered in the take-off checklist.

- Almost missed a change in flap settings. We use 20 degrees 99% of the time, and grow accustomed to that. When it's changed it's easy to miss, especially if late for departure. I finally caught it when setting the V-speeds because they were higher than normal (flaps 15 were called for in this instance). I have started circling critical items in red on the ACCU-LOAD.

Questionnaire 3

No responses.

2.1.12 Training (6)

Questionnaire 2

- Current CDU design and or database needs modifications. In NAV DATA on the B-757 you can not build your own waypoint. Unlike the B-737, this is a great draw back if the waypoints you want are not in the database. Most mistakes I see on the line are in reference to this one item.

- FO tried to fly a VOR approach using <the> localizer function. He reverted to VOR/LOC logic of his older aircraft.

- Old computer habits are hard to break.

Questionnaire 3

No responses.

Error Summary

The results of the open-ended error question reveal that programming the FMC and MCP seem to predominate in the pilots' responses. This is noteworthy, especially when one considers that there was relatively little reduction in programming errors over time (i.e., approximately 25 percent of the population were still making programming errors after a year on the line). One would expect numerous errors after transitioning to the line with a tapering off of errors over time. This does not appear to be the case with this population in that the programming error rate appears to remain steady over time.

Another interesting trend is the increase in automation error types while flying the line. One would expect automation surprises after transitioning to the line, and this seems to be the case, but an interesting trend is the shift in automation surprise responses in Q2 to the reliance on automation responses in Q3. This echoes the previously mentioned problem of "overuse of automation" in some aspects of flight (see error type 2.1.3 Automation Q3 on page 52 — "After arriving at LAX terminal area …" where a pilot became "hypnotized" by the FMC in a last-minute runway change).

One area of concern is the failure of energy management during descents. There are numerous responses regarding the failure to meet crossing restrictions, excessive speeds below 10,000 feet, and altitude busts. Previous studies (Wiener, 1989) also have noted a high frequency of altitude "busts" and a failure to meet crossing restrictions, and this seems to be the case in this study as well. Several pilots attributed the failure to meet crossing restrictions to the "clean" nature of the B-757. Meanwhile, other pilots mentioned ATC's tendency to keep the aircraft high until the last minute and then expect a rapid descent. In either case, the fact remains that the aircraft is not meeting the speed, altitude or crossing restrictions required of certain descents (and ascents in some instances).

Another interesting trend in the error responses is the increase in the action error types from Q2 to Q3. The increase in this category is almost exclusively failing to select LNAV after being in heading select. This is a curious trend in that there are relatively few mentions of failing to activate other functions with the FMC in a timely manner.

Other than the previously mentioned topics, the remaining error rates declined significantly from Q2 to Q3, which would be expected as the pilots gain more operational experience on the line and familiarize themselves with the aircraft. But this is mentioned with a caveat, in that "learning it on the line" may be associated with its own set of problems and errors types.

3.0 CRM

Introduction

As with Wiener's previous glass cockpit study (1989), pilots tended to view CRM as a workload issue. In addition, the proliferation of automated aircraft and two-member cockpit crews is premised on the "communication of information" in order to maintain situational awareness in the cockpit. This awareness is particularly critical during busy flight regimes or when the other crewmember is busy handling other duties and is "out of the loop."

Once again, the CRM open-ended responses are treated in a questionnaire-specific manner with responses grouped according to either Q2 or Q3 and the summary a reflection of both questionnaires.

3.1 What can you say about crew coordination and procedures in the 757?

Questionnaire 2

There were 24 specific responses to this open-ended question with the following being typical of those who replied:

- CRM needs to be emphasized all the time in the B-757. (4)
- The need for teamwork/CRM is very important in the B-757. (2)
- The design and layout of the flight deck make crew coordination very easy and effective. (2)
- With the abundance of information available in the glass cockpit, it is probably more difficult for pilots to ascertain the situational awareness of the other pilot crewmember. This places a little more pressure on the captain to communicate without trampling egos.
- As long as everyone is operating on the same page, then monitoring is good, but when new info is entered on different pages, especially at lower altitudes, workload increases.
- Crew members must interact verbally on what modes are being utilized and what the aircraft's expectations should be.
- Both pilots must define workload sharing in the advance of flight (capt. briefing) in order not to duplicate jobs.
- The B-757 is a high performance airplane and things happen very quickly in a short amount of time. I think it's important to brief the very basics in the event of communication break downs or emergencies. There is

a need to brief the aircraft's automation and treat it as a third crewmember.

- I like the ways we are operating and conducting procedures in the B-757.
- Excellent procedures in the B-757. Keeps you outside.

Questionnaire 3

Twenty-six pilots responded, with the following being typical:

- CRM/procedures in the B-757 are good/very good. (10)
- There is a need to be more of a manager of the automated assets and how to use them. (2)
- The (B-757) requires that we brief each other on what has been loaded into the FMC. (2)
- Standardization on the B-757 is good. (2)
- It's difficult to see what the other pilot is inputting when he/she is pushing buttons.
- Coordination in the B-757 requires "buy-in" by both pilots or results in the need for one pilot to maintain extra vigilance if the other doesn't understand the system and is unwilling to express it. The procedures are designed well, but complacency sets in.
- CAL's B-757 CRM and training procedures are the most advanced.
- Pilots need to treat the automation as a member of the team.
- One good thing is the sophisticated FMC is almost always right. Crew coordination is pretty simple if you both follow SOPs.

3.2 In what way are they different from previous planes you have flown?

There were four sub-topics that emerged from the response analysis with the following three topics being representative of the responses: (1) crew size comparisons, (2) procedural and checklist differences and (3) CRM.

3.2.1 Crew size comparisons

Questionnaire 2

There were 10 replies comparing three-crewmember cockpits with two-crewmember cockpits with the following being typical responses:

- I have always been on a 3-man crew and find both of us doing something with the FMC.
- I have been on a 3-man crew for the better part of my time. Switching to a 2-man crew changed the way flight was conducted. Once you get used to not having the third man onboard, the smoother flight progresses.
- Roles and pecking orders are much more apparent in 3-man cockpits.
- With an automated cockpit, each pilot *must* know what the other one is doing at all times. In previous planes (3-man), I paid more attention to basics. Including looking outside. Now both pilots just sit back and monitor what the airplane does.
- Coming from a 3-man cockpit (B-727), covering all the bases in a 2-man crew can be a little busy.

Questionnaire 3

There were seven replies which refer to crew size comparisons, the following being typical:

- Most captains, myself included, came off a 3-man crew. That took some getting used to.
- I believe the 3-man crew is a much safer operation. Our CRM and procedures are excellent, but situational awareness is unavoidably diminished with malfunctions and/or abnormal situations develop.
- I always have flown 3-man AC. This was my first 2-man AC, and it gets busy. But, crew coordination is the same to me.
- I prefer the 2-man crew when it works as we trained.
- There is more coordination required in a 2-man crew. All my other equipment has been 3-man crews.

3.2.2 Procedures, checklists and CRM comparisons

Questionnaire 2

There were 28 similar responses with the following being typical:

- No taxi checklist. (2)
- Average CRM. (2)
- Cockpit flow as <compared> to specific checklists. I prefer checklists.
- The B-727 has a very long drawn out series of checklists with a lot of switches and buttons, where the B-757 checklists are short and concise with system checks being short and quick as well.

- The simplicity of checklists.

- I came from the B-737-300/500 and there is more emphasis on “hitting the box.”

- Each pilot has to be aware of the other pilot’s input into the FMC and other pilot’s thought process.

- CRM and procedures are for the most part SOP. The main difference is higher pre-flight workload and closer coordination for in-flight programming.

- Crew coordination is about the same.

- Better coordination and procedures than any plane I’ve flown.

- <I> came from the A300 and CRM is adequate.

- CRM works very well and is stressed more than other planes.

Questionnaire 3

There were 16 similar responses referring to checklists, CRM and procedures:

- I prefer the short checklists and flows. (2)

- Checklists are simplified and there is no taxi check. (2)

- Same procedures. (2)

- I had previously spent 9 years on the B-737-300/500. The transition to the B-757 was fairly easy. The biggest improvement was shortened checklists and cockpit layout (most noticeably the HSI mode selector).

- Crew coordination is much more important in the B-757 than any current aircraft in the fleet.

- There is more coordination required on the B-757.

- CRM is stressed by CAL.

- They (procedures) don’t seem that much different than the CRM procedures for other airplanes. It is possible for the PNF to get out of the loop.

- Crew coordination is better (in the B-757).

- B-757 crews seems to work more as a team. Still have “hot-shots” who are always on the computer and push buttons too fast.

- The (B-757) requires better communication between crewmembers as info can be loaded in the CDU without the other crewmember knowing about it.

- More CRM in the B-757, some of it in relation to the increased capacity of the airplane.

- Crew coordination is simpler because it’s easier.

3.4 What areas can use improvement?

Questionnaire 2

There were 34 recommendations made by the pilots on how to improve procedures, checklists and CRM. The typical recommendation responses were as follows:

- We need a clearer separation of CDU/MCP duties. (4)

- More emphasis on standard procedure/checklist usage. (4)

- Would like a taxi checklist with the flight controls check done at that time. (2)

- There needs to be additional care taken in observing and cross-checking the programming of the FMC. (2)

- Have the PF make the CDU entries like on the B-737-300/500. Why not have consistency across all aircraft types? (2)

- Procedures for setting the ALT ALT/warning on the MCP should be changed. I think that if the PNF always made the ALT change (like A300), there would be less room for error.

- Would like to see some reference to flaps on a checklist, possibly on the after start check.

- I still find some people who are resisting procedures to call for CDU/FMC/MCP functions when they are the pilot flying, especially in the terminal environment.

- Duties regarding who should program the FMC when PF or PNF.

- Most FOs do not verbally announce changes in the MCP altitude settings. The flight manual mandates doing so and I think this is a training or awareness item.

- I am all for short checklists, but it bothers me that our take-off and landing checklists leave things to be done after the checklist is complete. We should be at our final flap setting before calling for the landing checklist instead of doing the checklist at 20 degrees.

- The company has gone overboard to keep checklists short. The flaps not being on the after start checklist is a crime given that there is no taxi checklist. They are part of the "flow," but don't appear on a checklist until before takeoff, when it's a little too late to be lowering the forgotten flaps. I've gone all the way to the runway with the flaps up, neither pilot noticing.

- It's hard communicating with all the flight attendants (we usually carry 5).
- Works fine as is, no improvements needed. (3)

Questionnaire 3

There were 19 suggestions from pilots with the following being typical responses:

- A more specific defined policy of one pilot programming the FMC. (3)
- Need to have better CDU input verbalization, especially in the terminal. (2)
- More checklist discipline: calling, responding, and timely execution. (2)
- More emphasis on less FMC/CDU below 10,000.
- The approach checklist is used at a time when the cockpit workload is very high.
- There is a need for PNF to monitor FMC inputs by PF, in order to verify and backup. There is a tendency by some captains who are PNF to make FMC inputs. This can be confusing to the PF.
- I am quite alarmed that while the B-757 procedures are instructed during training, there are many cross-over procedures that creep in to line operations "well, that's the way we always did it on the Airbus." We need enforcement of the concept that this is the B-757.
- Below 18,000', I'd like to have both crewmembers in the loop and not talking on the radio to company and doing maintenance write-ups.
- I believe that calling for the flight guidance changes helps keep the non-flying pilot "in-the-loop." Yet, there seems to be tremendous reluctance to do so. It embarrasses some pilots to verbalize commands they are used to performing themselves.
- There needs to be an improvement in interpersonal skills. Some pilots can not relate to their fellow man and equally as poorly with a know-it-all computer.

3.5 Miscellaneous CRM responses

Questionnaire 2

In questionnaire 2 there were nine responses which were not easily categorized; as a result, they were placed in this miscellaneous response category:

- I appreciate the active teaching/applications of CRM.
- CRM has always been good at CAL in my experience.
- I am a proponent of strong CRM. I stress it, set the environment for it, and it seems to work. This requires an open, receptive and forgiving captain for excellent CRM to work.
- Complacency could become a problem if everything is loaded properly and things work great. Success and ease brings complacency.
- At this carrier, I find CRM to be very good.
- CRM is a very good tool to improve cockpit inter-relationships.

CRM Summary

There appears to be an underlying theme in the pilots' responses that reflects a need to effectively monitor, communicate and manage information on the flight deck. In fact, one pilot referred to the automation as a "team member" and suggested treating it accordingly. However, the abundance of information could "swamp" a recently transitioned pilot or present difficulties ascertaining another crewmember's awareness of the current flight regime. This was alluded to in several statements regarding further clarification of duties and procedures for inputs into the FMC/CDU.

A topic that received many comments was the two-person vs. three-person cockpit. This still seems to be a prevalent topic among some pilots even though the two-person cockpit has been in service for several decades. It appears that most pilots transitioning from a three-person crew acclimate to the new situation fairly easily. However, there are still a few pilots who are opposed to the loss of the flight engineer and, in fact, returned to a three-seat aircraft based solely on that fact (see section 5.0 For Those Who Have Left the 757).

As for procedures and checklists, most pilots preferred the shortened checklists and flow patterns associated with the B-757. However, there was mention of "forgetting" to set the flaps before arriving at the runway threshold for takeoff, and this raises some concern. In general, most of the pilots endorsed the B-757 procedures, checklists and CAL's strong CRM approach associated with this aircraft.

4.0 Workload

4.1 How would you compare the overall workload in the 757 compared to your previous plane?

	Workload Compared to Previous Plane	Total	=	(Q2 + Q3)
4.1.1	Much less than previous plane	16	=	6 + 10
4.1.2	Less than previous plane	32	=	15 + 17
4.1.3	About the same as previous plane	26	=	13 + 13
4.1.4	More than previous plane	12	=	8 + 4
4.1.5	Much more than previous plane	7	=	3 + 4
4.1.6	Shifted or different from previous plane	3	=	0 + 3

General Comments on Workload

Questionnaire 2

ATC and effect on workload

- Last minute changes causes the workload to increase at critical times. (3)
- ATC has a tendency to keep you high expecting a rapid descent and or speed reduction which is hard to do in a B-757.
- Under normal conditions it is less. When ATC makes changes that were not programmed in the FMC, then it becomes more workload.
- ATC calls at inopportune times.
- Need to allow for published FMS arrivals. Too often ATC cancels them.
- ATC is always changing to their benefit and increases our workload.
- It's helpful when ATC understands how the automation works and clears us with that in mind.
- ATC is inconsistent.
- ATC interferes with the automation too often.
- Once ATC changes the flight plan the FMC needs to be changed and this increases workload.
- Some controllers at ATC still seem unaware of the aircraft's/crew's capabilities and do not make full use of what we can do. Sometimes they even become argumentative when we try <to> help.

Phase of flight and workload

- The majority of workload on the B-757 is prior to departure and after landing.
- Pre- and post-flight workload is higher. In flight workload is lighter.
- The overall workload seems to greatly reduced during most phases. However, the loading of the flight computer seems to take a lot of time and concentration. I am referring to the pre-flight phase.
- Overall workload in pre-departure, post arrival and most terminal environments is considerable higher. Especially in a fluid ATC environment.
- The loading procedure during preflight is laborious and time consuming. To do an effective loading of the FMC takes a good 10–15 minutes with numerous opportunities for errors.
- The workload is far greater during the departure and arrival phases of flight for FMS aircraft than for non-FMS ones.
- <Workload is> much greater except at cruise.
- The workload at the start of the flight (in chocks) is the highest I've experienced. However, once airborne, the load is very low and it's easy to lapse into complacency. The need for vigilance is even greater for that reason. One note: CAT III approaches and autoland are probably the place where the difference in workload is the most pronounced.
- Higher preflight <workload> is bad in B-757.
- An increased workload just after take off. After that, much easier.
- The important thing, however, is when it <workload> is less. I do most of my work before the flight even begins. Then I am able to better watch and/or manage the balance of the flight.
- I felt that one area of concern that I had, even after IOE, was descent management. In fact, I see the same thing in many of the new pilots coming on the line. The problem I am referring to is not "planning" a descent, but executing it safely and efficiently with the flight guidance.
- Descents are unpredictable in the B-757 system.

Workload and long-haul operations

- On B-757 there is less workload on all phases of flight except actual ETOPS and long-range NAV (look at ETOPS checklist).

- Very high! A very high workload is especially prevalent during international operations.

- I just flew to Manchester. The trip over was fine. Coming back we had everything changed en route (track, ETOPS altn 3 times, etc.). Two pilots were too busy to do all of this. An IRO was needed badly. If any abnormals would have happened, we would have been so busy that “flying or monitoring the A/C” would have been tough.

Workload and lack of a flight engineer

- More workload due to the absence of a flight engineer. The pilots have to pick up the company and cabin workload.

- Much greater — I came from 3 pilot A/C to 2 pilot A/C but automation lessens the workload.

- I was previously on a 3-man A/C (DC-10) and there is no comparison. Work was easier with the S/O doing his job.

- I did not assume 1/2 of the S/O’s workload, but from 50% to 100% additional. When an emergency requires radio coordination with company personnel, one crewmember’s workload increases many fold. Being a single engine, single seat trained pilot, I am somewhat accustomed to the workload. However, when the F/O has to confer with the capt. for information and/or decisions, the capt. can become overloaded. A third crewmember would be an enhancement in certain environments.

- Workload is slightly higher, but mostly during pre-flight (no second officer), but nothing unmanageable.

- Increased workload because of a 2-man cockpit.

- Workload is automated and it helps cover a lot of items that were manual by the second officer.

- The second officer is helpful in monitoring approaches, reading checklists, and obtaining ATIS and company data.

Workload and comparison to previous plane

- B-757 workload is about the same as B-737-300/500. (3)

- The whole cockpit of the B-757 is much busier than the old airplane (DC-10) with a 3-man crew, but that’s not the only reason. The automation has to be programmed and that takes time, knowledge, and practice. The FMC is nice for planning — if you have the time.

- Much less than B-727 compared to flying and following clearances.

- Easier than the B-737-300.

- Workload on the B-757 is greatly reduced versus the B-737-300/500 because of our long route segments versus the short ones on the B-737.

- The overall workload is certainly no more than the MD-80 or B-727, and, in most situations, considerably less. I think the workload is already easy to manage.

- I find the workload slightly less than the B-737-300/500.

- Much less than the B-727 and the B-737 (due to the long legs).

- The B-757 is not any busier than any other A/C I have flown.

- Workload on the B-757 is greater than on the older generation of aircraft. For example, on the DC-9, in order to plan a descent, I would figure the distance needed to cross a point at a certain altitude and the rate of descent or airspeed would be established and both monitored. On the B-757, I still have to figure the descent, then check the computer and if both agree, then start the descent at the correct time while making sure it holds the speed, autothrottles are coming up to try and hold the speed but then reduce for the descent rate, and the green arc is correctly displaying the situation. In this instance, it’s easier to fly the plane than the “computer.”

- It is higher than the DC-10.

- My previous plane was the DC-10 which had 3 pilots thus spreading the workload thinner, but I find the B-757 the easiest plane I’ve ever flown both in terms of workload and flighty characteristics.

- The B-757 and B-737-300 are equal during gate departure, takeoff, etc., but the B-757 is significantly higher during descent due to its tendency to get fast and high on descents. This causes much greater use of speed brakes, mode switching, button punching of the FMS, etc.

- The overall workload in the B-757 has increased substantially in the critical phases of flight, compared to the previous A/C I flew (B-747, B-737, B-727, DC-10, and DC-9/MD-80). An emergency arising during a critical phase of flight can overwhelm even a well trained and experienced crew. Your average crew could be overloaded or distracted with much less. This advanced twin engine, two pilot aircraft has now been flying for years and has managed to stay out of the headlines, perhaps due to its relatively small numbers.

Workload and gaining experience with the B-757

- The workload is now becoming less as I gain more experience.
- Right now with just a little over 100 hours, the workload is probably more than my previous plane, but I feel that with another 6 months or so, I <think> it will be the same if not less.
- As I become more familiar in the B-757, workload appears to be less and less.

Availability of information and situational awareness

- More information is available to me in the B-757. Workload is no more or less, but I have more options and displays from which to choose.
- The workload is greatly reduced in having the ability to evaluate and improve situational awareness.
- Workload is much lower yet have more information to help make good management decisions.

Questionnaire 3

ATC and effect on workload

- ATC has not fully upgraded equipment and is unable to make full use of today's automation. It <B-757> of course is restricted by combination of all A/C. Maybe 20-30 years from now when most A/C will be auto?
- In high density areas, the call in to Departure Control is right at our flap/power transition point. If ATC could live with just the call sign (company and flight number), we could be better at flying, looking, transitioning and being more coordinated/safer. At EWR (for example) we could auto switch to Departure Control at 500 ft (or some agreed on altitude). The point is that you've got radio calls, flaps to change, headings to dial, altitude to set (all in 5 seconds). Parcel it out.
- The problems with ATC, (LAX and SFO) it's hard to use all the automation, because airports like these are too busy. Speed up, slow down — stop your descent or climb so you're back to a basic A/C.
- ATC in arrivals and departures are the biggest workload. We need a better ATC system to manage ARR and DEP.
- ATC procedures have become a real pain. I don't believe the changes are necessary and I believe that controllers have an agenda that they are promoting through their "erratic changes" in traffic control.

Phase of flight and workload

- Too much company and outside interference during block preflight duties and check list.
- I believe the workload to be higher in the B-757 during some phases of flight i.e. preparing A/C for flight (on ground) and at altitude prior to descent (especially when changes occur to expected clearances, SIDs, runway changes). However, these normally do not occur during critical phases of flight — once programmed, the automated cockpit gives you so much more information during the critical phases of flight i.e. T.O., approach, landing.
- Higher workload during preflight and in general there is less workload in flight. However there is an increase in workload with the B-757 in the terminal area when there is a change in runway or instrument approach. At high density airport such as LAX, a greater EFIS workload reduces ability to look for other airport traffic. The slowness of the FMC contributes greatly to the problem computer speed should be increased.
- Ground duties present a much higher workload than other equipment such as B-727, B-737-100/200, DC-9 & MD-80 and close to DC-10. The pilots need to arrive at the aircraft to set up much earlier than the Jurassic jets. Thirty min show at operations at outstations is unacceptable. The duty day should be 1 hour show both at the start of the paring as well as downline. Competent crews that are ahead of the aircraft and not in <cabin> row 23 should have no problem managing the operations. If ATC can utilize FMS arrivals and sequence other A/C along those routes radio transmission could be cut substantially. This would provide a much safer environment.
- More in chocks, less in taxi, same on T/O, less in climb and cruise, more on descent, less on taxi, more in chocks.

Workload and long-haul operations

- More workload on NATRAC-ETOPS RTES <when compared to a DC-10>.

Workload and lack of a flight engineer

- It's much higher, naturally, since there is one less person in the cockpit. Normal arrival at gate communication procedures should be handled via ACARS up/down link. Having to make several radio calls and monitor frequencies other than TWR/GND is inherently error prone in a two-man cockpit.
- Much greater workload on B-757. 2-man cockpit in today's arena, with all required radio work, especially

if something goes away, i.e. divert, emergency, etc., overloads crew to a dangerous level. I do not have a solution, except to bring back the flight engineer.

- I was a F/O on B-727. My workload increased greatly! 2-man A/C should never have been approved to begin with. Too much inside and not enough outside!

- <Workload> is less than B-727 even with 2-man vs. 2-man crew.

- Generally less (than the B-747).

- The previous A/C had a flight engineer, <now> we have the FMS.

- Having the flight engineer is a wonderful luxury. However, in certain environments, must notably terminal arrivals and departures, a last minute clearance change (change of rwy, route, or approach) can leave me feeling overwhelmed. In these cases I generally revert to raw data automated operation (heading select, etc.). When time and workload allows I then bring the FMC up-to-date again.

- Workload from a 3-man aircraft to a 2-man aircraft increases no matter what automation is added.

- A third crewmember would be helpful to accomplish all “clerical” responsibilities.

- Much easier without the F.E. I enjoy doing the cockpit prep with all the datalink hookups and not having to forget to get a word in on a congested frequency. Captain can easily and efficiently validate the accuracy of the data.

Workload and comparisons to previous plane

- B-737-300/500 <is> about the same. (3)

- The initial loading of the computers takes more time and rechecking than the previous A/C (A-300). The uplinking of data is very helpful when it works.

- I feel the B-757 workload is easier than previous A/C due to glass cockpit.

- Previous plane A-300. How about <a difference in> night & day?

- I have flown every airplane type in the CAL fleet. The B-757 has without a doubt, the *lowest* overall workload.

- Much less than B-727 — once you master <the> FMC.

- The workload is much less than an MD-80 or DC-10.

- Workload between DC-10 and B-757 is very close to the same — the big difference is that EFIS in the B-757 results in better situational awareness.

- Higher workload than B-727 for arr-dep.

- The workload is higher in the B-757 than the B-737-300 because of the FMS design. Subtle mode switches, like VNAV Path to VNAV Speed, should have never been FAA approved. This increases workload by requiring a fixation on VNAV performance — to the detriment of everything else that is happening.

- Workload? What workload? In comparison to the MD-80 and DC-9 there is less to do i.e. Accuload via printer, PDC via printer, but A/C requires a different approach and method of conducting yourself. They also fly different stage lengths and frequencies. The B-757 has to be one of the least stressful aircraft, operating, usually one or two legs per day.

Workload and gaining experience with the B-757

- The first year much heavier. The 2nd year — the same; starting <the> 3rd Year — easier.

- When I first checked out on the B-757, I found the workload to be quite high! I was not accustomed to having to do so many additional duties. I now find the workload to be much lower. Automation helps and my flow patterns are refined.

- Until recently the workload in the B-757 was about the same as it was on previous aircraft. The difference was one of workload distribution.

Availability of information and situational awareness

- Much lower <workload>, the automation allows you to stay much further ahead of the airplane!

- The workload on the B-757 is much less. The navigation tasks are greatly reduced and there is a wealth of information about the flight that can be accessed. If there is a drawback it is that the system is so nice it breeds complacency.

- The map display really makes the flight progress nicely. I like the display system with the airport and runways shown on <the> screen.

- Workload during routing tasks in a low stress environment is greatly reduced. However, I am not absolutely sure that the workload is reduced during high stress situations, i.e. approaches or complicated arrival procedures particularly when a modification is introduced by ATC. Personally I find the workload to be increased because I must decide upon the manner in which the change <takes place>. I may have several options available to me and that in itself complicates the procedure. With the old "stream gauges" you tuned it, dialed it and flew it. Simple. And both pilots knew what procedures was taking place.

- Quicker, more accurate assessment of overall situations as so much information is available.
- The EFIS helps my situational awareness, which makes the overall workload on the B-757 even less.

4.2 Please mention anything you feel should be changed to help you manage workload (procedures, ATC, training, etc?)

Questionnaire 2

- No changes needed (so stated). (3)
- It would be nice if more routes could be stored in the database. (2)
- Having to reset the altitude to an intermediate altitude on the MCP on a profile descent defeats the automation and increases unnecessary workload levels. The intermediate altitude showing on the moving map, the legs page, and the descent page are all an adequate check that the AC will not bust an intermediate crossing restriction.
- We should have a sterile environment @ 20 minutes prior to departure and no cabin or company contacts or duties after descending for the purposes of landing.
- More defined procedures as to capt/F.O. responsibilities for cockpit setup (data loading, panel setup, etc.). <Also,> Orange County ATC — very busy and heavy workload. ATC is calling at the busiest time (tower to departure handoff). This occurs at the same time as a very busy FMS departure. Less talk would help.
- It would help all types of aircraft if the WX sequences would report runways in use at the reporting airport or if we could get ATIS farther away from the destination (or alternates en route).
- ATC procedures for FMS aircraft should be modified to minimize the time required for pilots to direct the FMC. This will probably occur naturally as the majority of airborne systems become FMS controlled. The problem exists due to a mix of FMS and non-FMS A/C in today's ATC environment. Arrival and departure procedures could be modified to simplify the phase of flight requirements for all A/C.
- The company needs to standardize databases on both the "glass " A/C (B-737-300/500 and B-757).
- Some of the preflight CDU entries could be automated or eliminated.

  Examples: (1) descent winds have to be input twice, (2) engine oil quantity, (3) DFDMU data, (4) origin and destination (route page 1), and (5) shutdown fuel.
- No company business below 18,000' but call company when on the ground and taxing in.
- Complete and maximum utilization of datalink capabilities in order to ensure 100% concentration in monitoring the aircraft during critical phases of flight (i.e., descent in dynamic traffic environment, low altitude transitions, etc.).
- Maybe an updated ATC system with less power failures or equipment problems would help to bring down the workload of *both* the pilots and air traffic controllers.
- (1) Speed up the computer, and (2) an extension line to ILS final should not have to be manually input. This would eliminate one step which is heads down time in the terminal area.
- The software should be examined to see why the airplane always gets fast and high on descents. During my first 100 hours, I have only had one descent using VNAV path which did not require a significant application of speed brakes. This was not the case on the B-737-300.
- The only thing I'd like to see is a redesign of ATC to cater to the automated aircraft and not keep messing up our plans. I believe they are working on it but time will tell. After all, most A/C are FMC equipped these days.

Questionnaire 3

- The slowness of the FMC contributes greatly to the problem <of high workload.> Computer speed should be increased. (2)
- No changes needed (so stated). (2)
- Make it possible to retain <past> waypoints on the CRT for a while.
- Too much company and outside interference during block preflight duties and check list.

- Reduce the flying workload for long haul so more situational awareness can be given to terminal areas.
- ATC should get up to speed with the rest of the world with their computers, training, facilities, etc.
- I do not have a solution <for increased workload>, except to bring back the flight engineer.
- Approach checklist is a nuisance — should be changed.
- Training should emphasize MCP first below 10,000 ft.
- ATC realizing and using automation.
- (1) Center the HSI display and TCAS. <Also,> both now wipe out anything under you or immediately behind you. (2) GPS updates to position (both 1 and 2 would have helped the B-757 crew in South America <Cali, Colombia accident>).
- Automated ATIS info in ACARS would help.
- The biggest restraint I feel out there is ATC. I calculate the optimum descent point to the nano-second and ATC starts me down 100 miles early, or late. I don't need an FMC for that.
- I would change the chiming of the no smoke sign at 10,000 ft to 18,000 ft. At 10,000 I feel the crew is to busy i.e. slow to 250kts, ATC, traffic watch.

Workload Summary

As mentioned in the previous section (3.0 CRM), the two-pilot vs. three-pilot flight deck is a prevalent topic among some pilots. Some of the reasons given for maintaining the second officer are for safety reasons (i.e., "extra" pair of eyes and for emergency situations), but also for routine duties such as company communications and paperwork. In fact, one respondent mentioned the need for a "secretary" instead of a flight engineer to handle "clerical" duties.

The topic of ATC and workload received many comments that were almost unanimously negative in tone. There seems to be a perception that ATC is a major factor in some high-workload situations, especially in arrivals, departures and failing to make full use of the B-757's automation. It is an unfortunate situation when pilots have a negative perception of ATC with respect to automation and workload, and perceive ATC as acting in their own interest. In addition, international operations (ETOPS) also received unanimously negative comments due to the high workload involved.

When comparing workload to their previous planes, a majority of pilots perceived the B-757 as having less or the same amount of workload as before. There were a few comments stating that the B-757 was more workload than their prior plane. However, one must take into consideration whether or not there was a shift or difference in workload when compared to their prior plane. Although only three pilots stated that there was a shift or difference in workload, many pilots commented that the workload increased during pre-departure and post-arrival, and decreased in cruise. The workload issue also must be approached with a caveat that many of the B-757 flights were long-haul flights instead of shorter legs associated with some glass aircraft previously flown (B-737-300/500, etc.).

5.0 For those who have left the 757 (questionnaire 3 only)

5.1 After you left 757 and went to another aircraft, what was your reaction?

5.2 What did you miss about the 757 avionics and automation?

5.3 What did you like better about the older-technology plane? (Please state the seat and plane you went to).

- (Unknown, unknown). I like the 3-man cockpit. Also, at CAL, the B-757 trip schedules in the Houston base are terrible. For the same pay, the lines on the B-737 are far superior, I miss the B-757 and ILS automation. But I don't miss the schedules.
- (Captain, MD-80). I left the B-757 training program after completing ground school training. The avionics and automation surpassed both the DC-10 and B-747 I had previously flown as first officer. A company bid allowed me to move to MD-80 captain, my present aircraft position.
- (Captain, B-727). <I> will start training on B-727 March 5, 1996. <I> will miss B-757 plane but not the schedules.
- (Captain, MD-80). I felt it was a step down in technology. All the bells and whistles. The glass cockpit, the features in the database. The older plane works better in today's environment because of the speed of technology in the A/C is exactly 20 years behind and exactly where today's ATC environment is.
- (Captain, B-737-300). As I stated earlier, the B-737-500 is more advanced NAV-wise than the B-757. I do miss some of the system automation and the EICAS system on the B-757 however.
- (Captain, B-727). The only thing I miss from the B-757 is the map mode. Favorite items of B-727: the 3-man crew of the B-727.
  - ability to hand fly much more.
  - more "in the loop" — a pilot again instead of systems monitor.

- (Captain, DC-9). First I went from F/O on the B-757 to F/O on the DC-10. That wasn't too bad of a transition. Then from DC-10 F/O to DC-9 Captain. Then I saw the changes from automation. No auto throttle, no full auto pilot. No VNAV or LNAV. Life was good. Now I work.

- (Captain, B-737). I have flown the B-737-300 and B-757 for 10 years. I miss the automation.

- (Captain, DC-10). Moving to the DC-10 was like meeting an old friend. I liked the B-757 simplicity of items to be checked before flight and checklists. I miss the map on the B-757. The two best features about the DC-10 are: three crewmembers <and> international FAR's concerning flight time limitations. Allows you to have much more time off. The domestic trips on the B-757 are terrible due to ridiculous FAR limitations.

- (First officer, B-727). I bid off the B-757 because of the automation and bad trips. The only thing I really miss about the B-757 is automation is the printer. The older technology is real flying and it's fun. The older technology makes you a better pilot, by hand flying and using your brain.

- (Captain, DC-10). I missed the moving map and the auto departure features in LNAV and VNAV for complicated departure and arrivals.

- (Captain, DC-10). The B-757 is the best aircraft I have ever flown. The glass display was easy to program and maintain situation awareness. I have been off the B-757 for 8 months and have probably forgot about small problems that I encountered. Navigation comparison of B-757 vs. DC-10, I hate the "old way" of getting there. So much more info is quickly accessible in the B-757; I believe it to be the safer way.

- (First officer, DC-10). Miss the FMC and map on screen. I like the 3-man crew in DC-10.

- (Captain, DC-10). The B-757 instrumentation results in much superior in situational awareness (a quick glance at the Map and you know exactly where the landing runway is and your orientation to it). The DC-10 requires at least two mental maneuvers to change the existing instrumentation into an "estimate" of where the landing runway is — and may even require a frequency change on a VOR or ILS. I changed the A/C because of better schedules (more days off) on the DC-10.

- (First officer, DC-10). I miss everything. I wish the automation was in the DC-10 or B-747-100/200. The reason I left was <that> the company's workload, days off, and limited crew rest at destination was undesirable. Domestic flying is not a challenge and boring so I switched. My dream would be a B-747-400.

- (Captain, DC-10). I am planning on returning to the DC-10 ASAP for the following reasons: (1) 3-man cockpit, (2) 3-man cockpit, and (3) 3-man cockpit. I would very much would like to have "some" of the technology to augment or enhance situational awareness/auto land capabilities and not to replace the resources necessary to operate airlines safely.

Summary, for Those Who Left the B-757

Seventeen pilots responded to these questions and most seemed to miss the automation, but a few respondents preferred the older "steam gauge" cockpits and the three-person flight deck. Several comments were made regarding the dislike of the B-757 flight schedules and left the aircraft for this reason (ex. "bad schedules," "bad trips," etc.). Of the 17 respondents, 11 transferred to the captain's seat in other aircraft. It is understandable to desire a captain's position, and one may suspect that this may have influenced a pilot's desire to leave the B-757, especially if one has never held a pilot-in-command position previously.

D. Conclusion

In conclusion, CAL's training program for the B-757 received much praise from the participants. This is a commendable achievement for the training department and all those involved in developing and implementing the program, especially considering the B-757 was a new aircraft for CAL at the time. Although there were numerous complaints and suggestions put forth on specific topics, not one pilot was dissatisfied with the training program in general. This does not imply that the training program would not benefit from refinement or incorporating some of the suggestions put forth by the pilots in this chapter. Some of the suggestions and comments put forth by the pilots are quite apropos and worthy of further examination for their potential applicability to CAL's training program as well as other airline's training programs.

VII. Crew Resource Management and Human-centered Automation Training

> *Our company doesn't teach CRM. We teach pilots to fly and to manage checklists, communication, ATC and systems. CRM is an integrated part; the parts are inseparable. We integrate CRM into everything we do, every minute that the crewmembers function together as a crew.*
>
> — B-757 flight instructor

A. History of CRM at Continental

CAL was early on the scene of cockpit resource management (or *crew* resource management, which is presently more in style due to its generality). The programs today, and the general acceptance of CRM training, can be traced back to the pioneering work of Capt. Frank Tullo. By the end of the 1970s the movement was underway at several U.S. airlines (Cooper, White and Lauber, 1979). By 1981, United Airlines had its own program (CLR — Command, Leadership and Resource Management) in position and offered it for sale to other carriers. As early as 1977, Texas International developed a simulator program that today would be called LOFT.

Tullo and others at CAL watched the United experience with great interest. Tullo once gave the following example (personal conversation with first author, 1993) of the sort of thing that bothered him: A Boeing 727 taking off from Phoenix, Arizona, lost an engine at V_r (rotation speed). They managed to get into the air, and at 200 feet AGL, the crew ran the engine failure checklist. Tullo stated that the crew "got nothing in return" for their efforts. "They could have climbed to 800 feet, accelerated, cleaned up the airplane, and then run the checklist. Perhaps United had the right idea: some non-technical training that would emphasize teamwork and communication skills might be the answer," he stated.

Following the strike in 1983 (see Chapter I), Tullo was named lead flight instructor on the 727, and took the opportunity to press for a program in what would later be called CRM. The first course, called Crew Coordination Concepts (CCC), and later called Phase I, was something of a hodgepodge of personality and small-group dynamics, communications, the theories of the situation of Professor Lee Bolman of Yale, and the Blake-Mouton grid (see Foushee and Helmreich, 1988, pp. 201–203). The grid would soon enjoy great popularity in the years to come. CAL management supported the proposal, resulting in a two-day course that was case oriented, stressing as raw materials carefully selected accident reports. These are the basis of many of the programs around the world today.

In 1986, the company felt that the course was running so smoothly that it could be marketed to other airlines. And in the 1980s, there was a plethora of accidents that would make excellent examples of the need for improved CRM in the cockpit (see chapters in Wiener, Kanki, and Helmreich, 1993, especially the chapter by Kayten). Management made a long-term commitment by appointing Tullo as manager of the CRM program. The CRM program today runs under the guidance of a committee of pilots and a full-time non-pilot administrator. In 1988, a Phase II program (one day) was installed. Phase II dealt primarily with decision making. The next (Phase III) program stressed teamwork and leadership. Work began in 1987 on recurrent LOFTs for the many fleets of CAL. The LOFTs were strictly recurrent exercises, not "CRM LOFTs," which were gaining in popularity and which might soon be required in order to meet AQP requirements (FAA, 1998; General Accounting Office [GAO], 1997). For excellent discussions of LOFT design, philosophy and execution see R. Butler, 1993 and Orlady, 1994.

Today, the programs are still influenced by Capt. Tullo's early work. By 1988, CAL had filed applications for AQP programs for most of its fleets. The CRM programs were one day for existing pilots and two days for new hires. By the 1990s, most pilots in the United States had been through some kind of CRM program. The emphasis was changing from communications and personality dynamics to newer concepts such as error management, decision making and situational awareness. A tidal wave was sweeping though airlines' fleets. It was called the "glass cockpit" (Wiener, 1989). CRM managers fell heir to the unexplored problem of training for the high-technology aircraft (Wiener, 1993). The frustrations of the early days of the glass airplane have been documented in Chapter II. It was concern over these problems that brought the current (NASA/CAL) study into being. For detailed discussions of integrating CRM into an AQP environment, see FAA (1998), Chapter 9 (Crew Resource Management), and McKenna, (1996a).

B. Modern Approaches to CRM

The post-Tullo era at CAL saw a change of emphasis. The key word was *integrated*. The quotation at the beginning of this chapter captures the meaning of the word when applied to CRM training. Integrated CRM training simply means that CRM was no longer taught as a subject matter in itself, a skill that the airman would master in its abstract form and might some day have the opportunity to apply to his work. Instead, the subject matter would be taught with CRM woven into each topic. For example, in the B-757 transition training, the instructor would discuss not only the maneuver and the technical procedures to be employed, but also would include the call-outs and briefings required, and show the students how to combine technical skills with CRM skills. The communication, leadership, division of duties, etc., would be taught as the ingredients of the maneuver, not as separate functions to be performed by the pilot.

Influences

There were two influential agents that led to the move toward integration. The first was the demands of AQP (FAA, 1998). Compliance with AQP required instructors to teach integrated maneuvers rather than procedures, to grade the CRM aspects of the maneuvers as strenuously as they might grade the execution of procedures, and to grade the crew, not individual crewmembers. This in itself was a radical notion, that grades would be handed out to *the entire crew*, rather than focusing on the performance of individuals within the crew.

The second influence was the instructors who were encountered by CAL's initial training cadre at Boeing's training center. Apparently one Boeing instructor had a tremendous impact on the CAL instructors: he demonstrated how CRM could be integrated with technical flight training. The training cadre was determined to bring both the spirit and the methods of integrated training back to Houston to become training doctrine at the airline. This turned out to be particularly helpful in the glass cockpits (at that time, the B-757 and 737-500). As one instructor put it, "The more tools you give the pilot, the more CRM is needed." In previous field studies, Wiener (1985b,

1989) had said essentially the same thing, that high-technology cockpits required more, not less CRM training.

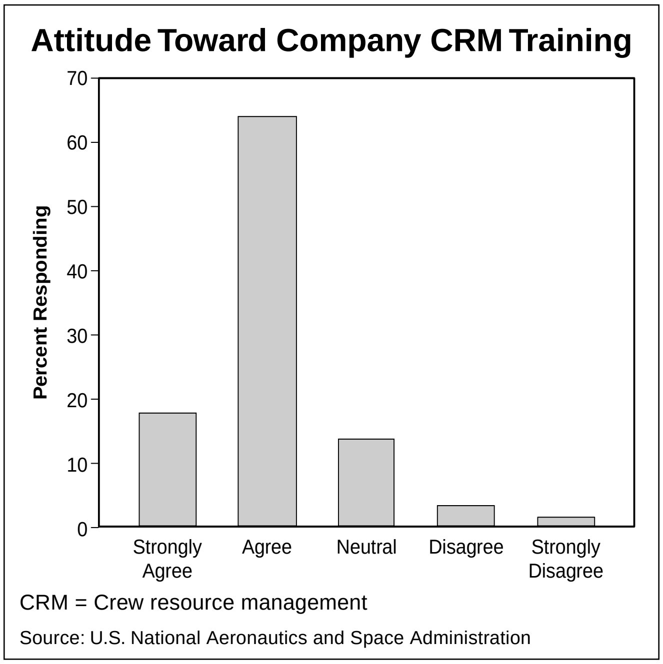
The Success of the Program

The success of the CRM programs at CAL are shown in Figure VII-1 (Phase 1) and in the data from Phases 2 and 3, as displayed in Appendix A, page 103. The results of this probe show an extremely positive attitude toward CRM, compared with data we had seen in earlier opinion polls and attitude studies. We are not accustomed to encountering attitudes this favorable. It is difficult to pin down just why the CAL program in CRM has been so favorably received, especially at a company that had recently been through such brutal labor relations. The answer may lie in part with the prestige of the instructors responsible for designing and implementing the program. It also may be due to the fact that CAL's programs were always oriented toward practical applications in the cockpit, toward procedural compliance, professionalism in the cockpit and down-to-earth presentation of accident reports. Absent from CAL's programs were the "psycho-babble" and "parlor games" that alienated pilots in the earlier CRM programs. Recently, the generality of CRM principles was demonstrated when they were taught to non-cockpit specialists within the company: flight technical and maintenance workers, flight attendants and others (Fotos, 1991).

C. Human-centered Automation Training (H-CAT)

The Influence of Delta's Experience

In the summer of 1987, Delta Airlines suffered an embarrassing series of incidents and close calls. In most cases, lack of communication or ineffective communication between the crewmembers seemed to be the problem. Under the direction of Capt. Reuben Black, Delta launched an aggressive program to remedy the situation (Byrnes and Black, 1993). A CRM program was installed for the entire pilot group, over 9,000 pilots. New hires had their own program. This occurred simultaneously with a growing concern over the potential hazards of automation (see Chapter I). One of Delta's incidents involved the inadvertent shutdown of both engines on a B-767 at about 1,000 feet after takeoff from Los Angeles; but most involved aircraft with traditional cockpits. Delta decided to attack the automation issue at the same time as the communication problem. A special automation task force was formed, and out of its deliberations came a ground school course named "Introduction to Aviation Automation" (colloquially "I. A. Squared"*)*.



CRM = Crew resource management

Source: U.S. National Aeronautics and Space Administration

Figure VII-1

Students about to transition to a glass aircraft for the first time went through the course. It was a *model-independent (*"generic"), non-technical exploration of the benefits and hazards of automation, making use of a variety of graphical material, lectures, television news clips and accident reports. The aim of the course was to familiarize pilots encountering glass for the first time with the general problems of operating a highly automated aircraft, and the company's philosophical stance. At that time, Delta flew the following glass aircraft: MD-88, B-757 and 767. Within a short time, it would add also the A310 through its acquisition of Pan American Airways and would also obtain MD-11s. The automation course was considered by Delta to be a great success and was soon imitated by a number of other carriers (Dornheim, 1996b; McKenna, 1996a).

Corporate Philosophy

The term "philosophy of automation" became popular, as a result of the work of Wiener in automation (1985b) and Degani and Wiener (1994) in procedure design. The notion was that the highest level of flight management should spell out a *philosophy* of automation, an over-arching view of the company and how it would expect automation to be addressed. From this over-arching view would follow, according to Degani and Wiener, *policies*, then *procedures*, and the results would be *practices* (what is actually done on the line). They called this approach "The Four Ps." It became the part of the curriculum of the various carriers' automation course — explaining the company's philosophy of automation. See also p. 21.

CAL's Response

CAL's automation program closely followed the Delta model. It was nicknamed the "glass class." After several name changes it stabilized on "H-CAT" (Human-centered Automation Training). [We shall use the term *glass class* in this report to mean generically any form of classroom-based automation training, at any company, involving generic FMS and glass equipped cockpits. This excludes technical courses on particular models.] At CAL, as well as other carriers, the glass classes played to mixed reviews, for a variety of reasons.

1. Many of the pilots, although encountering glass for the first time and clearly in a position to profit from the model-independent training, were impatient to get moving into the "real stuff" (aircraft-specific systems). Anything that impeded this was considered a waste of time.

2. Classes included (1) pilots who were virginal to glass or FMC operations; (2) former 737-300 pilots who were trained in FMC operations, but not glass, and (3) 737-500 pilots upgrading to the 757 (glass to glass). Most of the pilots with prior FMC experience and certainly prior glass experience found much of the H-CAT course redundant. Most reported that they enjoyed the discussion of the accidents, but felt that the rest of the material was a waste of time.

3. There was a lack of agreement about where in the transition syllabus the class should be placed. Some (including the authors of this report) felt that it belonged, as traditionally positioned by most carriers, at the beginning of the first day, for a variety of reasons, among them the perceived need to allay fears and misconceptions, as discussed in Chapter II. Others in management and training felt that the course was misplaced by being offered in the early days of transition, before the trainees even knew what the terms meant. They felt that the instruction should be at the very end of the transition training, as a capstone following ground school and simulator, a kind of "pre-IOE wrap-up." Clearly, a case can be made for this approach.

4. We heard at several carriers that the glass class should follow the systems oral examination by the FAA (and designees). Captains, we were told, could think of nothing but passing the oral, and were not interested in any instruction not provided for that purpose. The statement applies equally to first officers, who were also type-rated in CAL's 757 program in order to give the airline flexibility in crewing its ETOPS flights.

5. Questions about cost of the course and who should teach it were unavoidable. Many of the carriers began to reduce the time allotted: At one carrier, it went from a day to a half-day to two hours, even though the original course was considered highly successful. At the same time, questions were raised about the cost of the instructors. Cost-conscious managers saw no reason why CRM or glass classes had to be taught by line qualified pilots, and at some carriers the task was turned over to less-expensive ground-school instructors. This was an offense to many of the pilots, especially to those who had been chosen to give CRM/glass class instruction. Perhaps a non-pilot could give instruction in systems. Aircraft systems work according to a clear-cut and unambiguous design. So they are not difficult to teach. But only a pilot who had "been there and done that" could provide the rich and hard-earned experience needed to discuss actual line operations and decisions, crew interactions and ambiguous situations.

   For example, it might seem ludicrous to have a ground instructor (non-pilot) discuss the operational aspects of handling a communication or decision problem (e.g., whether to divert due to an ill passenger, and where to go). Only a pilot, many might say, could lead such a discussion. The debate over who can teach CRM-type material continues, as airlines struggle to contain what, to many, have become runaway training costs.

6. It is generally felt that within a few years, the whole idea of an introduction to flight-deck automation will be obsolete, since all pilots will have flown glass aircraft, even *ab initio* students right out of training academies (Glines, 1990; Ott, 1989; Johnston, 1993b). This may be true, but in the short term, perhaps another decade or two, there will still be the DC-9 and the 727 crews working their way up the seniority ladder, for whom the introduction to automation training will still be necessary and desirable. Telfer (1993) outlines a "human factors" course for *ab initio* students.

One instructor pilot offered this: Glass classes are being overtaken by events in the real world. They are going out of style and need to be modernized. And you can no longer tell the pilots the three adages of the age of automation:

1. Don't be afraid of the computer.

2. Don't let the computer take over.

3. Don't fly into a mountain pushing buttons.

Despite its sometimes rocky history, marked by frequent changes in the course materials, pedagogical approach, management techniques and occasional philosophical reverses, H-CAT and CRM still exist at CAL, and in various forms at other carriers. As the General Accounting Office report on CRM stated (1997, p. 5), "regardless of the form, the importance of CRM cannot be denied."

The Politics of CRM Instruction

CRM committees at most carriers we have visited or worked with seem to live in suspension, often distrusted and suspected by others within the company. Perhaps this is because they deal with "soft" systems and values, social sciences in an industry that admires engineering. CRM committees may be misunderstood and not loved by all. These committees do valuable work, often at personal sacrifice, and produce generally worthy products. But they are still subject to distrust and political vulnerability. CRM revolutions and palace plots are not unusual anywhere in the industry.

D. The Future of CRM and H-CAT

AQP

So far we have said little about AQP in this report. This is because the movement was not highly active at CAL during the period in which we were collecting data and conducting interviews. Now, with the massive Boeing orders and deliveries, the fleets have been working on AQP plans. In the way of an update, we note that all models of the 737 at CAL now operate under AQP (-100 and -200 models have disappeared), and the 757 will be by July 1999. There is disagreement among the ranks at CAL as to the economics of AQP. Some do not believe it will save money at all, but may still be worthwhile because of the scrutiny of one's programs or plans and the self-criticism it requires. Others point to cost-savings in a plan such as the 757. With a higher rated FTD, 757 simulator time will be reduced. This certainly translates into dollars. Planning for the 777 AQP proposal produced similar results — apparent time and cost savings under AQP.

The savings expected from AQP are elusive. Even some of its adherents agree. They argue that an AQP program is inherently expensive, and reducing the amount of time in a program does not compensate for this. What AQP does, they state, is force the training department to do a better job, but not a cheaper one. We do not take a stand on this — in time there should be figures to clarify this most important point.

H-CAT

We envision a future H-CAT that will be lean and cost-conscious, and more "generic" (model independent) than its predecessors. Whether this instruction will eventually disappear from the training plan, since, as we have suggested, every pilot will soon have had his/her one-time inoculation, is largely up to the training departments. To a degree, this question may depend on the direction that AQP takes in the years ahead. Pilots will migrate in and out of seats, as fleets expand in the near future. Training departments will be heavily loaded with transition training, upgrades and new hires. The expansion has already begun (Sparaco, 1996; Ott, 1996; Proctor, 1998a). As of this writing [summer 1998], CAL had placed orders with Boeing for 92 next-generation 737s, 15 B-767-400s and 14 777s. Fifteen 757s were also due from an original purchase of 45 (Proctor, 1998a).

New hires, be they experienced pilots or *ab initios*, will have already been exposed to one or more forms of CRM instruction. The big problem will be to standardize a pilot group that comes from a variety of automation and CRM backgrounds and corporate cultures. If we had to guess, we would see the programs as no more than a half-day, discussion-oriented (rather than lecture-oriented), with heavy dependence on accident reports and other materials that can be obtained inexpensively. If taped lectures are used, they will be employed to motivate discussion, rather than played without interruption in the manner of a classroom lecture.

There are two questions that we would not place a bet on: (1) Whether H-CAT programs will be placed at the beginning or end of the transition package (presumably not elsewhere); and (2) Whether they will be taught by line pilots or by professional ground instructors (who may or may not be former pilots). Airline training departments will have to decide when it is time to abandon H-CAT instruction, assuming that it does not become required subject matter. We predict that in another 10–15 years, generic H-CAT and CRM, as training topics *sui generis*, will vanish and the worthwhile material will be absorbed by the overall transition training syllabus.

CRM

Clearly CRM, in one form or another, has a bright future in the aviation industry, although the future form may not be readily recognizable by today's practitioners. Already the predicted expansion beyond the cockpit is taking place, with CRM being taught, and we presume applied, in such domains as maintenance, the cabin and dispatch (Fotos, 1991; Helmreich, Wiener, and Kanki, 1993; Helmreich and Merritt, 1998; Proctor, 1998a). It is not difficult to envision a company, airline or otherwise, where all of the employees are trained in CRM techniques, and that communications are thereby improved. For this to work, we caution that at least within a company there must be consistency of philosophy, approach and instruction. We would not want to see one segment of a company trained on "Type A" CRM and another on "Type B." A CRM culture clash within an organization might be an interesting thing for social scientists to observe, but would not be helpful to the organization. The predicted expansion of CRM-like instruction into non-aviation fields (Helmreich, Wiener, and Kanki, 1993) has already come to pass. We will not pursue that matter here, as it is beyond the scope of this project.

One trend that we expect to continue and expand is for the airframe manufacturer to be the provider of the CRM instruction and materials. Airbus Industrie has led this field: CRM instruction is part of the "package" when a carrier buys an Airbus. "A pragmatic approach to automation is the key element in our training," according to Capt. Pierre Baud, senior vice president for training and flight operations support. This approach was the result of the business plan of that company, which saw its products as aircraft not only for technologically advanced nations, but also for the Third World. From the beginning, Airbus sought, in its instruction, to understand and manage cultural affinities and differences (Sparaco, 1996, p. 133). As part of its training doctrine, Airbus will use unusually small training groups, sometimes reaching a student-to-instructor ratio as low as 1:1.

The trend toward manufacturer-provided instruction will no doubt continue. Its success may depend on whether crewmembers can accept instruction that is generic, rather than model-bound, generic not only with respect to models, but to company culture. We can already imagine the emergence of a joke about the first-day in CRM/H-CAT class. The instructor begins his introductory remarks with, "This instruction is designed specifically for pilots flying the *you-fill-in-the-blank aircraft* for *you-fill-in-the-blank* airlines. The standardization of cockpits of various models, which Airbus has stressed, makes CRM, as well as other instruction, easier. There are simply fewer exceptions that must be taught. Is keeping instruction "generic" a good thing or bad? Due to the costs involved, there may be no choice. The carrier cannot expect to either develop its own tailored, model-specific packages, or obtain them from the airframer.

Finally, we predict the end of the era of "parlor games," personality inventories, authority grids and psycho-babble. Perhaps such simplistic approaches were appropriate in the early days of CRM, since little else had been developed. But they have not served us well. The link between personality and flying duties, communication or technical, still is not established except in the extreme. In brief, the personality approach was not line-oriented.

Now, in the age of AQP, the preparation of an AQP proposal to the FAA forces all the training issues: CRM, H-CAT, LOFT, use of simulators and FTDs, and others. A 757 training captain put it this way: "We (each fleet) must make our own AQP program, and not try to use an adaptation of another fleet's proposal."

E. Conclusion

AQP proposals guide the development of the flight training programs. But they must not only answer to the FAA, they also must be appropriate to the carrier's perceived mission and consistent with the corporate culture. As Degani and Wiener pointed out (1994), flight-deck procedures for operating the same piece of equipment vary from company to company, reflecting the carrier's culture. Thus AQP and the training doctrine it spawns must be sensitive to and flexible for local conditions, values and goals. The CRM and automation programs must do the same. There is no one correct way to design any training program, especially one as culturally sensitive as a CRM class. Under AQP, the FAA mandates a CRM program, but stops short of telling the carrier what to do (Orlady, 1994).

It is regrettable that there has been such a lack of creativity in addressing the automation philosophies. Every philosophy statement we have seen so far has been a rehash of Delta's. They usually follow this pattern:

1. These are the advantages of automation.

2 This is the philosophy, from which policies will flow.

3. The company expects every pilot to be able to use the automation at every level.

4. But the ultimate decision on the level chosen remains with the pilots.

We hope that in the future, some more imaginative work will be done on determining philosophies of automation.

VIII. Discussion

A. Introduction

In this chapter, we shall briefly discuss a number of training concepts, based on what we have found from the CAL experience, field observations and a literature review. These discussions are not meant to be comprehensive — more complete articles and book chapters are cited. We will include in this discussion the administration of training and the costs of training. Finally, we will take a look at training technologies of the near future and how they affect the future of transition training.

At most airlines, training has been highly tradition-based. Usually when a new plane is brought into the fleet, the training department operates as it did before, until a dramatic change in technology (e.g., the jet engine; the swept wing; computer-graphic visual displays in the simulator; the FMS and glass cockpit) comes along. This calls for a dramatic change in training, a "paradigm shift." Seldom is there a paradigm shift in the training pedagogy or method — the big changes are hardware driven (e.g., visual displays in simulators) or regulation driven (e.g., AQP).

B. Costs of Training

For various reasons, training has become a runaway cost at many carriers. Throughout this chapter, we shall be concerned with the rising costs of training and the acquisition and use of various training devices. It is difficult to find materials on training costs. We recommend Dornheim's (1992) article on the MD-11 training program at Douglas. With the rapid modernization of the fleets, airlines are scrambling to buy simulators and lease simulator time. They also are acquiring less exotic, though still highly expensive, FTDs, some of which are so sophisticated (and expensive) that they are essentially simulators, lacking only visual scenes and motion platforms.

New Aircraft

The vast fleets of new aircraft carry with them the high costs of transition training for the pilots who will fly them. Some of this will be improved by commonality between models of the same company. Airbus Industrie deserves honorable mention for their contribution to commonality: their aircraft have very similar cockpit designs and configurations, making transition training less burdensome and allowing a single simulator to be superficially changed to allow its use by different fleets.

For Boeing, it was more difficult to achieve commonality (except in the 757/767s, which have essentially the same cockpit — and same type rating), as they did not have the privilege of starting *ab initio* and designing a fleet of aircraft. The 757/767 was a revolutionary design, which had no technological parents in the civilian world. The continuation of the Boeing advanced aircraft was the 747-400, a redesign of its traditional 747-100/200/300. The -400 had advanced EFIS/FMC systems and a two-pilot flight deck. The 777 flight deck is based on that of the 747-400. The new-generation 737 aircraft promise a high degree of commonality. The great popularity of all models of the 737, as well as the new, has sparked a flurry of simulator orders and construction of simulator buildings and bays, and a scramble to purchase simulator time from various sources.

Collective Bargaining

Collective bargaining by the pilots' unions also affects the price of training. Increasingly, the pilot contracts contain negotiated language about the type and amount of training, the time of day at which it can be conducted, and the administration of the training. For example, some contracts contain language making performance on LOFT sessions "non-jeopardy," meaning that grades or other performance measures are not reported to management, but used only as feedback by the student and the instructor.

Due to the costs of providing transition training and the fact that pilots in training are essentially non-productive, management attempts to limit the migration from seat to seat, sometimes by putting a freeze (i.e., two years) on further bids after training for a new seat.

But enforcing this is often more difficult than it appears. With rapid acquisition of new-technology aircraft, management finds itself breaking its own rules by unlocking the freeze process and allowing newly trained pilots to enter new bids. This was carried to an extreme in June 1998 when CAL and IACP agreed on a pilot contract that changed the entire pay process to the more conventional "weight differential" system — the bigger the airplane, the greater the pay. A discussion of the longevity-based system and its effect on the training facility can be found on page 26. As we have pointed out in Chapter IV, the change from a longevity-based pay scale to the more widely used weight differential scale resulted in a top to bottom rebidding for seats in the summer of 1998. It was called a "flush bid." The entire pilot assignment list was abandoned, and each pilot was free to bid any seat at the airline. We will not discuss the effect of the contractual change in detail, as it took place beyond the data-collection phase of the study. But we here note that the flush bid placed an enormous load on the training center, as any dramatic contractual change might.

For the 757 fleet, whose composition we discussed previously, the change was dramatic: the younger-than-usual, technology-oriented captains and first officers stood to be bumped out of the 757 by senior pilots who had been flying lighter aircraft. Suddenly the 757 looked attractive as a mid-weight aircraft for mid-seniority pilots, as it was at other airlines (Wiener, 1989). The resurrection of the B-767 order made it even more so. The only things that kept the 757 from being more attractive were its reputation for poor schedules (from the pilots' point of view) and the heavy concentration of 757 lines in Newark, which was not considered a desirable area in which to settle.

Management Backing — A Clean Sheet of Paper

We have written briefly in previous chapters on the importance of management's commitment to quality in aircraft training and its support for new transition programs. The phrase we heard time and again from the 757 flight management group was, "We had the right people and a clean sheet of paper." The meaning of this was that the 757 cadre was free to propose the program they felt was best, unfettered by tradition or orthodox ways of doing things. And all important, they had a commitment from management that any reasonable request would be supported financially. These were important pledges on the part of management: they not only assured the fleet cadre of support, but also relieved them of budgetary game playing and financial uncertainties. This freed them to design the program that they felt was best suited to the airline and to the task at hand, relieved of financial concerns and confident of management backing.

As it turned out, there was an added dividend for CAL. So successful was the 757 program that when it came time to prepare for the 777, which arrived in September 1998, the cadre for that fleet was drawn from the 757. The wheel had turned: the 757 fleet managers, who had only three years before been given *carte blanche* to build their team, found the 757 ranks being raided for the 777.

AQP

Toward the end of the project, we were hearing hints both at CAL and elsewhere that carriers that had installed FAA-approved AQP plans found that they were not living up to claims for lower training costs, due primarily to the high "up-front" costs of designing a program, obtaining FAA approval, and then implementing and managing it. This matter is also discussed in the previous chapter. We are not certain whether this view is the result of systematic studies of the costs of AQP, or just opinions. As we heard frequently, AQP is "data intensive." And data intensive is dollar intensive. There was general agreement that even without cost reduction, AQP was worthwhile, since it forced training management to look very carefully at what they were doing and take full advantage of any opportunity to cut costs. Others held that AQP has performed "as advertised" and has been well worth the investment. Only time and experience in training under AQP will tell the story.

C. Future Pilots and Future Training

Ab Initio and Very-low-time Pilots

It is difficult to estimate, at any given time, the market for new airline pilots. On the demand side, it varies with the plans of the airlines to expand their fleets and route structures. We say expand because that is the expectation for U.S. carriers for at least the next decade (FAA, 1991). The same is probably true for other parts of the world as well, with the possible exception of Asia, where major airlines are actually cutting back, due to the weakening of business prospects. The economic downturn in Asia may indeed be a temporary phenomenon, and fleet development may resume, though perhaps not at the optimistic levels of predictions made in the mid-1990s. Where will the pilots for these expanded fleets come from?

The availability of former military pilots, the traditional source of at least one-half of the airline crewmembers at U.S. carriers, depends in turn on the military budget voted by Congress, which impacts two areas: (1) the amount of the budget devoted to training new military pilots; and (2) the restrictions on the freedom of military pilots to leave the service. Presently military flight training is at a low level; even graduates of the U.S. Air Force Academy cannot count on a flying slot. About half of the members of the graduating class are currently assigned to non-flying posts.

The regional airlines are another principal source for the majors, but the same question can be raised about the regionals: Where will their pilots come from? Will the regionals be able to keep their young and inexperienced pilots? Will the regionals become very expensive farm teams for the majors? One should not assume that “regional” implies low-technology cockpits. Many of the regionals are now flying glass cockpit aircraft fully as automated and high-tech as those of the majors.

Another alternative is the *ab initio* (from the beginning) pilot. (This is discussed briefly on page 18.) This student has trained, usually at his/her own expense, obtained commercial and instrument ratings, and joined the pool of available pilots (see Johnston, 1993b; Telfer, 1993; Marino, 1993). The prospect has never been particularly attractive in the United States, perhaps because the pool of available pilots has never been that dry (see Glines, 1990). CAL does not plan to recruit *ab initio* or very-low-time pilots.

The usual migration pattern would be to a flight school to serve as an instructor to build up flying time, then to a regional, and hopefully later to a major air carrier. The *ab initio* program may be sponsored by the carriers, as it is in parts of Europe and Asia, where there is no other source of pilots and the carriers must take a hand in training them. Unlike the expected migration pattern of new, low-time pilots, these *ab initio* pilots may go straight from school to a major carrier. Their first-duty aircraft could be an A320 or a new-generation 737. It is difficult for most of us to believe that a 300-hour pilot could handle the duties of a first officer in a highly technical aircraft such as an A320. But the carriers who have tried it say it works well. Fiorino (1998) describes one of those rare cases in which a school went in search of bad weather in which to train:

> “Emirates, the international carrier of the United Arab Emirates, will be sending new recruits for ab initio commercial airline pilot training to the School of Aviation Sciences at Western Michigan University (WMU) in Battle Creek. Until now the carrier has trained its student pilots at British Aerospace Flying College at Prestwick, Scotland. Aside from the technical facilities and training, other factors in Emirates’ decision to switch its basic training included the ‘more challenging weather’ … Student pilots will train for 62 weeks at WMU’s Pilot Training Center, graduating with a Joint Aviation Authorities commercial pilot license and instrument rating. Training will include 1,000 hours of ground school and 300 hours of flight and simulator training, including three hours in a fully aerobatic aircraft.”

Children of the Magenta Line

Capt. Bruce Tesmer of CAL (personal communication, 1998) speaks of the new brand of pilots as “children of the magenta line.” (The magenta line refers to an executed course displayed on the HSI.) His concern is shared by many: that these pilots, who go essentially straight from the cockpit of a trainer to the cockpit of an advanced FMS aircraft never build the basic airmanship and sense of the airplane that comes from working one’s way up through traditional cockpits and finally to the FMS/glass cockpit. An example is described by Proctor (1988): “Cadets with no flying experience are sent overseas for about a year to receive an initial pilot’s license, normally from flight training centers in the United Kingdom. Upon graduation, they spend a year as flight engineers in Singapore 747s before moving to the copilot’s seat in either Boeing 757s or Airbus A310s.” Thus, the pilot has one year of *ab initio* training, a year at which he/she does not touch the controls, and then finds him/herself performing the duties of copilot in a highly sophisticated cockpit.

This is clearly a legitimate worry. What, the critics ask, would happen if an A320 captain were incapacitated. The 300+ hour *ab initio* pilot would more than have his/her hands full. Others dispute this, saying that if such an event occurred, at least the inexperienced pilot would have available advanced autopilot modes to help save the day. Better that they are flying an A-320 than a DC-9. Only time will tell on this argument.

Personal-computer-based Training

We have noted previously (p. 19) the possibility of making use of the growing popularity, versatility and declining price of personal computers. If every pilot could have his own computer (see also pages 28–29) or at least have one available, then these could be networked so that instruction could be managed for the pilot group (Nordwall, 1995). We envision a computer network by which pilots could receive instruction on their own schedule. They could download and print out portions of the lesson if they wished, or merely take instruction from the screen. For a review of the potential for Personal computer-based training in aviation, see Koonce and Bramble, 1998.

Personal-computer-based training has high initial costs, but low per-user costs. Tied to the Web (see below), it would guarantee that all users would have the same version of the program, the latest version at that, and would eliminate much of the cost of printing and distribution of materials compared with traditional training. It would be easy for training administration to correct errors at the central source and to maintain centralized quality control. Dornheim (1996a) provides an example of a personal-computer-based trainer for FMS function. FMS training is where it may be needed the most, as this is the area that is costly for training using current technologies, and the area where new trainees feel the weakest in their IOE and early line experience. A low-cost, personal-computer-based alternative may be the answer. Dornheim goes on to suggest that one of the biggest advantages is that a $14 million simulator is not held up while pilots learn FMS functions and programming. A commercial software house provides the system, with a cost (at the time of his publication — 1996) of $200,000 for a site license.

A personal-computer-based network would be useful for such activities as learning new systems when they appear (e.g., the enhanced ground-proximity warning system [EGPWS]), new procedures (e.g., fire fighting and security), and other topics normally put off until recurrent training. In fact, recurrent training is a good example of instruction delivered at a very high cost. Ground instructors must visit each base time and again until all pilots have received the required subject matter and special subject matter for the current year. We believe that the effort previously put into lesson preparation could go into preparing software, allowing network-wide use and permanent storage of instructional material.

We would not envision the network as playing a major part in transition to a new aircraft, as we recommend in the next chapter that an instructor be available when students are involved in CBT activities. The reader may recall that many student pilots in the original cadre objected that at Boeing an instructor was not available to answer questions or clarify material, or in some cases to confirm that the instruction contained an error. In spite of this, there would be some material for transition training that could be available on the instructional net that could reduce the heavy load on the student during ground school, a subject of frequent complaints (“drinking from a fire hose”).

The development of these materials could impose a heavy burden on the carrier. Hopefully a consortium of carriers could be formed to develop and share the software. They would have to be extremely careful when the instruction contained procedures, rather than just introduction to systems, as even for the same hardware and software, each carrier has its own procedures (Degani and Wiener, 1994), and this would be reflected in computer-based instruction. To the degree that aircraft could be standardized across companies, CBT would be potentially useful and also lower in price. But we do not anticipate a widespread movement toward cross-carrier standardization.

Another approach is to have the airframers play a larger part in development of computer-based (and other) material, just as Airbus Industrie has done with CRM materials. They have been successful in developing general CRM instruction and then tailoring it to the culture of the individual airlines.

Friendly and Unfriendly Programming of the CBT

While attending the ground school, we noted several examples where the CBT programming was not particularly supportive of the student. Most of these have since been corrected, and we will discuss programming and instructional design in the next chapter. We include these “unfriendly” cases in this chapter only as examples of what can happen in mechanized instruction.

1. By and large, the CBT is a well-used and well-formatted device. The lessons are clear and logical, and the way the lesson plan mixes CBT, instructor briefing (two hours a day) and fixed base trainer (FBT) is quite effective. Particularly beneficial is the manner in which questions/answers are provided within the instruction. Also helpful is the proficiency test at the end of the lesson and the fact that the student must stay with a lesson until mastery on the test. If the test is “failed,” there is guidance on what areas were missed, and a review can take place. We think this is an effective pedagogy, due to: (1) its ability to aid in the transfer of technical information; (2) its ability to focus on the student’s apparent weak spots; and (3) its self-motivating property. Everyone likes to do well on tests, including self tests, even if there is no immediate reward or punishment for performance.

2. The CBT formatting has some flaws, the biggest being the way it goes backward to earlier frames when requested (BACK). The problem is that the student has no way of knowing how far back it is going to go. Usually the trainee just wants to hear the current “frame” again — there is no capability to do this. The student should be able to go back to the beginning of current lesson, or merely replay the current frame.

3. The beginning trainee should be given a hard copy of the acronym definitions — it is distracting to have to stop instruction and branch to the definitions page.

4. There is a confusing terminology in the electrical portion of the program. When a question is missed,

the tape says “the correct answer is in blue.” What it should say is “the correct answer is in the blue frame.” Blue is used in the electrical lesson to designate alternating-current systems (direct-current systems in red), and this results in unnecessary confusion.

Miscellaneous Notes from Training

1. The quick-reference handbook (QRH) is not in a user-friendly format. It is difficult to find items. Where would you look for a wheel well fire? It is under landing gear, brakes and hydraulics. Maybe all fires should be grouped together. We are not prepared to say, so this is not a recommendation. *Hot start* is in the alphabetical table of contents under “abnormal starts.” No problem if you know that.

2. Ground instructors we have known love instructional “gimmicks,” which they coin and use effectively. One we learned was the instructor’s restaurant analogy for mode control panel/flight mode annunciator (MCP/FMA) agreement. This is an all-important source of possible serious error, entering something other than what was intended into the computer. The instructor advised the students: Think of MCP as the *waitress* — you tell her what you want. But the FMA is the *table*. The only way to know if you got what you ordered from the waitress is to look at what’s on the table. [This is simple, neat, to the point and easy to remember.]

Web-based Instruction

The locus of instruction also must be considered, with pilots living in far-flung places, often commuting around the country to their bases. In days gone by, some instruction (such as recurrent) was made available at each base, to avoid bringing thousands of pilots to a training center. One example where training was carried out by devices in each base was the introduction to TCAS. Companies developed a variety of instructional devices, including slide shows and VCR tapes, to provide the training for the new device. There may have been computer-based instruction for TCAS as well, but we are not aware of any.

But usually pilots, especially those living at some distance from their bases, pass through the base very quickly, with little time for instruction. Clearly, the answer is to bring the instruction to the pilots’ homes, so they can do it at their convenience. There are a variety of ways to do this, but packaging material and sending it out by whatever carrier has it perils and limitations. The World Wide Web (WWW) offers an attractive alternative: material could be stored on the Web by the training department and then downloaded by each pilot into his computer. (For an example, see Hughes, 1998, p. 65). This would bring new instructional material to the doorsteps of members of the pilot group, wherever they may live, and do it in a timely manner.

Web-based instruction and delivery would allow virtually instantaneous updating of materials and could ensure that all pilots have a current version of instructional materials and manuals. It also could allow students to post notice of what they believe to be errors in the materials and obtain rapid corrections from flight training management. Likewise, questions could be asked by the students by posting on the Web. It would be management’s responsibility to monitor the Web for questions, comments and presumed errors, and to respond appropriately.

In the next chapter, we will discuss conclusions and recommendations for training for the high-tech aircraft. Many of our recommendations will involve the training techniques discussed in this chapter and may be somewhat repetitious of this writings in this chapter.

IX. Conclusions and Recommendations

In this chapter, we propose some guidelines for transition training and administration, and for appropriate use of automated equipment, with the emphasis on training issues. Our conclusions are based on our work at CAL, as well as visits to other airline training centers and jump seat experience with several carriers. The conclusions and recommendations may apply more to one airline than another, depending on their corporate culture, present state of training, fleet, type of operations and many more factors. We have tried to be cost-conscious in this chapter, remaining mindful of the price tags as well as the benefits of our recommendations.

A Generalization

“Training must be considered during the design of all cockpit systems and should reflect that design in practice. Particular care should be given to documenting automated systems in such a way that pilots will be able to understand clearly *how they operate* and how they can best be exploited, as well as how to operate them.” (Billings, 1996, pp. II-11, II-12).

Management Support

When initiating a new program, particularly a large program such as transition to a newly acquired aircraft, management should find the best person for the job and then give him/her a “clean sheet of paper,” meaning put aside the past and launch the program with an open mind and the full support of management. (See also page 70.) Management should never “nickel-dime” the program manager. It does not pay in the long run to be over-restrictive with funds or to require excessive justification of expenses. Extra dollars put into a training program will pay off in various places. For example, in this study it was clear that the 757 program was not only fulfilling its primary mission by turning out 757 pilots, but as an additional benefit was producing what would soon become the 777 cadre. This was an unexpected dividend, which became apparent when it was time to put the 777 program in place, with a very short lead time.

Curriculum Development and Standardization

Determine which skills will be taught in ground school and which will be considered "hands on" and left to IOE and line checking. It is very easy for ground school instructors to say, "Don't worry about that — you'll get it on the line (or in IOE)." This attitude can result in serious flaws in the training product, and possibly erroneous learning techniques and improper procedures.

Likewise, the transitioning pilot tends to hear on the line at many companies, "I don't care what they taught you in ground school and simulator. This is the *line* out here. This is the *real* world."

There must only be one standard, and it must be taught and checked constantly. It is a failure of management if a pilot discovers that there is a difference between what he is taught in ground school and simulator, and what he finds on the line. All instruction that is given a pilot must be *line oriented*. What other orientation could possibly be entertained?

We have often advised: *Standardize the airline, not the pilots*. We offer the following example. At one large carrier (not CAL) where we did some work on cockpit-cabin communication, the flight attendants had a special page in their manual that listed the four pieces of information that the cockpit would pass to them in an emergency (e.g., signal to brace, time to prepare). The first letters of the four formed an acronym. The page was considered so critical that it was given a unique color and a nickname based on that color. Unfortunately, the pilots that we interviewed had never heard of the sheet and could not name any of the four items the cabin needed.

It is not up to each instructor to skip over a lesson or avoid questions by reassuring the pilot trainee that he will learn this during his IOE. True, there are things that can only be learned on the line, such as airport environment, taxi procedures and communication with ground crews. But what the pilot is taught and where and when it is taught are determined by the training syllabus, not the whim and judgment, however well meaning, of each instructor. Again, *standardize the airline, not the pilots*.

No single program can optimally serve two sub-populations, one with and one without glass experience. We believe there may be some promise in developing a semi-generic introduction to glass that is technical instruction material on flight-deck automation. We envision a pilot taking this course only one time, unless there were changes in philosophy at the company. Taking the course only once would eliminate redundant training, which is both costly to the company and frustrating to the pilot. The answer may be a two-tiered class for transition to glass:

1. Past Glass (pilots who have flown some glass aircraft); and,

2. No Glass (pilots who have never flown glass).

This would allow writing a syllabus that minimizes the re-teaching of materials already learned and understood by the first group, and one that starts at "square one," teaching basics of automation and glass cockpits.

Documentation and Manuals

An airline initially should draw as much as possible from the manufacturers' checklist, procedures manual, master minimum equipment list (MMEL) and other documents. But ultimately all procedures, documents, and training methods must be tailored to the operations and philosophies of the airline, and approved by the FAA principal operations inspector (POI). Wherever the material comes from, it now becomes the standard documentation of the airline and the one that is taught and reinforced. This is particularly important when an airline goes through a merger or acquisition.

We again recommend that cockpit documentation materials be subjected to a thorough human factors study. Specifically, we recommend that NASA's human factors experts examine the QRHs and checklists at various air carriers, and make recommendations regarding design and use of cockpit documentation.

An industry group should examine the products of the "cottage industries," with an eye toward possibly incorporating them into the airline documentation, with FAA approval. Flight training management should be curious as to why these unofficial and uncertified products are being purchased, when the official manuals are furnished free by the training department. One company told us their sales of FMS manuals are in the thousands. They must provide something of value, in the mind of the purchaser, if airline pilots, with their legendary reputation for penuriousness, are spending their own money on these products.

Training Devices

[See also pages 72–73 of the previous chapter for a discussion of faults and recommended improvements in training devices.]

While attending ground school, we observed that the CBT devices contained numerous factual errors and inconsistencies. This propagates false information, annoys the pilots and diminishes the authority of the CBT. Every effort should be made to detect and remove these errors before introducing the CBT, by testing on a cross section of the user population, not just ground school instructors. Management should be scrupulous about minimizing errors in all training software. We also noted several examples where the CBT programming was not supportive of the student. Some of these have since been corrected.

A qualified ground school instructor should be available at all times when students are studying via CBT. (Failure to do this was the most frequent complaint about CBT training). The instructor can answer questions and resolve differences, when they occur, between manuals and CBT text.

Explore the potentials for Web-based training, and its ability to centralize the timing and distribution of new or revised software. Make it easy for pilots to obtain updated software.

Examine the use of FMC/CDU part-task simulators. These were not available in this study. Especially evaluate "free play" (exploratory learning) on these devices, and research whether free play or a more structured approach is the most effective utilization of part-task simulators. Attempt to determine the cost effectiveness of the FMC/CDU devices, compared to the more expensive FTDs.

We have found in our interviews and questionnaires a high incidence of FMC errors in the first year on the line, These include, but are not restricted to, failure to arm lateral navigation (LNAV) after heading selection, confusion over the various autopilot-autothrottle modes, confusion over vertical navigation (VNAV) path and VNAV speed, often resulting in failure to make a crossing restriction, and the need to update winds. We feel that a part-task simulator with opportunities for "free play" should be examined as a potential remedy for these errors.

CRM Training

Attempt to shield CRM from "company politics." CRM training (and trainers) seem to be particularly vulnerable to the changing whims of management at the carriers we have visited. CRM instructional programs rise and fall very quickly. This may be due in part to the fact that these programs are not well understood by airline management or the FAA. It may also be due to the fact that the goals are vague, and the methods appear to be rooted in psychotherapy, in an industry that values engineering over social sciences. The instability of CRM instruction may also be attributed to the difficulty in finding "hard" measures of success and of value vs. cost.

It is not easy to say how CRM programs can be protected from political whim, but we have little doubt that it must be done, or the effectiveness of CRM instruction will suffer and the costs will increase. [Imagine that at an airline, once every few years, there occurred a movement to radically change the teaching of hydraulics, and the proponents of the present methods, along with their teaching programs, syllabi and materials were swept away to make room for the new!]

Ab Initio and Very-low-time Trainees

If *ab initio* training results in the hiring of low-time pilots for sophisticated cockpits, the airline must carefully examine its training program. The training appropriate for the more experienced pilot new-hire may be inappropriate for an *ab initio* graduate. It would be wise for any airline, contemplating hiring ab initio pilots to become familiar with the experience of the European and Asian airlines that have years of experience with low-time, new-hire pilots.

Style of Instruction

There is disagreement in the industry and among the three authors of this report on where to put CRM and H-CAT in the syllabus. One side says that if there is going to be an instructional block on CRM, human factors or philosophy of automation, it should be offered in the first session of the first day in the ground school program for three reasons: (1) this is the most effective place for introductory material; (2) it prepares the student to "think CRM" from the very first session on the FTD and incorporate CRM concepts into his/her behavior; and (3) once the student is exposed to aircraft systems, it is too late. The typical pilot then does not want to be exposed to anything else. The pressure to pass the oral exam starts to build.

Another equally respectable view prefers to place the systems instruction first, let the pilots take their oral exam and put that behind them, and then turn to the CRM/H-CAT block, which the student can now learn, freed of "orals stress."

Develop a culture of helpfulness on the part of instructors toward the transitioning students. Discourage any non-constructive behavior on the part of the instructors. The "helpfulness" and "friendliness" of the CAL 757 instructional personnel and the Boeing instructors were commented upon frequently by the pilots in this study, both in questionnaires and in interviews. Alterations in a company culture do not come easily and cheaply.

Administration and Scheduling

Distribution of pre-ground-school information may help reduce apprehension and misinformation. Materials could be mailed to each pilot scheduled to attend transition training for glass for the first time. Pilots frequently ask for manuals for the new plane prior to transition for the plane. This request should be accommodated. Perhaps the answer is to provide each pilot on the roster for a future transition to glass with a "pre-training package" of what to expect, a syllabus, reading materials and a schedule of events. Some of our pilot group called this a "heads-up package."

Pilots also should be encouraged to take a jump seat ride in the model they will be flying, or if not possible, in any glass aircraft, prior to transition training. If this is not deemed practical, it may be possible to schedule the trainee to observe a simulator session.

At some carriers, pilots' unions have questioned recommendations such as the above on the grounds that they constitute work without pay. This might be a valid point that must be worked out by management and labor. We have no recommendations on this matter, as labor-management contractual affairs are outside the scope of this study.

Minimize delays between transition training and IOE or line assignment. Also attempt to minimize time between transition training and the rating ride.

Avoid if possible sending newly transitioned pilots back to their old planes.

Scheduling should provide mixed lines of domestic and overseas flying for all fleets that do both. This will keep proficiency for both types of trip at a higher level than flying "pure" lines. This is particularly important for those who tend to bid only transoceanic ETOPS flying, and whose basic flying skill (and possibly automation skills) may suffer from flying only very long legs. The use of international relief pilots makes this all the more critical. A trip with a few long legs and an augmented crew to share the approaches and landings also raises the issue of proficiency loss. Mixing domestic and international lines in trips will relieve this problem, and probably at little cost.

Checking and Evaluation

Explore the potential of using flight operations quality assurance (FOQA) data as a source of feedback for the effectiveness of the training program. The flight crews must be in no jeopardy from company or FAA enforcement action. The first time FOQA data are used against a pilot, the program will come to a stop.

Explore the use of electronically based FAQs (frequently asked questions) for ongoing design and development of training programs.

Do not restrict check procedures to full-up automation. Doing so can have several negative results, the most critical being that it deprives the crew of revealing, and the check airman from observing, the most important aspect of automated flying, the crew's choice of modes and options. Crews should fly a check ride as they would any other leg on a trip, and in accordance with company policies on use of automation, utilizing the autopilot/autothrottle mode that they consider appropriate to the circumstances. If they are not allowed to do this and are required to fly "full-up," not only are they forced to fly in an artificial and perhaps unsafe configuration, but also the check airman is deprived of the most valuable data on which to evaluate the crew.

The training programs themselves should be subjected to continuous evaluation.

Encourage feedback from the student pilots and evaluation of all training programs, from ground school and simulator through IOE and rating rides, including recurrent training. We recommend a formal, structured process for a running evaluation of all training programs. The evaluation should probably be done by an outside agent, reporting high-up in the training and standardization hierarchy. The results of these evaluations must not be mere "number crunching" for its own sake, but should affect changes in the training program (e.g., curriculum, use of devices, instructional methods). Thus, the training department creates an instructional feedback loop that should result in continuous improvement and quality management in the training program and product.

IOE

Many pilots reported that the first IOE should not be an Atlantic crossing, as there was too much to learn, bordering on overload. They felt that the first IOE leg after transition training should be a normal, domestic leg. Introduce international flights and especially ETOPS flights only after the "normal" domestic IOE has been completed.

Our analysis of the NASA ASRS reports (sampled from their entire database, names of the carriers unknown) isolated IOE as an instructional phase prone to problems, namely competing priorities that could jeopardize the safety of the flight. The IOE check airman has two possibly conflicting duties: safely flying a revenue flight and rendering instruction to the newly transitioned trainee. Pilots in this study regarded IOE as an important learning experience. However, the role of the check airman as an instructor must not be allowed to vie with his simultaneous responsibility to fly the aircraft in the safest manner.

We do not know the answer to this complicated question and have no recommendation except that the problem be studied by both operations experts and human factors experts. Obviously, the newly transitioned pilot has to start somewhere, but perhaps the present IOE structure is not the safest way to go and may not be most conducive to integrating skills and knowledge recently learned. Further research should be conducted to identify the specific phases of flight and procedures that are most vulnerable to conflicts and how these conflicts might best be handled. Additional research should contribute to the design of strategies for the enhancement of line instruction while ensuring the safety of flight.

Early Line Experience

Some routes are more difficult than others (e.g., more sidesteps, last-minute changes in the terminal area, holding, vectors, noise abatement arrivals and departures, and more difficult airports). Scheduling should assign easier, less-demanding routes to inexperienced crewmembers (somewhat in the same manner as less-demanding airports for high-minimums captains). We recognize that this recommendation places a heavier burden on the scheduling department, but we feel that the benefits to training and safety would be worth the cost.

Consider scheduling a one-day follow-up training session at some time during each pilot's first year on the line. The session would be used to answer questions, expand on automation techniques and reinforce little-used or weak procedures and skills. A program of this sort would be very expensive, and we recommend only that its costs and benefits be considered.

Cockpit Environment

Engender the concept of "mutual aid" in line pilots, as contrasted with "separate work stations" with only the procedurally required communication. This is especially important when one or both pilots are inexperienced (e.g., recently post-IOE).

Pilots should not hesitate to reveal to each other on initial contact their experience level on the new aircraft. We recommend that this be addressed as a form of CRM training. At times, great differences in time-in-type will be encountered on the flight line. This should be known by both pilots, as one may have to compensate for the inexperience of the other. It is probably an endorsement of the CRM training that captains we have observed have little hesitation in saying to the first officer, in so many words, "I'm new at this (glass cockpit), and I'd appreciate all the help you can give me." Such a statement we would regard as good planning, good briefing and good CRM, and it should promote a more relaxed cockpit atmosphere.

Briefings

The importance of briefings should be taught and emphasized all along the way in transition training. Briefings are the foundation of effective communication and the proper performance of duties in the cockpit. Briefings should be demonstrated by FTD and FFS instructors, check airmen and IOE instructors, and the students should practice briefing in every session. The connection between briefings and CRM should be noted. Stress the importance of briefing by the captain (or PF) to the other pilot(s) and to the lead flight attendant. Training for briefings should be part of any AQP proposal.

Flight attendant briefings also should be taught and practiced. Topics should include, but not be limited to: (1) management of unruly passengers; (2) suspension of service during turbulence; (3) clarification of sterile cockpit procedures; (4) anticipated weather; (5) communication between the cockpit and the cabin. Captain/flight attendant briefings are a two-way street: the lead flight attendant should brief the captain on any special problems or requirements that he/she anticipates for the flight (e.g., heavy passenger load, meal service on a short leg). For a good example of a captain's flight attendant briefing, see Chute and Wiener (1996, p. 226). Briefing of flight attendants should be an integral part of the pilot training syllabus and the flight operations manual, and practiced during transition training, including during FTD exercises. Annual recurrent training may be a good time to review the contents and technique of briefings.

Planning is closely related to briefing. It is particularly important in two-pilot, glass aircraft and is the foundation of workload management. Planning should be emphasized in the H-CAT program, and in FTD and FSS training. The FTD is the place to learn and test planning techniques

Method of Flying and Flight Safety

Flight management should formulate a policy on maintaining manual (hand flying) skills and convey this to the pilots. Hand flying of the new aircraft during transition training is highly desirable, and some portion of the simulator training should be devoted to this. Guidelines for hand flying should be developed, specifying where it can be done, under what weather conditions and what types of approaches. As always, the captain's discretion prevails. We must not forget that hand flying can have negative consequences as well (e.g., high workload and failure to scan the "big picture").

Allow for the practice of non-automation-based problem-solving skills and infrequently used procedures.

In all flights, observe fundamental rules of safe piloting. Several interviewees commented that pilots were not clearing turns in visual meteorological conditions. This precaution goes back to the first day any pilot began his flight training. One pilot remarked, "At least *glance* in the direction you are turning."

Consider the FMC/MCP as a control to be "handed off" to the other pilot, and formalize the handoff, perhaps with a call-out such as "your FMC," to provide feedback that a transfer has been completed.

Workload Management

Management should clarify the policy and procedure on PF/PM duties and sharing of workload. It is critically important in the glass cockpit to specify clearly "who does what" and to conform to procedures, and to stick to the task assignments. [At CAL, the term "pilot monitoring" (PM) has replaced the familiar "pilot not flying" (PNF).]

We recommend that airlines consider replacing the term "pilot not flying" (PNF) with "pilot monitoring," as CAL has done. It gives the position a more positive duty, stressing what the pilot does, rather than what he/she does not do. It further enhances the task of monitoring, an increasingly important activity in the age of automation.

Reduce, through systems analysis, the frequency, complexity and length of "company reports," especially at low altitudes or in crowded airspace, whether they are done by voice transmission or by data link. Routine calls could be made at high altitude, or preferably at cruise. Many calls can be made via existing data links (e.g., ARINC communication and reporting system [ACARS]), but we are not prepared to say that this is a big improvement over traditional voice transmissions. Use of ACARS probably does solve the problem of frequency saturation that occurs in terminal areas, but preparation and transmission of an ACARS message is time consuming. In the near future, much more sophisticated data link systems will be available, and standard messages can be stored and sent, with a minimum of keystrokes, possibly reducing cockpit workload.

Flight management should examine all company business required of the cockpit crew, with an eye toward minimizing or, better yet, eliminating duties that must be performed below 18,000 feet. This recommendation, in one form or another, appeared in various places in this study.

Consider placing some type of terminal, either voice or data link (e.g., ACARS) in the cabin for flight attendants to use for passenger matters. We see no reason, other than tradition, why flight attendants have to come to the cockpit with requests for gate information, galley supplies or wheelchairs.

Impact on Future Air Traffic Management

We have noted throughout this study that pilots are having difficulty with navigation, specifically VNAV, in achieving level-offs, meeting crossing restrictions and initiating descents. The FAA should take note of these implications for the design of future air traffic management systems such as “free flight.”

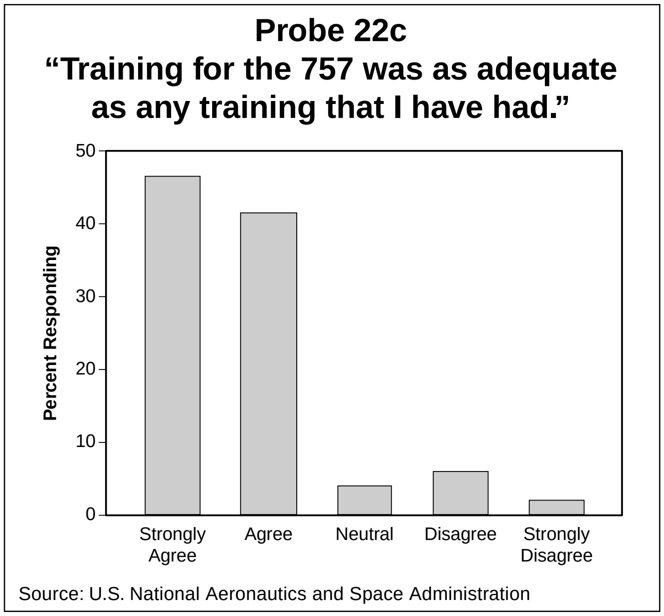
Hardware Standardization

Where possible, standardize over models by the same manufacturer. This will cut cost and time required in training pilots, cabin crews and maintenance personnel. It may also enhance the quality of maintenance and make easier the cross-qualification of crews. It may also allow cross-utilization of simulators to train for various models.

Epilogue

In this study we have examined the development and installation of a training program designed to transition pilots from old technology to new, computer-based cockpit technology. We have commented on what is good and what is not. We feel that the success of the program, its nearly zero failure rate, and its acceptance by the pilots is the result of the right people, the meticulous design of the program and the strong support of management. The “clean sheet of paper” policy has obviously paid off.

Pilot opinion is not everything, but measured correctly, it is one valuable assessment of the program. Shown below is one of the graphic displays of pilot opinion, taken after slightly over a year on the line. The results speak for themselves.


Probe 22c
“Training for the 757 was as adequate as any training that I have had.”

Source: U.S. National Aeronautics and Space Administration

Figure IX-1

We add only that in prior field studies involving various airlines in the United States, with over 40 opinion probes administered to hundreds of pilots, we have never seen a response this extreme on any subject, nor such an endorsement of a company’s pilot training program. The authors give credit to the men and women throughout CAL for this success. We hope that others will be guided by CAL’s experience, and will not only make use of these results, but will make improvements. Aviation safety comes not in dramatic breakthroughs, but in slow, cautious, sometimes tedious, step-by-step expansion of what we already know.

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3. The term "fleet" has two meanings in the airline industry. In one sense it has the usual meaning, similar to that of sea-going vessels, of all of the aircraft of all models and types in a given company's inventory. The other sense means all of those aircraft of a given type, including all models and derivatives, in inventory (e.g., the B-737 fleet). Many airlines have a management pilot designated as a "fleet manager" or "fleet captain," consistent with the second usage. In this report, "fleet" usually refers to the latter meaning. In those cases where the intended meaning is all aircraft operated by an airline, this will be made clear.

   A distinction must be made in the case of the DC-9 and the MD-80 series aircraft. The MD-80 series aircraft are derivatives of the DC-9; they were originally designated the DC-9-80. At CAL the DC-9 models and the MD-80 series are treated as separate fleets, even though pilots flying them have a common type rating, allowing them to fly both.

   At most airlines which operate both the B-757 and 767, they are considered one fleet, due to the commonality of their cockpits. This is the case at CAL.

4. We wish to acknowledge the support and cooperation of CAL. Special recognition goes to Capt. David Lynn, original fleet manager 757/767, and later fleet manager 737, and Capt. David Sanctuary, who became the second fleet manager 757/767 and our point of contact to the end of the study.

   We also acknowledge the support and encouragement of Fred Abbott, James Starley, Don Osmundson, Philip Beeson, Frank Tullo, Erik Kolker, Bruce Tesmer, William Nogues, Kay Richter and the 757 ground and flight instructors, and check airmen. We appreciate also the support of the Safety Committee of the Independent Association of CAL Pilots.

5. The units of measure in this report are in feet and nautical miles, as appropriate to air navigation in most of the world. For those wishing to convert to metric units, 1,000 feet equals approximately 300 meters, and one nautical mile equals approximately 1,600 meters.

6. It is assumed that the reader is familiar with common aviation terminology and abbreviations. A glossary of some of the less familiar abbreviations and acronyms, particularly those used in connection with high technology aircraft, is included as Appendix B. Be aware that each manufacturer has its own set of nomenclature and acronyms. There is no standard lexicon for cockpit features and devices. What Boeing calls EICAS, Airbus calls ECAM.

7. All but one of the pilot volunteers, and all of the management pilots and ground school instructors who participated in this study were males. Accordingly, we have used the male gender in writing this report. We gratefully acknowledge the support of the 757 line pilots who volunteered for this study.

8. We also recognize the support of the staff of NASA's Aviation Safety Reporting System. The reports quoted in the chapters and in Appendix H came from a search that we requested. We sought reports in which the incident contained elements of two factors: automation and training. We again wish to make it clear that these are not reports of CAL crews. The identity of the reporter's company is not placed on the report form, nor if it were to appear, in the ASRS database. The cases were selected from the search output because they represented the factors that we wished to consider. If any of the reports came from CAL crews, we are not aware of it, and it would be strictly the "luck of the draw." The same is true of the aircraft type. We did not attempt to select B-757 reports. Some obviously are not 757s, as the reports contain Airbus Industrie names and acronyms.

   We did the minimum amount of editing of these reports, as we wanted the reader to be able to view them in the pilots' language and idiom. What little editing we did was merely to make the report readable.

9. The opinions expressed here are those of the authors, and not of any agency, institution or organization.♦

[FSF editorial note: This report is reprinted from the U.S. National Aeronautics and Space Administration's *Transition to Glass: Pilot Training for High-technology Transport Aircraft*, NASA/CR-1999-208784, May 1999. FSF editorial staff worked with the report's authors, and some changes were made for clarity and style.]

Appendix A

Likert Attitude Scales for Three Phases of the Study

On each of the following pages in this appendix, the data from the Likert attitude scales are displayed in graphic form. There is a plot for each probe and for each phase of the study.

For the first 20 pages (86 to 105), there are three plots per page, in the following order:

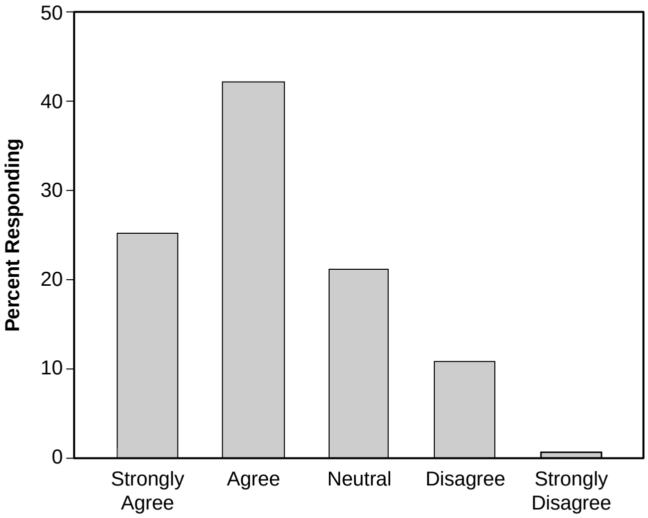
Phase 1	(first day of ground school)
Phase 2	(about 3–4 months after training)
Phase 3	(about 12–14 months later)

Thus, the reader can compare the graphs over time. For a graphic presentation of the phases and sample sizes, see Figure III-1 on page 23.

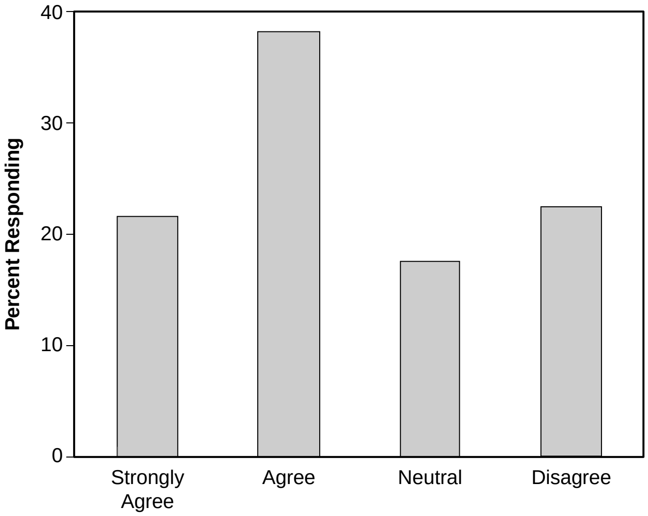
Probes 21 through 24 were administered only in Phase 2 and Phase 3, because the probes were inappropriate for pilots not yet out on the line in the B-757. Pages 106 through 109 show graphs only for the Phase 2 and Phase 3 probes.

Probe 1:
“Flying today is more challenging than ever.”

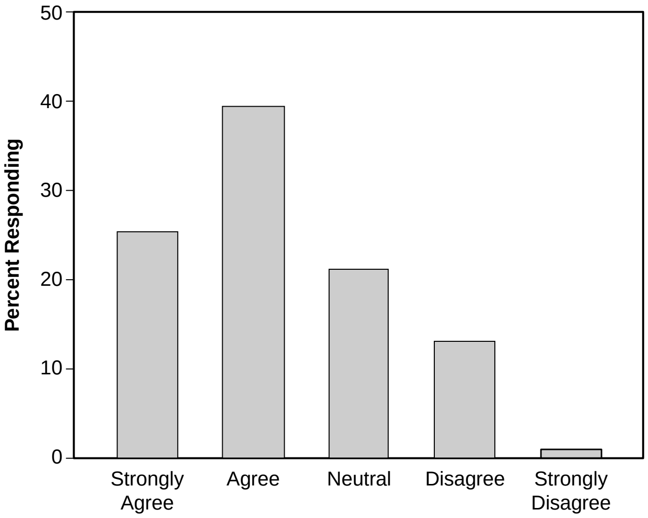
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)

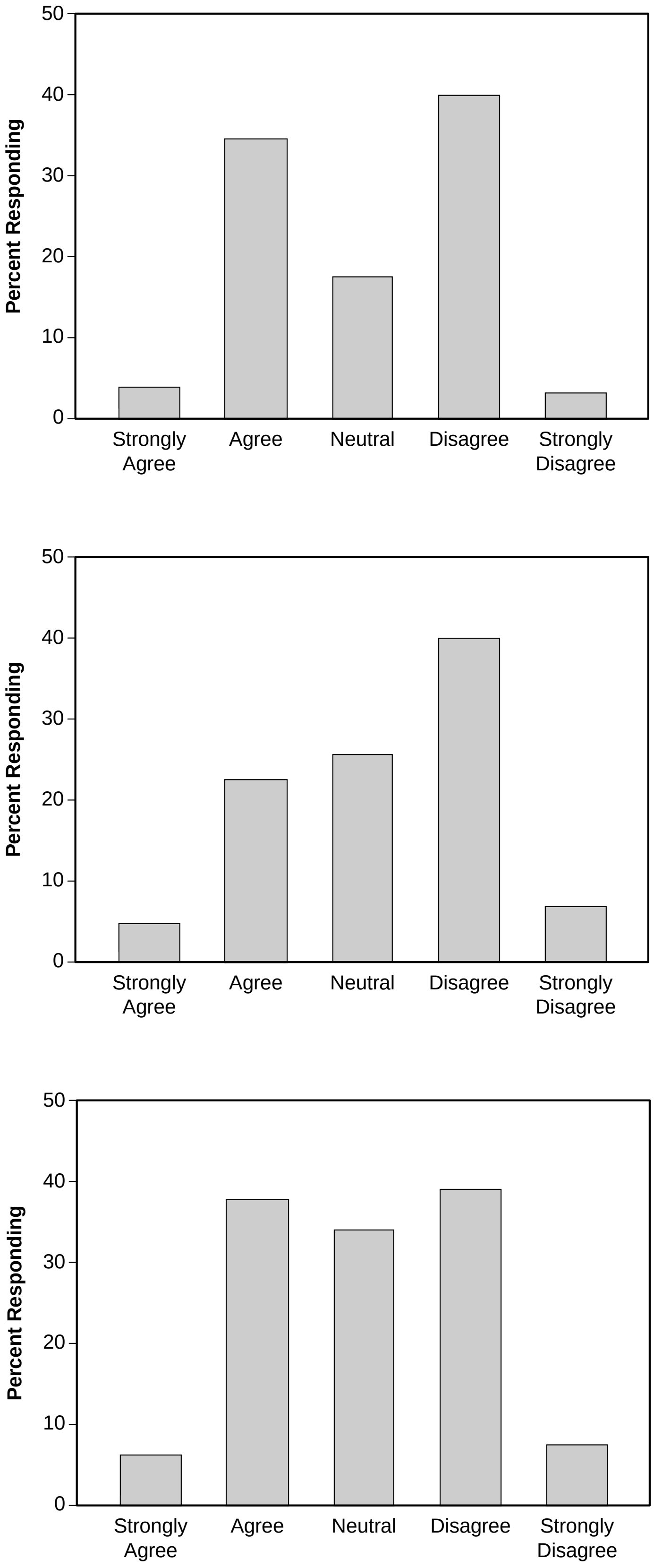


Phase 3
(about 12–14 months later)



Source: U.S. National Aeronautics and Space Administration

Probe 2:
“I am concerned that automation will cause me to lose my flying skills.”



Phase 1
(first day of ground school)

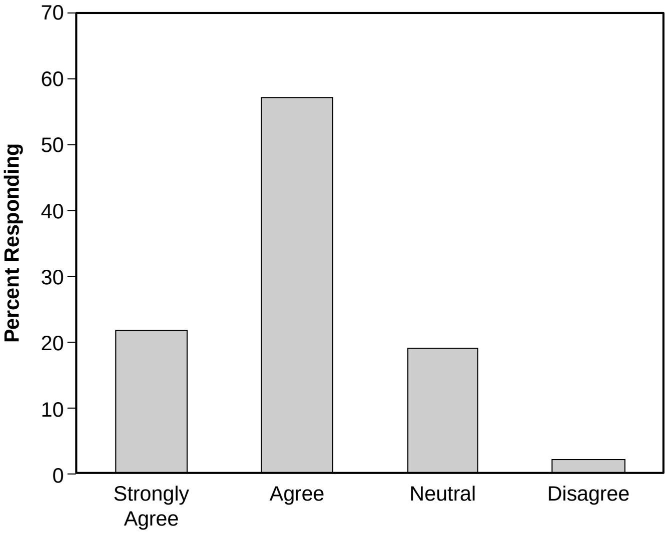
Phase 2
(about 3–4 months after training)

Phase 3
(about 12–14 months later)

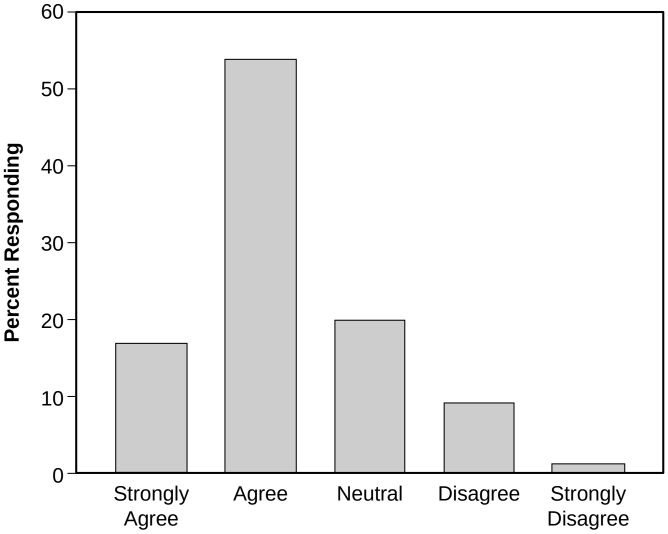
Source: U.S. National Aeronautics and Space Administration

Probe 3:
“Automation leads to more efficient, safer operations.”

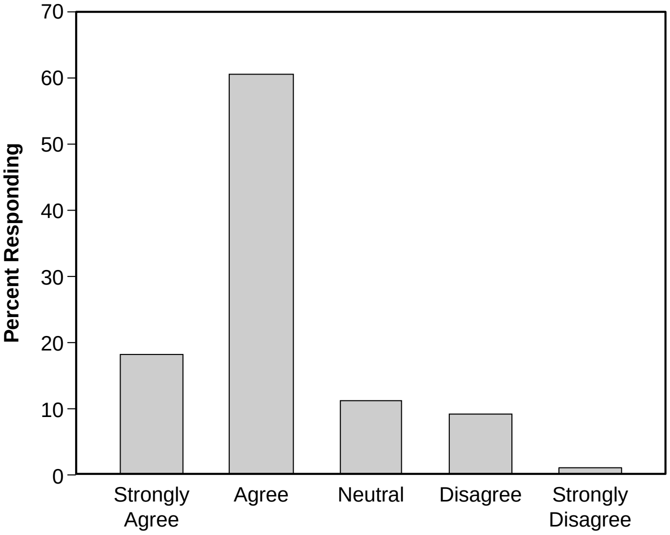
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



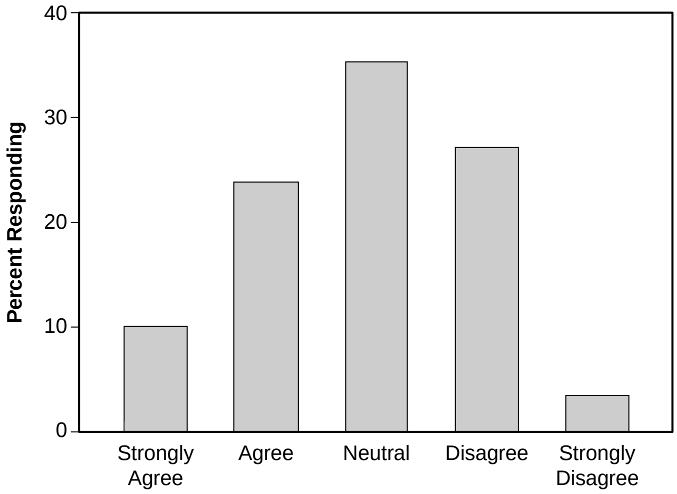
Phase 3
(about 12–14 months later)



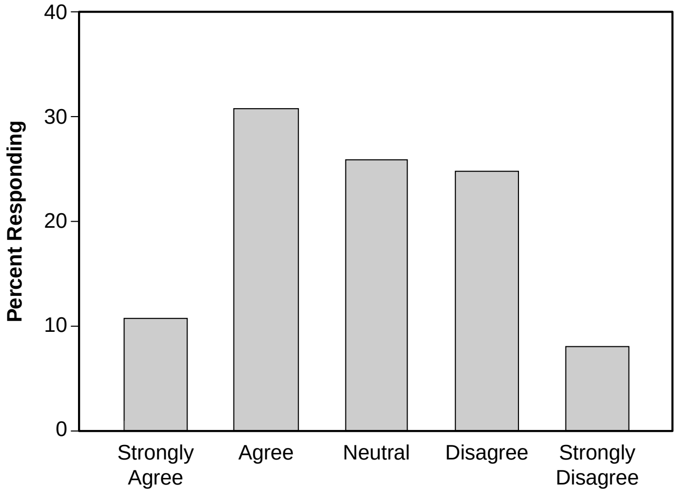
Source: U.S. National Aeronautics and Space Administration

Probe 4:
“It is important to me to fly the most modern plane in my company’s fleet.”

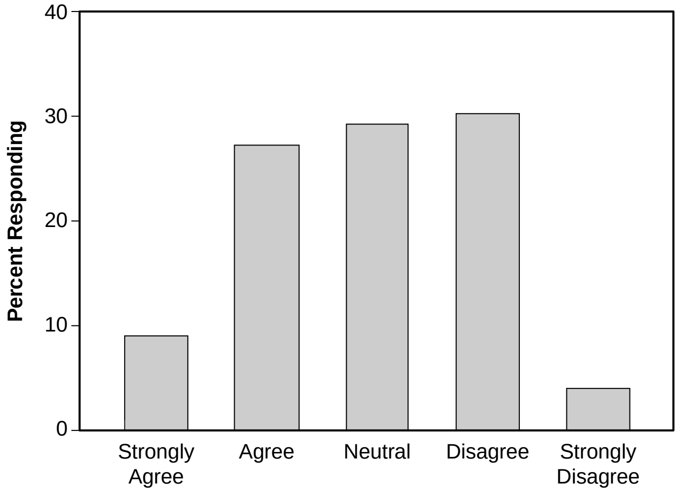
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



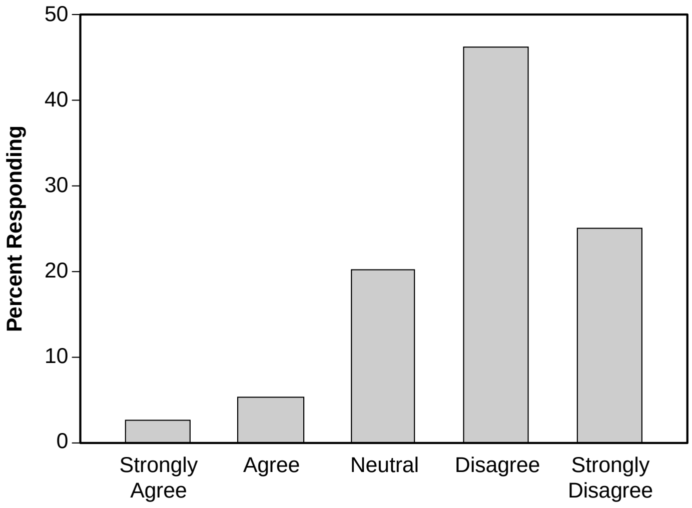
Phase 3
(about 12–14 months later)



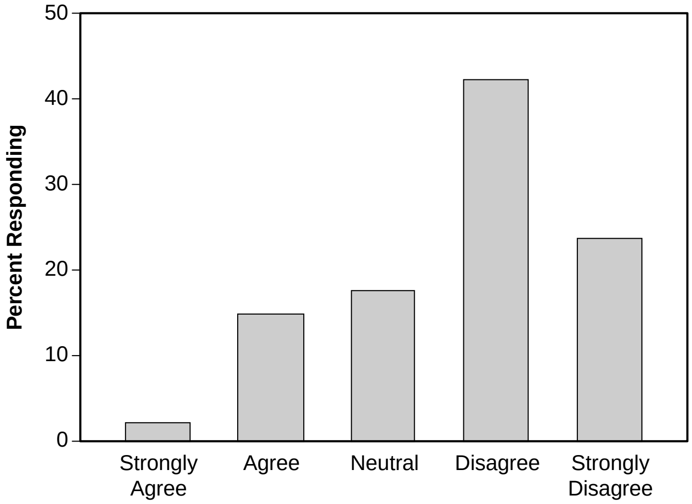
Source: U.S. National Aeronautics and Space Administration

Probe 5:
“As I look at aircraft today, I think they’ve gone too far with automation.”

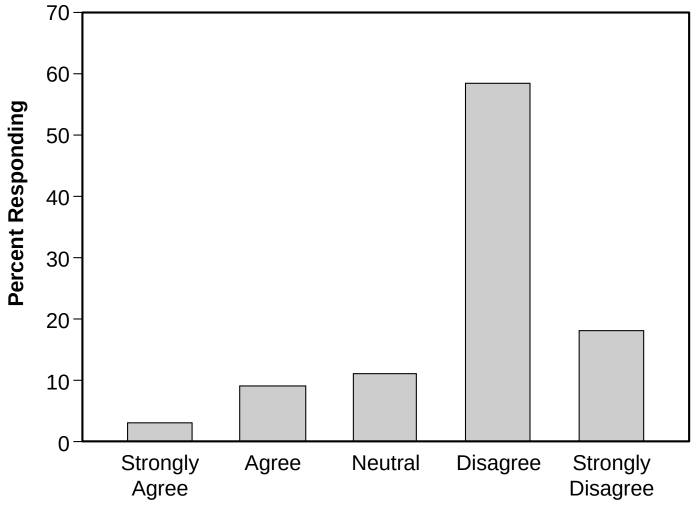
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



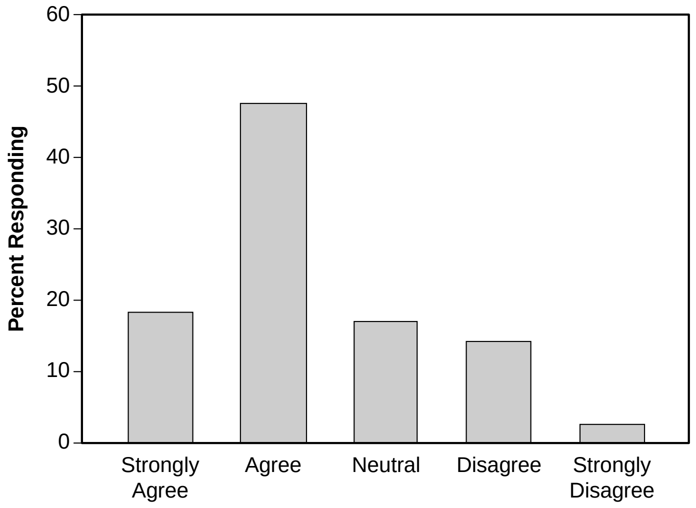
Phase 3
(about 12–14 months later)



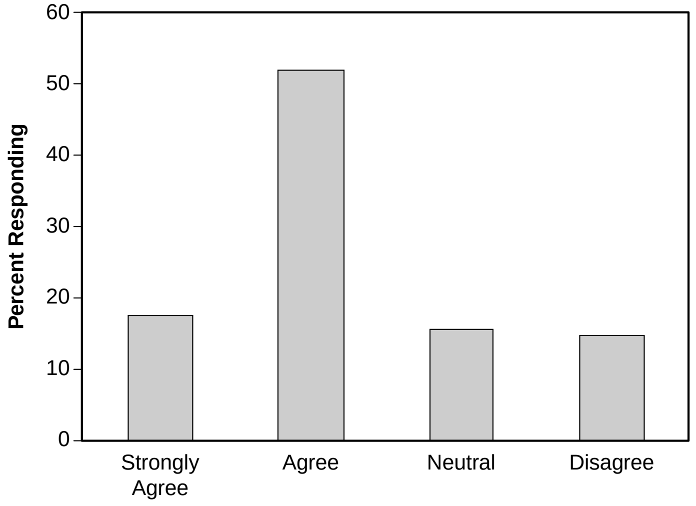
Source: U.S. National Aeronautics and Space Administration

Probe 6:
“Automated cockpits require more cross-checking of crewmembers’ actions.”

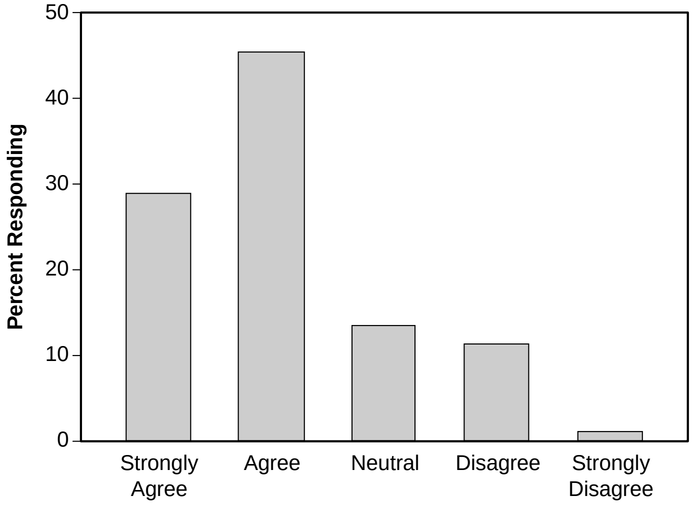
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



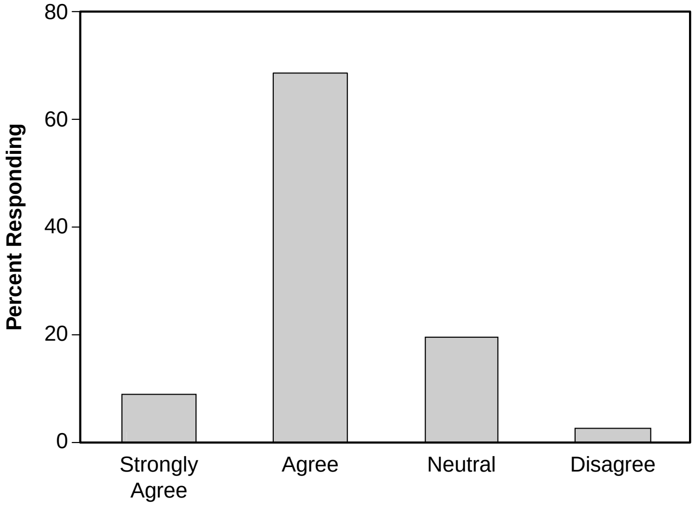
Phase 3
(about 12–14 months later)



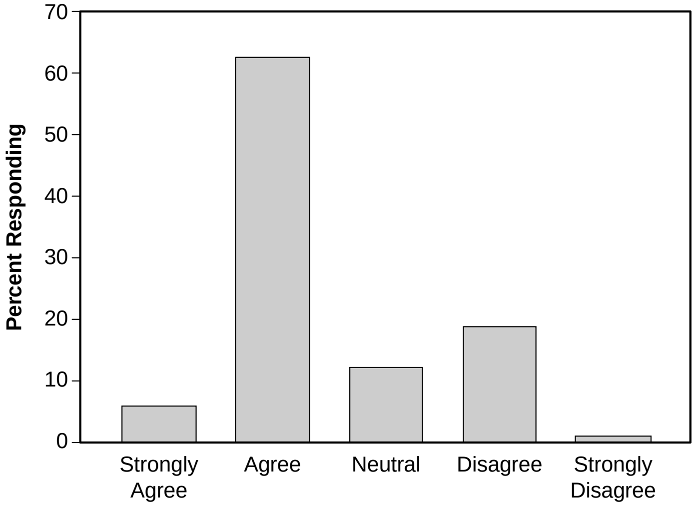
Source: U.S. National Aeronautics and Space Administration

Probe 7:
"In the aircraft I am presently flying, it is easy for the captain to monitor and supervise the first officer."

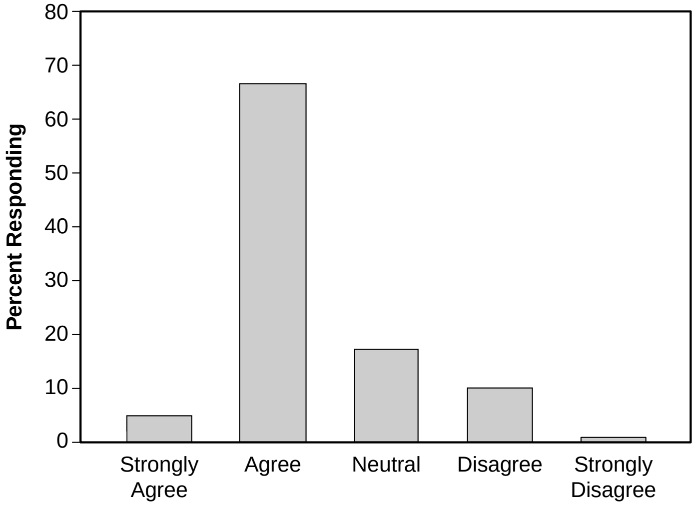
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



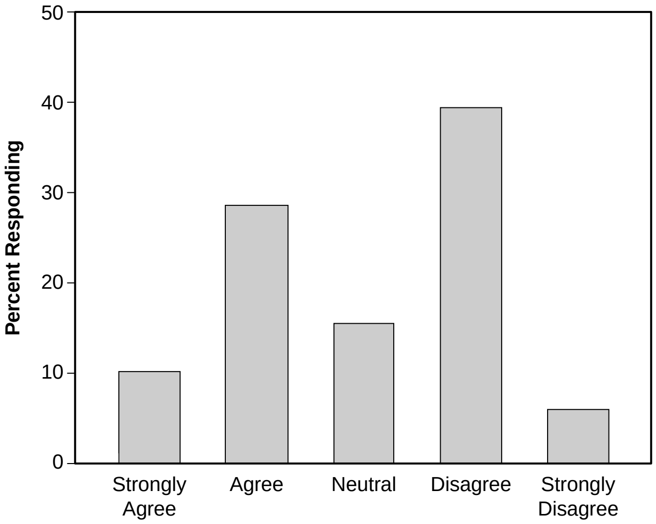
Phase 3
(about 12–14 months later)



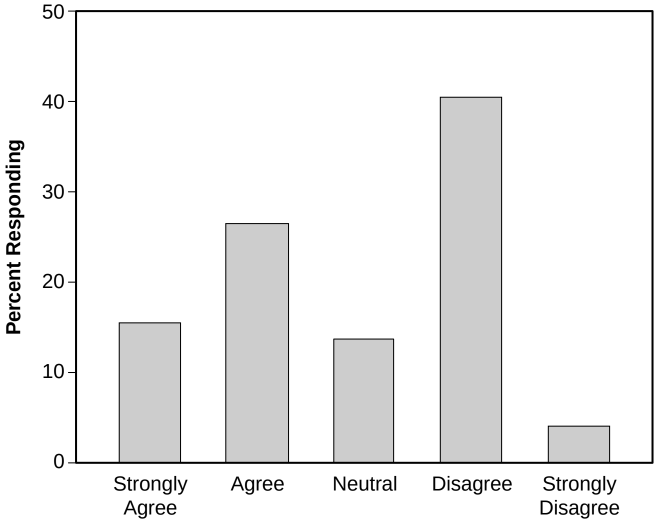
Source: U.S. National Aeronautics and Space Administration

Probe 14 (Phase 1) and Probe 8 (Phases 2 and 3): “Automation does not reduce total workload.”

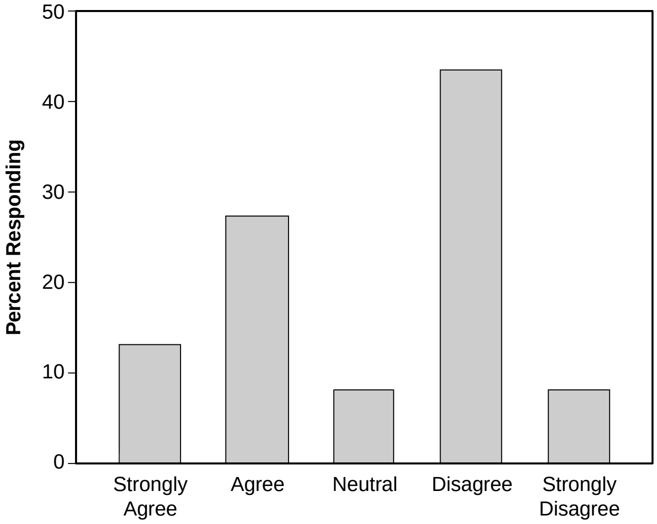
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



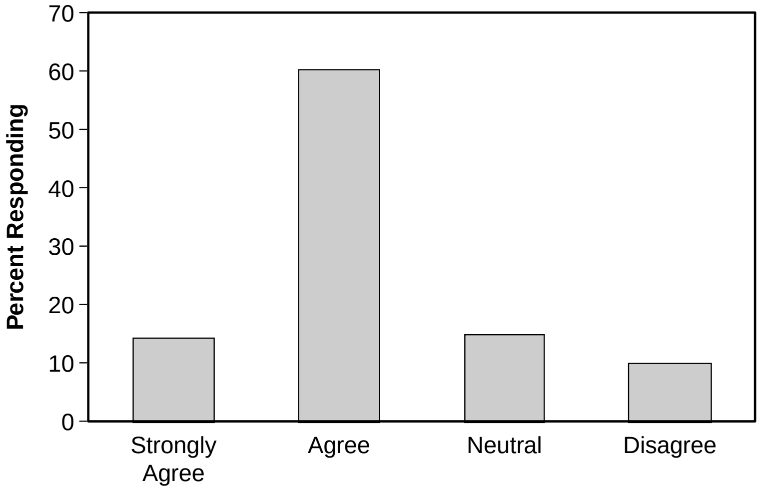
Phase 3
(about 12–14 months later)



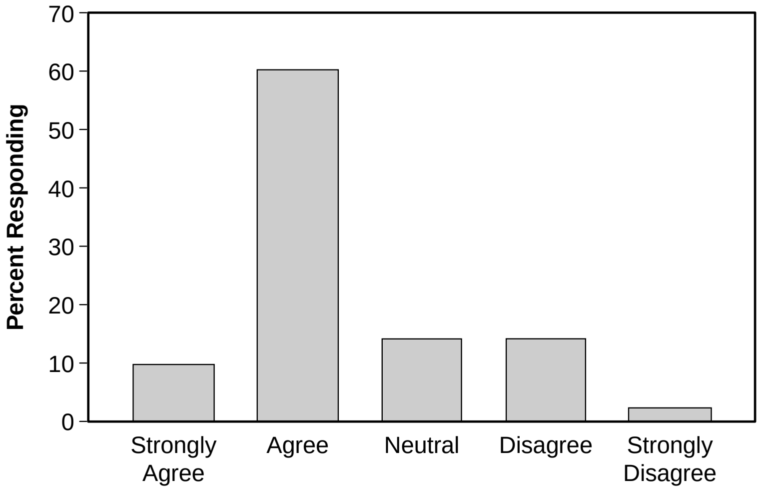
Source: U.S. National Aeronautics and Space Administration

Probe 9:
“Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on ‘managing’ the flight.”

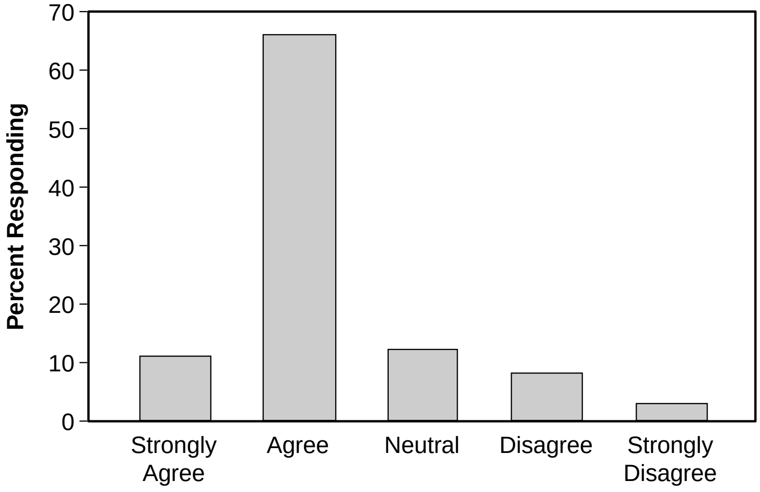
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



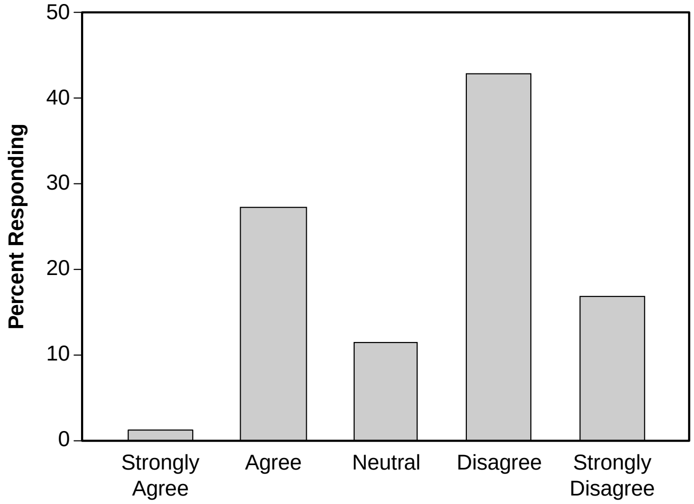
Phase 3
(about 12–14 months later)



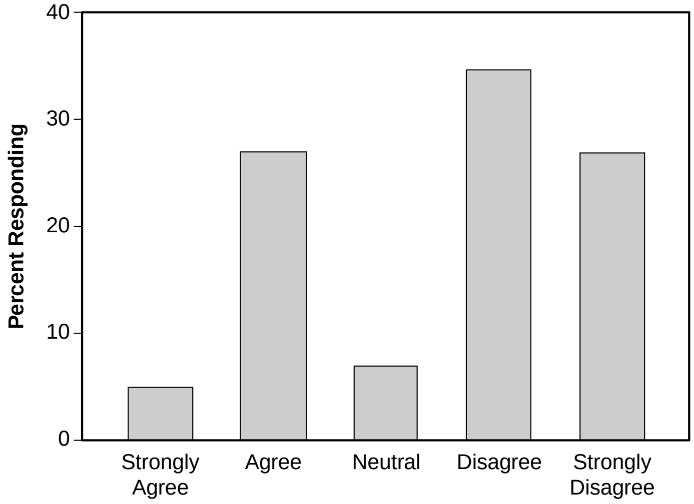
Source: U.S. National Aeronautics and Space Administration

Probe 10:
“I am not concerned about making errors, as long as we follow procedures and checklists.”

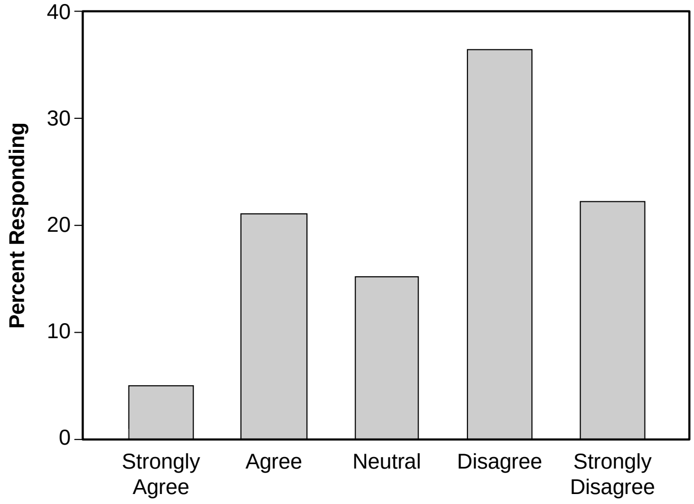
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



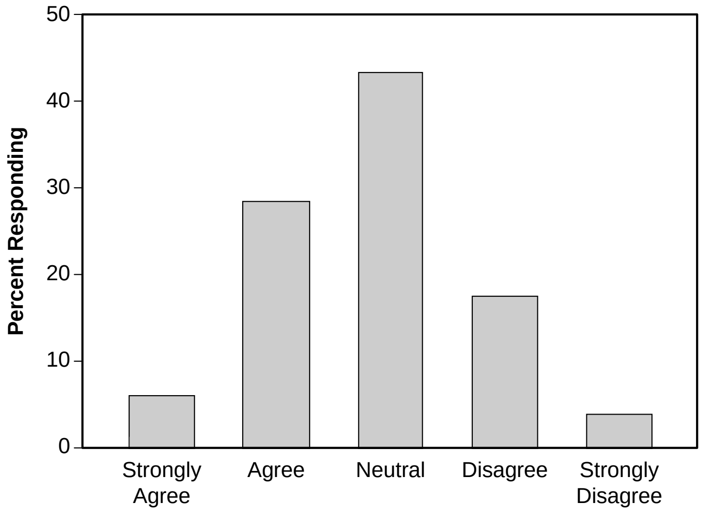
Phase 3
(about 12–14 months later)



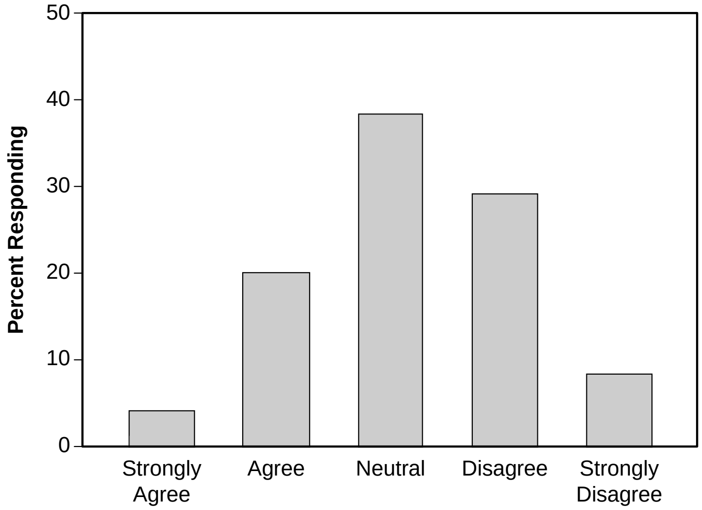
Source: U.S. National Aeronautics and Space Administration

Probe 11:
“I look forward to more automation — the more the better.”

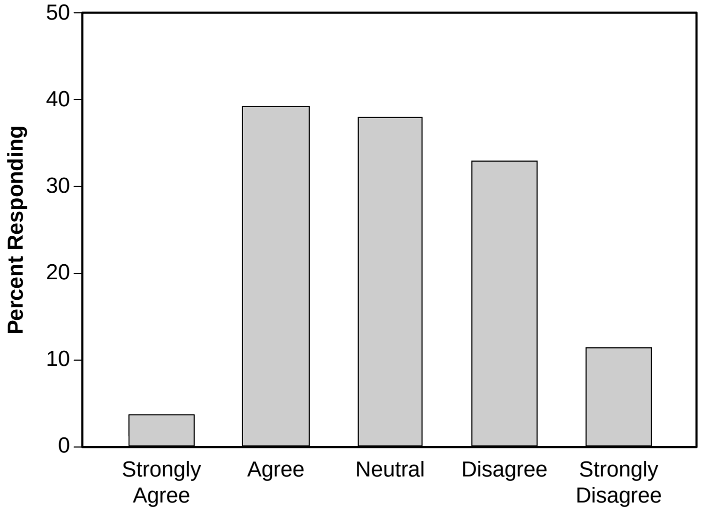
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



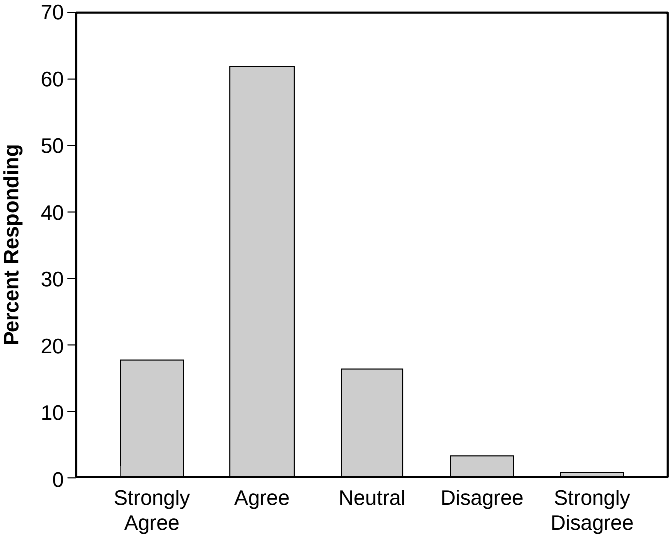
Phase 3
(about 12–14 months later)



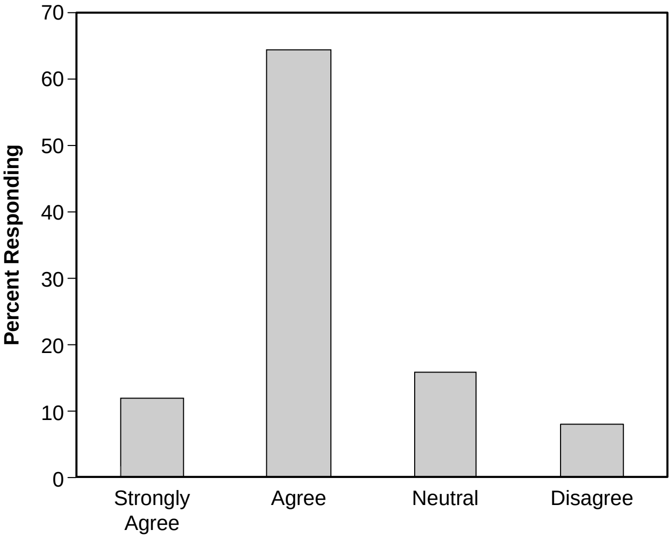
Source: U.S. National Aeronautics and Space Administration

Probe 12:
“I have no trouble staying ‘ahead of the plane.’”

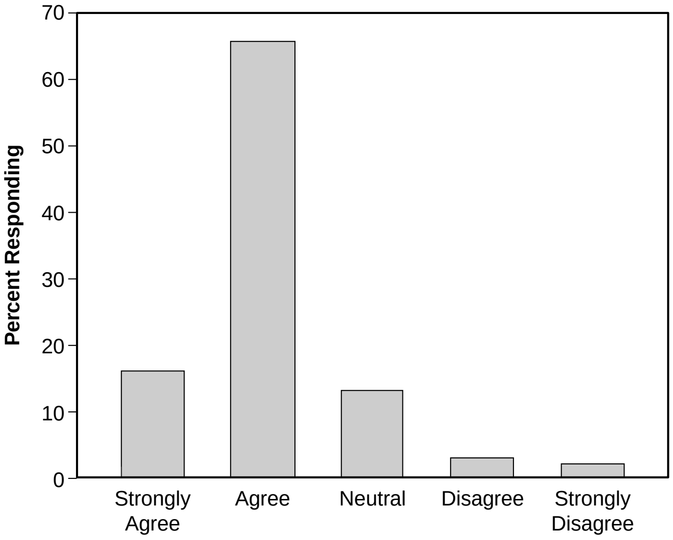
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



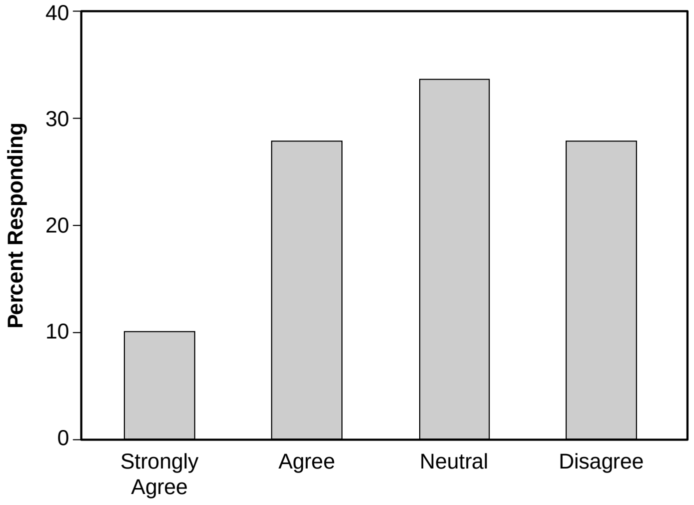
Phase 3
(about 12–14 months later)



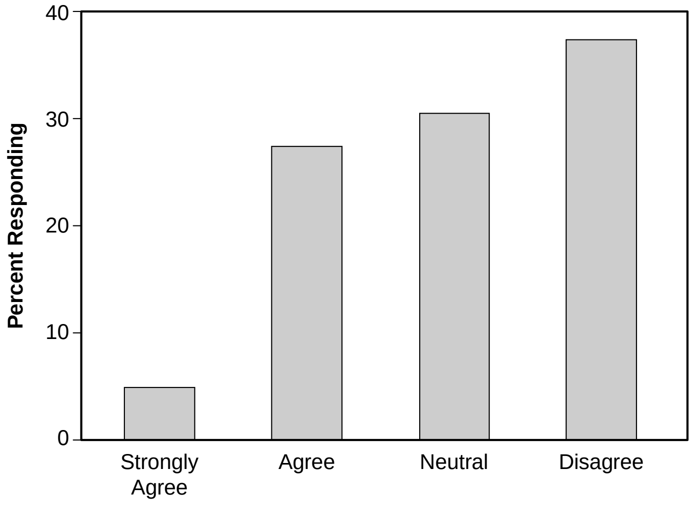
Source: U.S. National Aeronautics and Space Administration

Probe 13:
“There is too much workload below 10,000 feet and in the terminal area.”

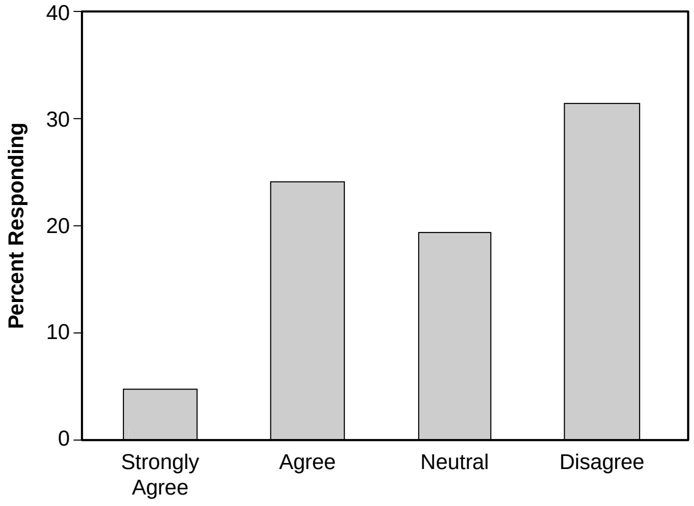
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



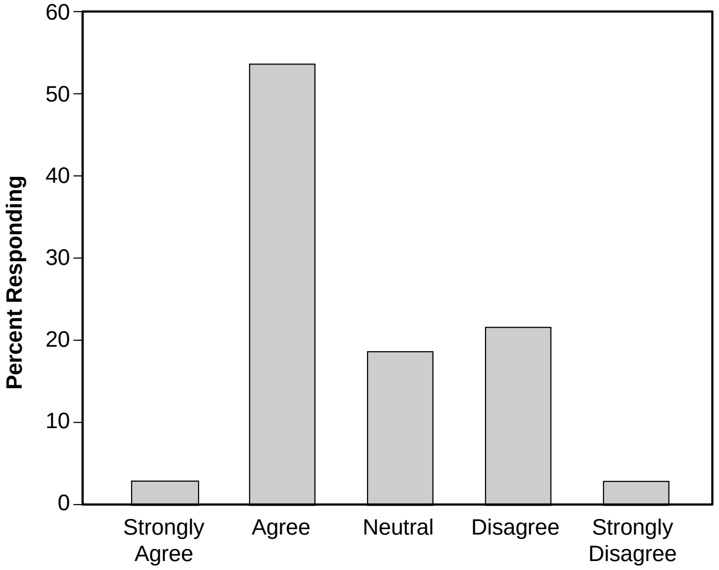
Phase 3
(about 12–14 months later)



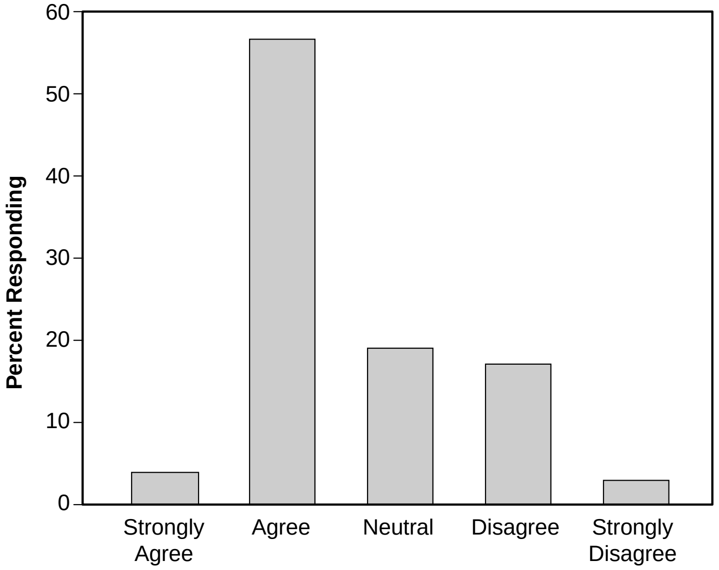
Source: U.S. National Aeronautics and Space Administration

Probe 14 (Phases 2 and 3):
“I always know what mode the automation is in.”

Phase 2
(about 3–4 months after training)



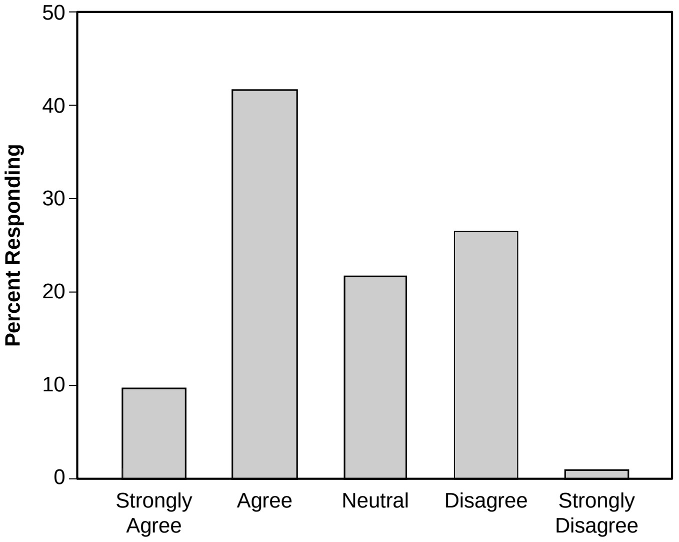
Phase 3
(about 12–14 months later)



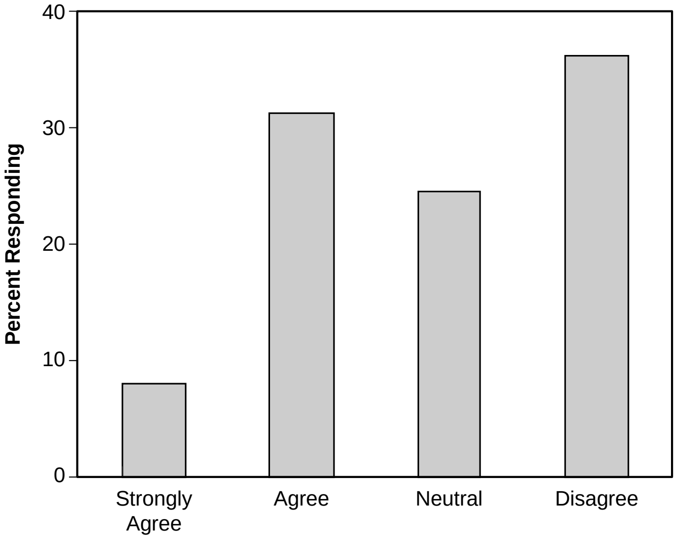
Source: U.S. National Aeronautics and Space Administration

Probe 15:
“It is easy to bust an altitude in today’s environment.”

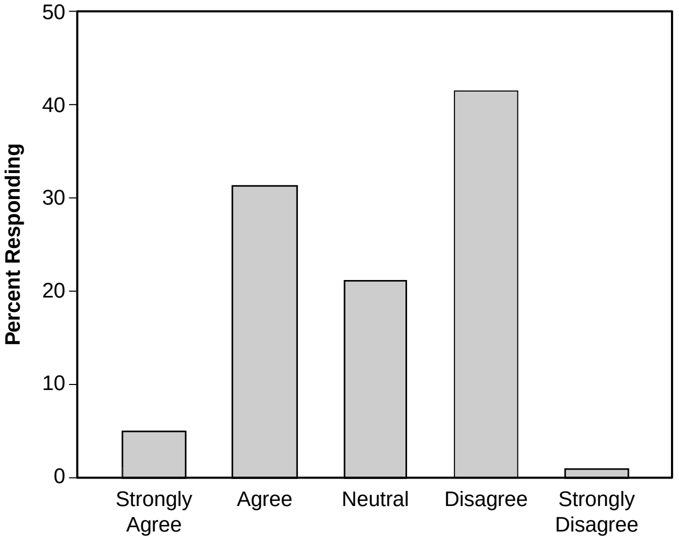
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



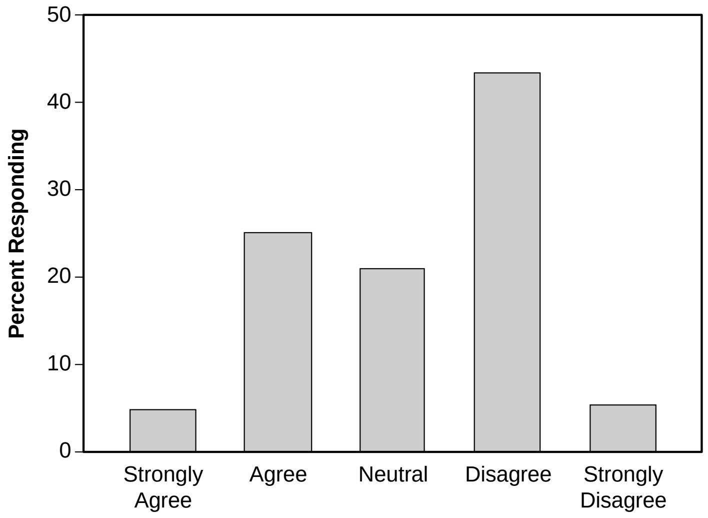
Phase 3
(about 12–14 months later)



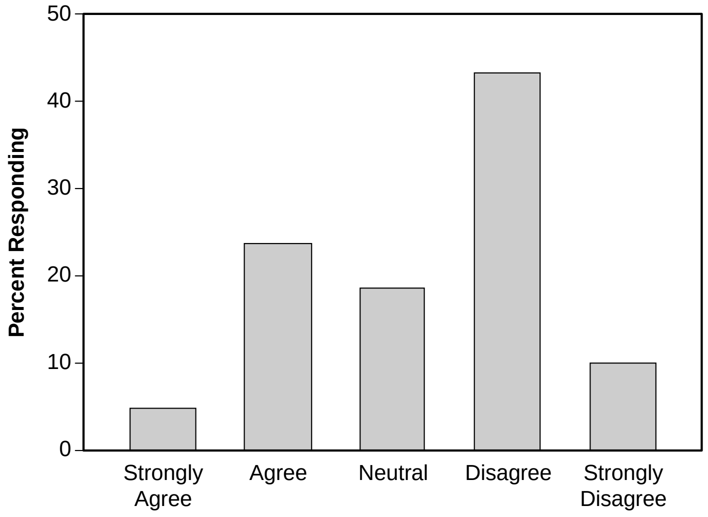
Source: U.S. National Aeronautics and Space Administration

Probe 16:
"I am concerned about the reliability of some of the automation equipment."

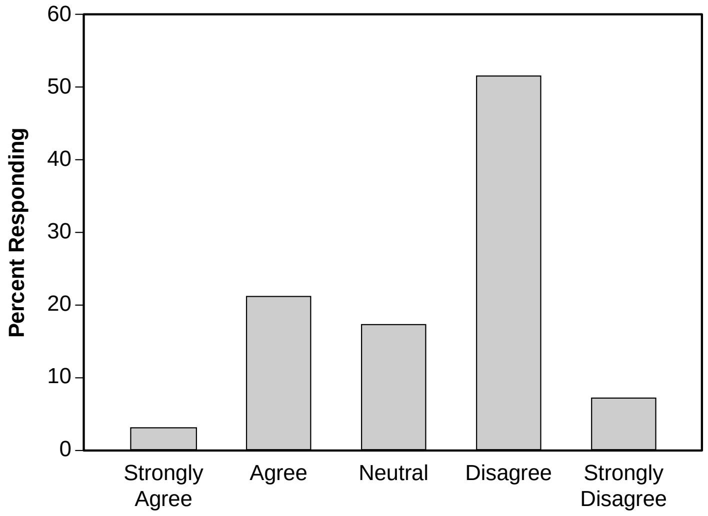
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



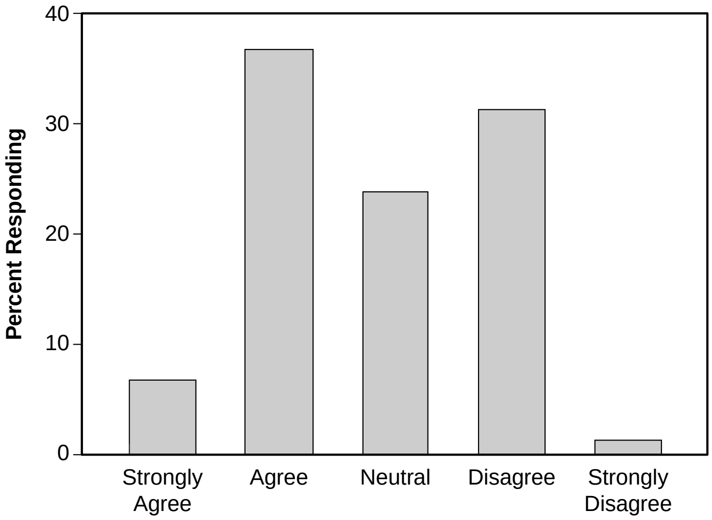
Phase 3
(about 12–14 months later)



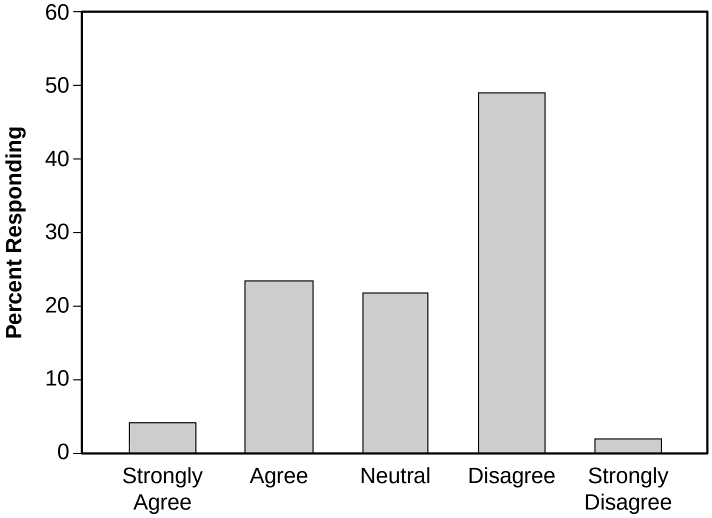
Source: U.S. National Aeronautics and Space Administration

Probe 17:
"I am concerned about the lack of time to look outside the cockpit for other aircraft."

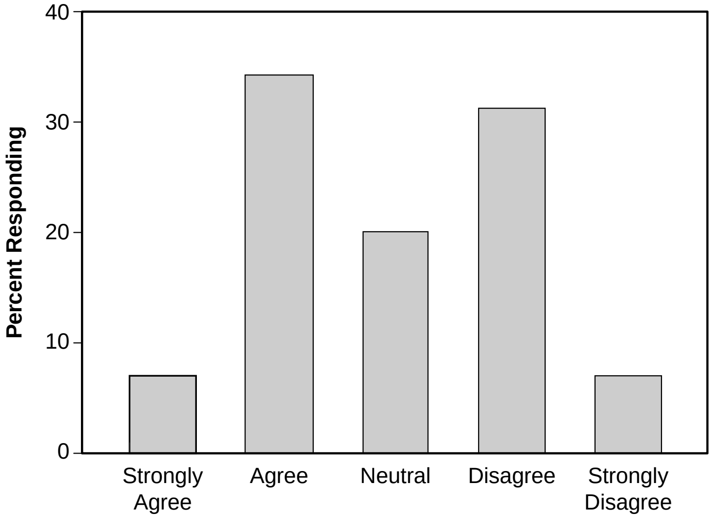
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



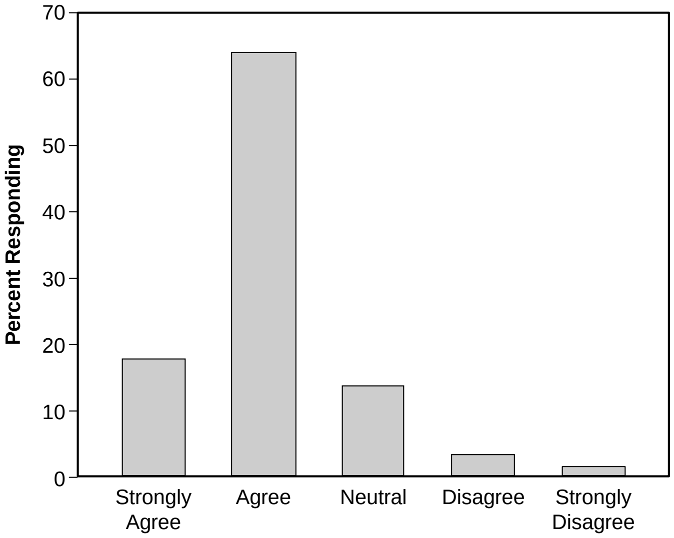
Phase 3
(about 12–14 months later)



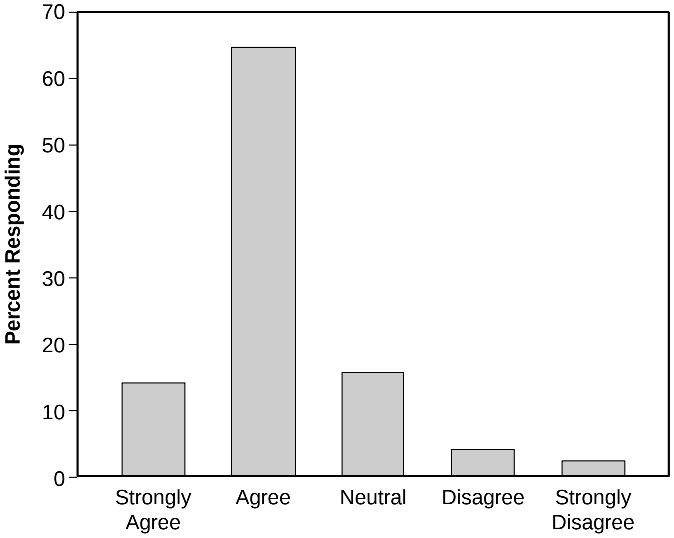
Source: U.S. National Aeronautics and Space Administration

Probe 18:
“Continental’s CRM training has been helpful to me.”

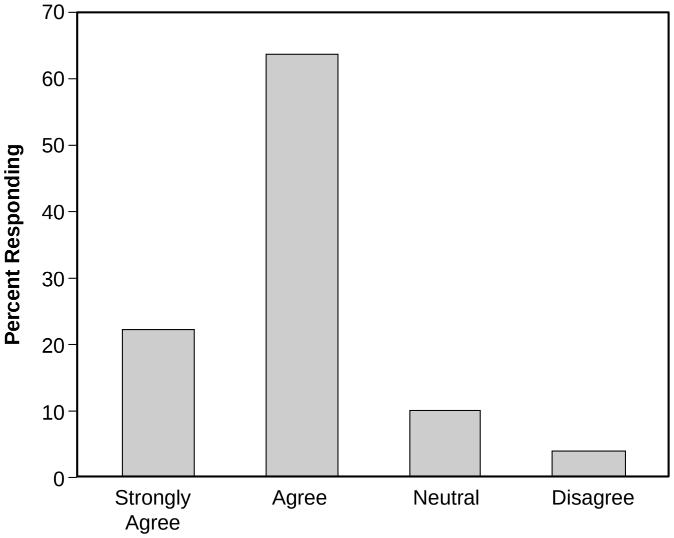
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



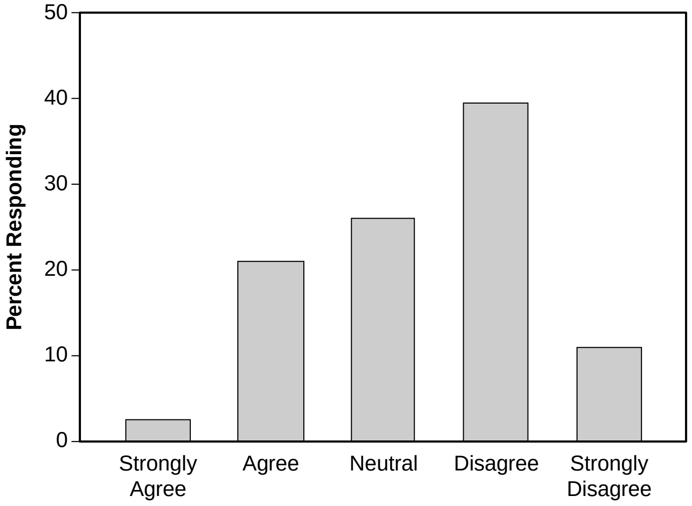
Phase 3
(about 12–14 months later)



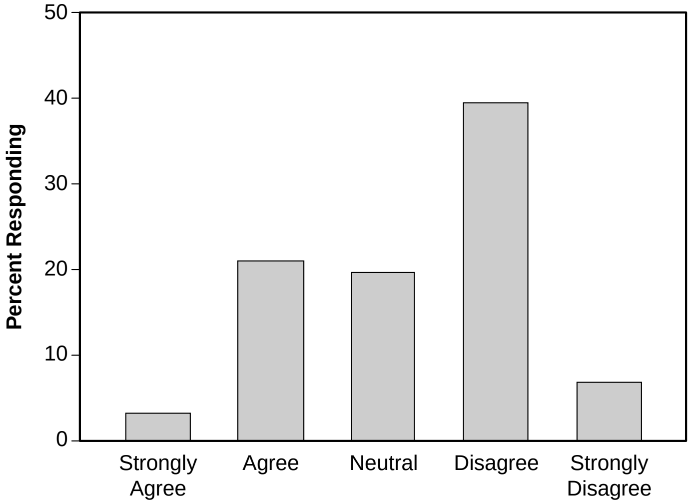
Source: U.S. National Aeronautics and Space Administration

Probe 19:
“Sometimes I feel more like a ‘button pusher’ than a pilot.”

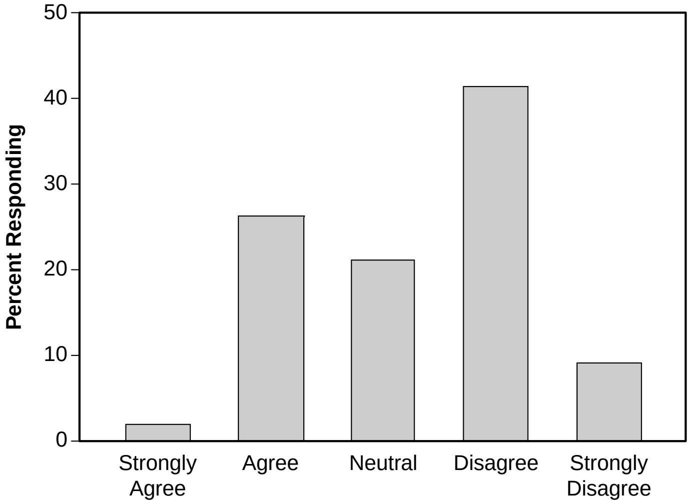
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



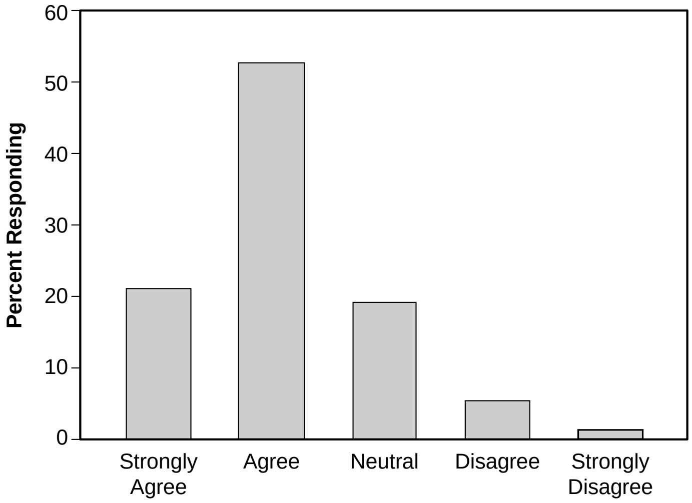
Phase 3
(about 12–14 months later)



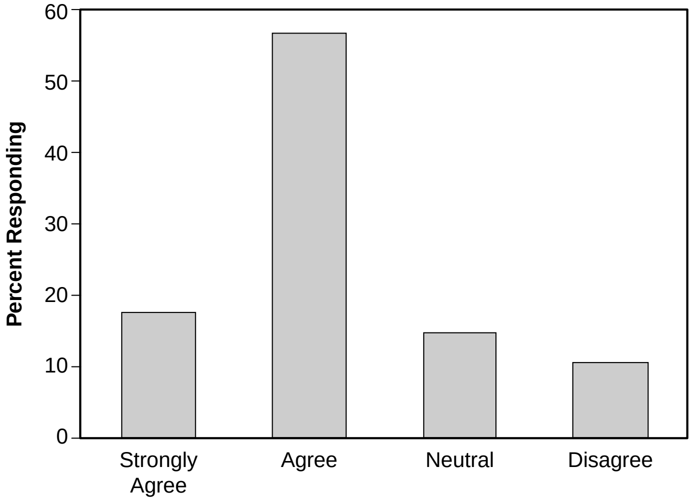
Source: U.S. National Aeronautics and Space Administration

Probe 20:
“I regularly maintain flying proficiency by turning off automation and hand flying.”

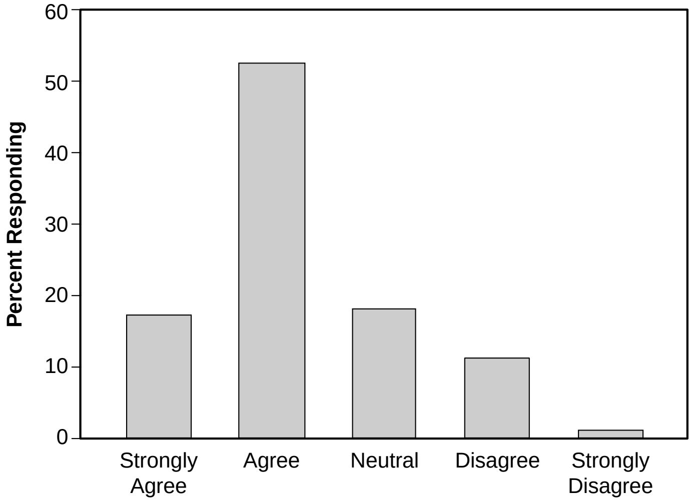
Phase 1
(first day of ground school)



Phase 2
(about 3–4 months after training)



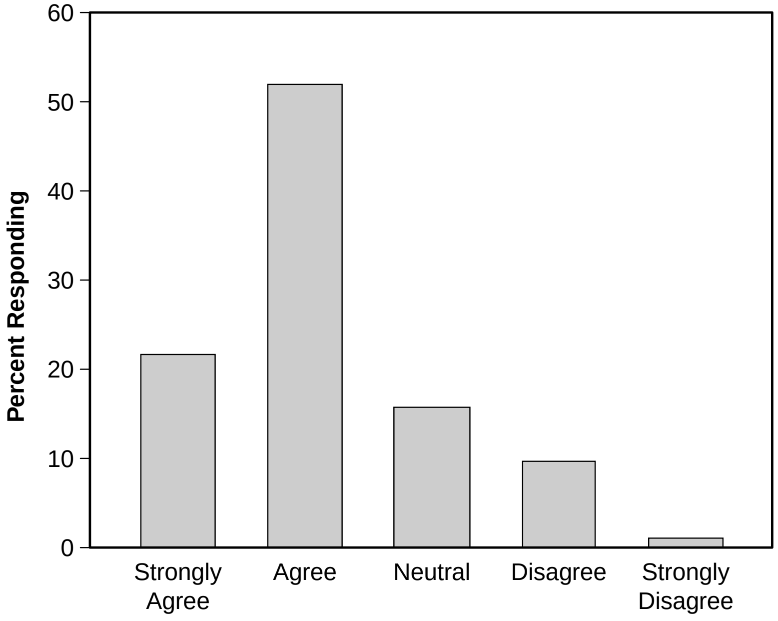
Phase 3
(about 12–14 months later)



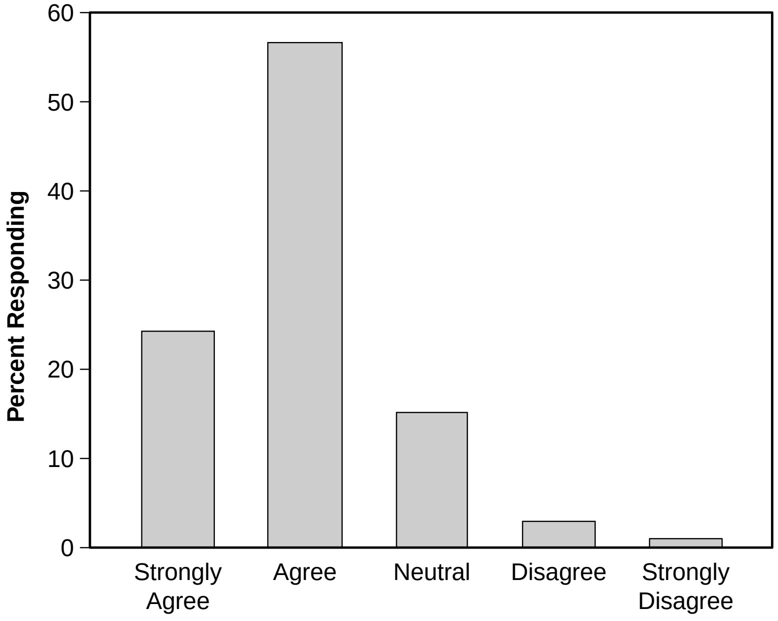
Source: U.S. National Aeronautics and Space Administration

Probe 21:
“The 757 works great in today’s ATC environment.”

Phase 2
(about 3–4 months after training)



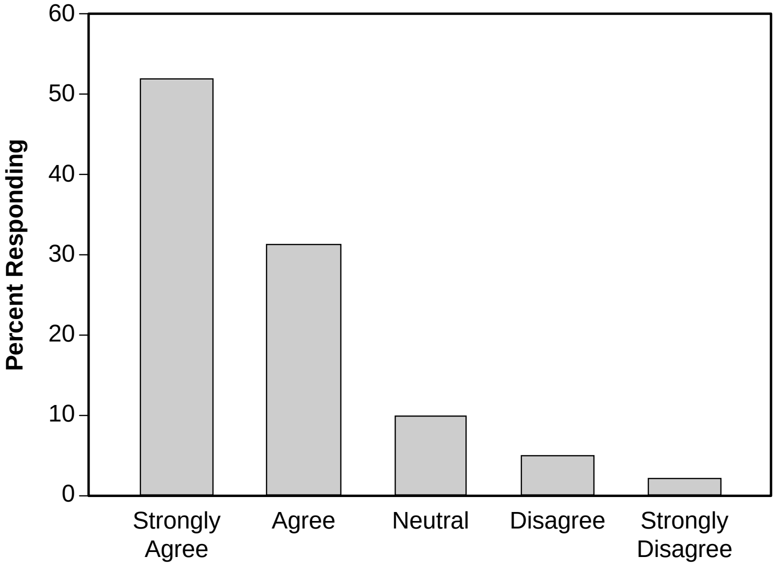
Phase 3
(about 12–14 months later)



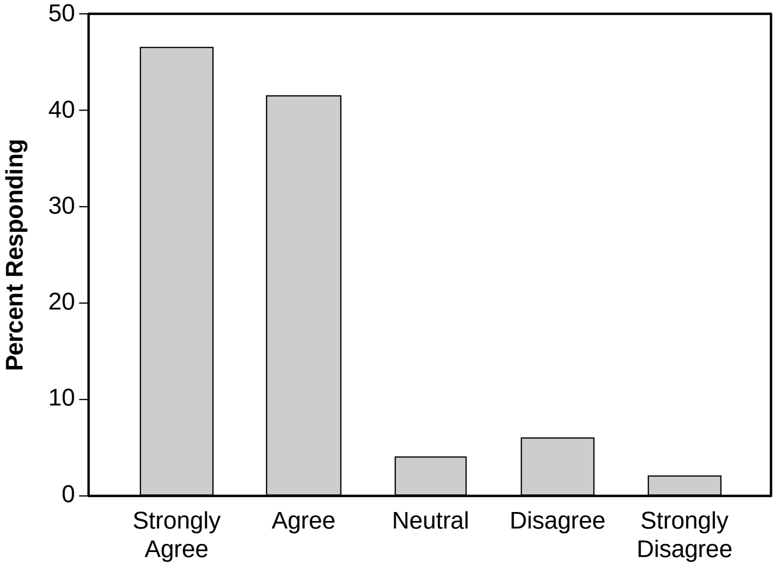
Source: U.S. National Aeronautics and Space Administration

Probe 22:
"Training for the 757 was as adequate as any training that I have had."

Phase 2
(about 3–4 months after training)



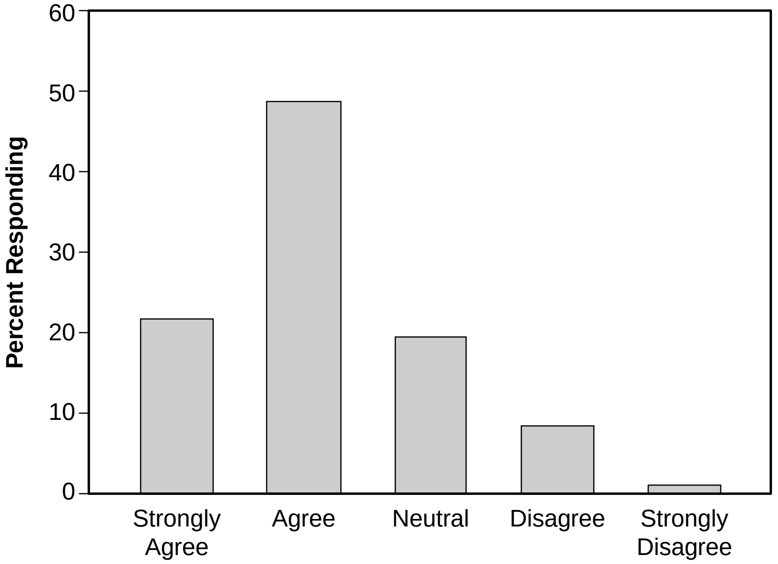
Phase 3
(about 12–14 months later)



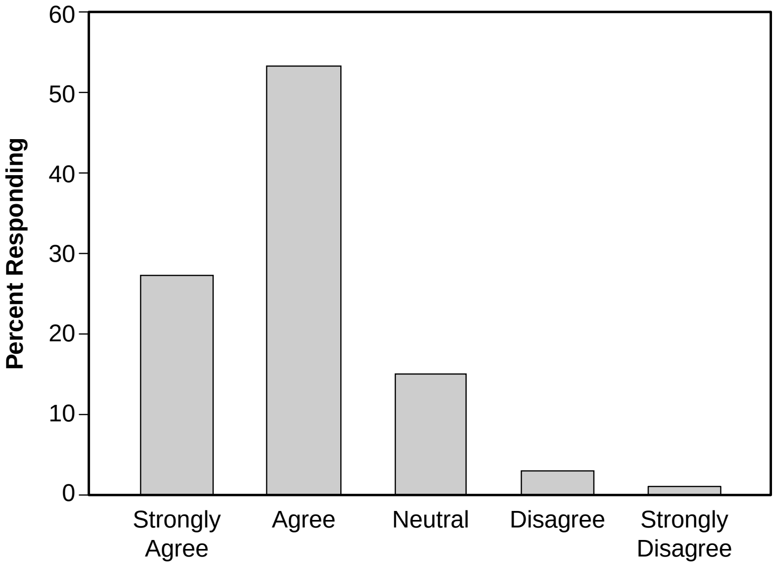
Source: U.S. National Aeronautics and Space Administration

Probe 23:
“Electronic flight instruments (‘glass cockpits’) are a big advance for flight safety.”

Phase 2
(about 3–4 months after training)



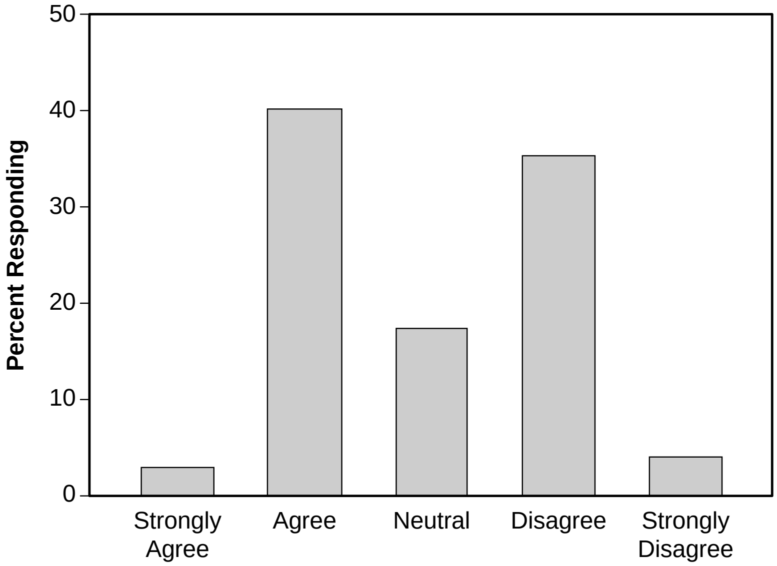
Phase 3
(about 12–14 months later)



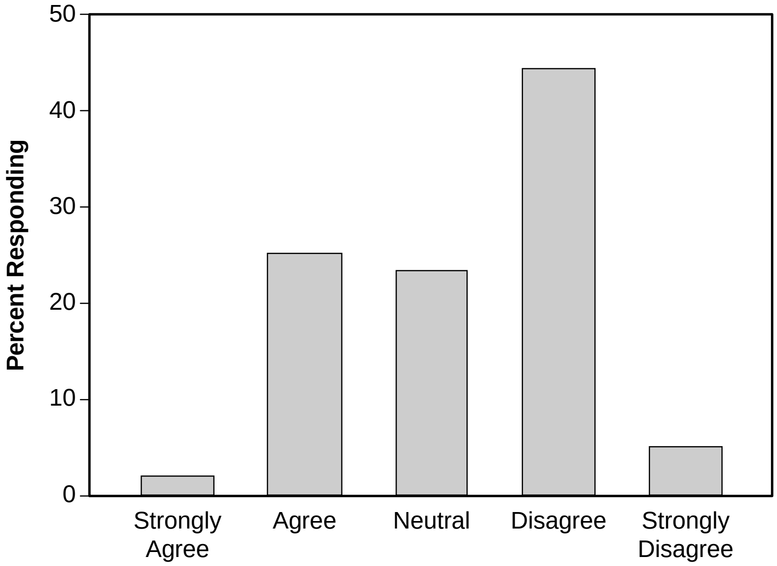
Source: U.S. National Aeronautics and Space Administration

Probe 24:
"There are still modes and features of the 757 automation that I do not understand."

Phase 2
(about 3–4 months after training)



Phase 3
(about 12–14 months later)



Source: U.S. National Aeronautics and Space Administration

Appendix B

Glossary of Abbreviations

AC	Advisory circular (FAA)
ACARS	ARINC communication and reporting system
ADF	automatic direction finder
ADI	attitude director indicator
AFCS	automatic flight control system
AFDS	automatic flight director system
AI	artificial intelligence
AOA	angle-of-attack
AQP	advanced qualification program
ARINC	Aeronautical Radio, Inc.
ASRS	Aviation Safety Reporting System (NASA)
CBT	computer-based training
CDU	control-display unit
CFIT	controlled flight into terrain (accident)
CRM	cockpit resource management; crew resource management
CRT	cathode ray tube
CVR	cockpit voice recorder
ECAM	electronic centralized aircraft monitor (Airbus)
EEC	electronic engine control
EFIS	electronic flight instrument systems
EGPWS	enhanced GPWS
EICAS	engine indication and crew alerting system (Boeing)
ELS	electronic library system
ELT	emergency locator transmitter
ETOPS	extended two-engine operations
FARs	Federal Aviation Regulations
FBS	fixed base simulator
FFS	full flight simulator
FMA	flight mode annunciator
FMC	flight management computer
FMEA	failure mode and effects analysis
FMS	flight management system
FOQA	flight operations quality assurance
FTD	flight training device
GPS	global positioning system
GPWS	ground-proximity warning system (see also EGPWS)
H-CAT	human-centered automation training (CAL)
HSI	horizontal situation indicator
INS	inertial navigation system
IRO	international relief officer
IRS	inertial reference system
IRU	inertial reference unit
LNAV	lateral navigation
LOFT	line-oriented flight training
LOS	line-oriented simulation
MEL	minimum equipment list
MMEL	master MEL
MCP	mode control panel
MOA	military operations area
MSAW	minimum safe altitude warning
NATRAC	North Atlantic tracks
NDB	nondirectional beacon
PC	proficiency check
PF	pilot flying
PIP	product improvement package (Boeing)
PM	pilot monitoring (see also PNF)
PNF	pilot not flying
POI	principal operations inspector (FAA)
QRH	quick reference handbook
RNAV	area navigation
RT	recurrent training
TCAS	traffic alert/collision avoidance system
TMC	thrust management computer
VNAV	vertical navigation
WPT	waypoint

Appendix C

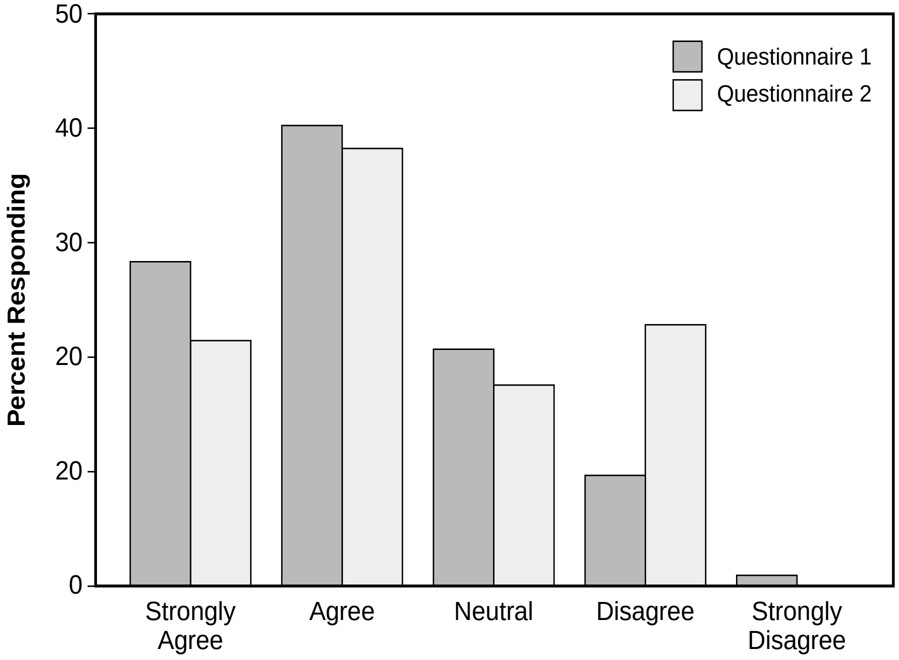
Marginal Homogeneity Tests: Q1 vs. Q2

The eight pages that follow show graphically the results of the marginal homogeneity tests, and histograms of the before and after Likert scales. Only the eight probes resulting in significant differences on the marginal homogeneity test are included. The table on the bottom half of the page displays the homogeneity matrix.

As explained previously, if there is no change in attitude, the tally would be in the main diagonal. Taking for example page 111, there were 15 pilots who strongly agreed with the probe in Phase 1, and again in Phase 2. There were 9 pilots who changed from “strongly agree” to just “agree.” Off-diagonal tallies indicate changes in attitude. The further the tally from the main diagonal, the greater the pilot’s change in attitude from Phase 1 to Phase 2. For example, on page 111, in response to the probe (“Flying today is more challenging than ever”) four pilots changed their vote from “strongly agree” to “disagree,” a rather extreme change.

The top graph is similar to the other Likert plots that have been shown, except that two sets of data are included in each graph: Phase 1 and Phase 2. These plots give the reader a comparison of mean responses from the two phases.

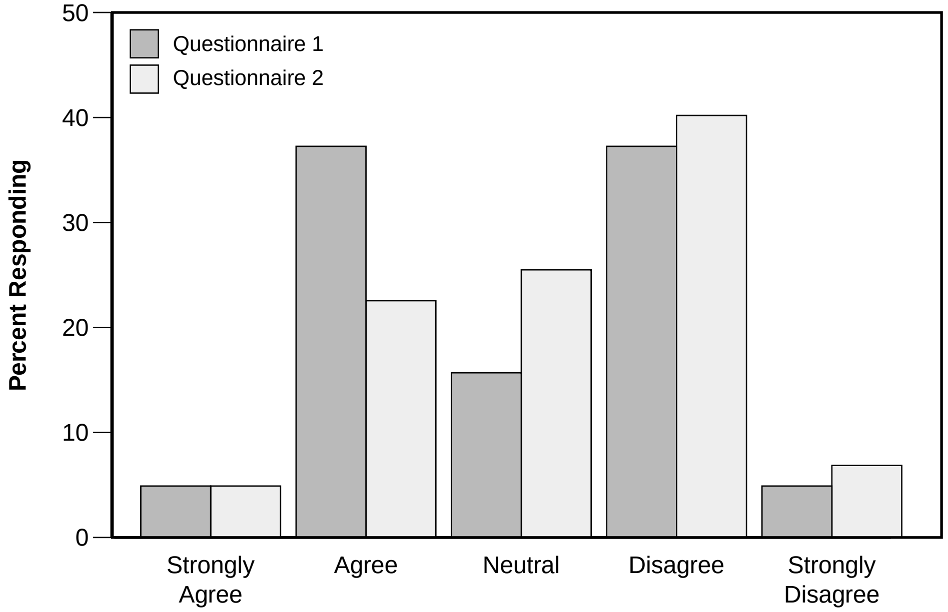
Probe 1:
“Flying today is more challenging than ever.”



		Phase 2					
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Row Total**
Phase 1	**Strongly Agree**	**15**	9	1	4		**29**
	Agree	6	**21**	6	8		**41**
	Neutral	1	8	**8**	4		**21**
	Disagree		1	3	**6**		**10**
	Strongly Disagree				1	**0**	**1**
	Column Total	**22**	**39**	**18**	**23**	**0**	**102**

Source: U.S. National Aeronautics and Space Administration

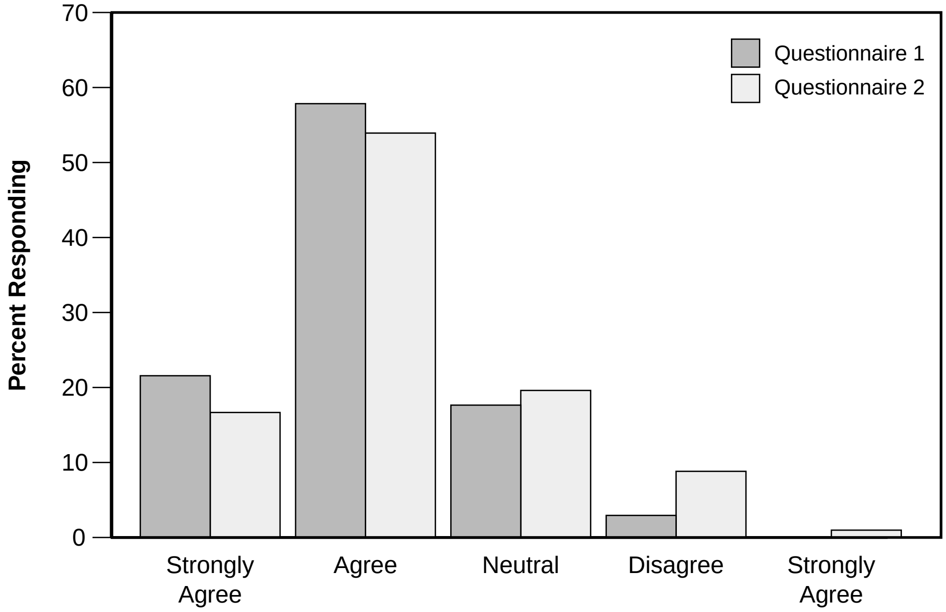
Probe 2:
“I am concerned that automation will cause me to lose my flying skills.”



		Phase 2					
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Row Total**
Phase 1	**Strongly Agree**	**0**	2	1	2		**5**
	Agree	4	**16**	12	6		**38**
	Neutral	1	4	**4**	7		**16**
	Disagree		1	9	**24**	4	**38**
	Strongly Disagree				2	**3**	**5**
	Column Total	**5**	**23**	**26**	**41**	**7**	**102**

Source: U.S. National Aeronautics and Space Administration

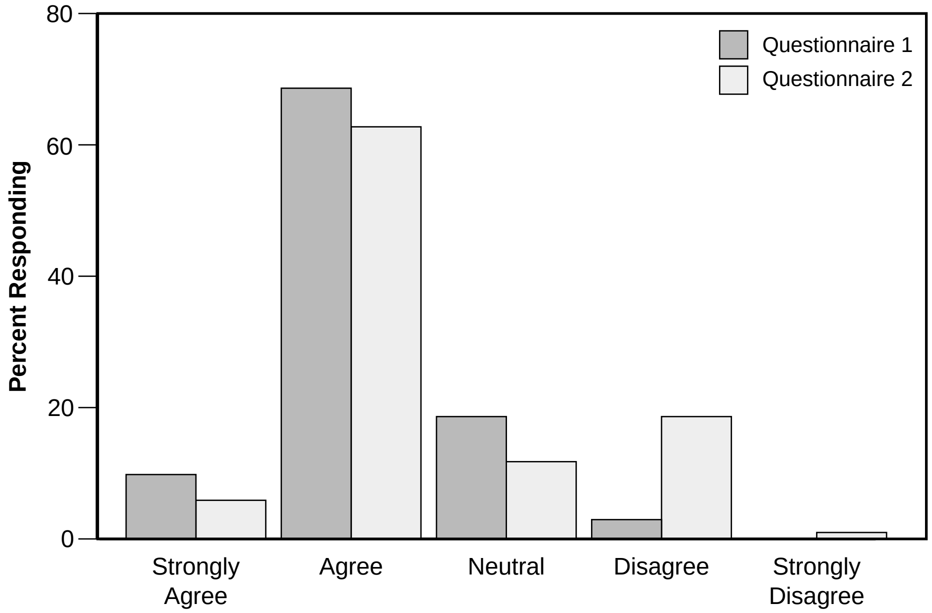
Probe 3:
“Automation leads to more efficient, safer operations.”



		Phase 2					
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Row Total**
Phase 1	**Strongly Agree**	**7**	11	3	1		**22**
	Agree	10	**37**	9	3		**59**
	Neutral		7	**7**	4		**18**
	Disagree			1	**1**	1	**3**
	Strongly Disagree					**0**	**0**
	Column Total	**17**	**55**	**20**	**9**	**1**	**102**

Source: U.S. National Aeronautics and Space Administration

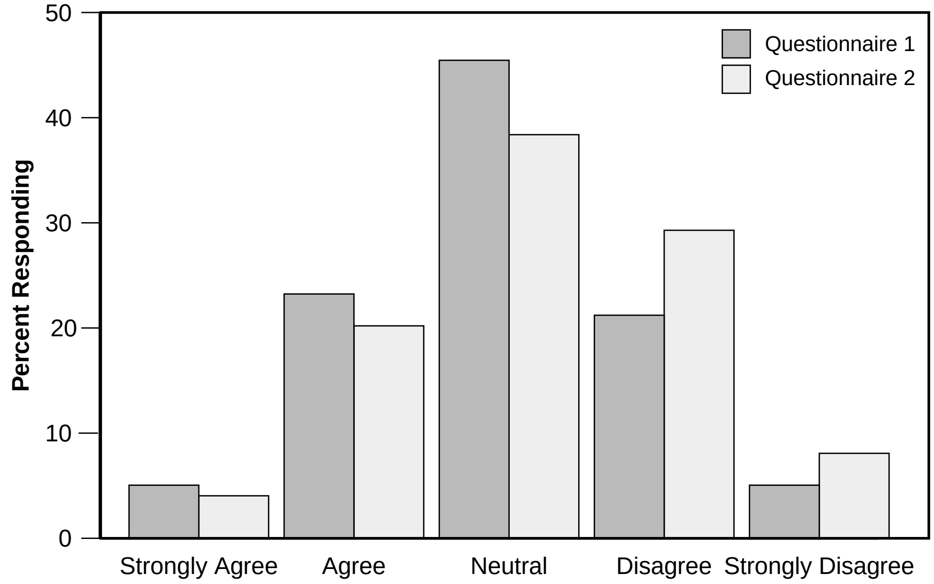
Probe 7:
“In the aircraft I am presently flying, it is easy for the captain to monitor and supervise the first officer.”



				Phase 2			
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Row Total**
Phase 1	**Strongly Agree**	**4**	5	1			**10**
	Agree	2	**49**	7	11	1	**70**
	Neutral		8	**4**	7		**19**
	Disagree		2		**1**		**3**
	Strongly Disagree					**0**	**0**
	Column Total	**6**	**64**	**12**	**19**	**1**	**102**

Source: U.S. National Aeronautics and Space Administration

Probe 11:
“I look forward to automation — the more the better.”

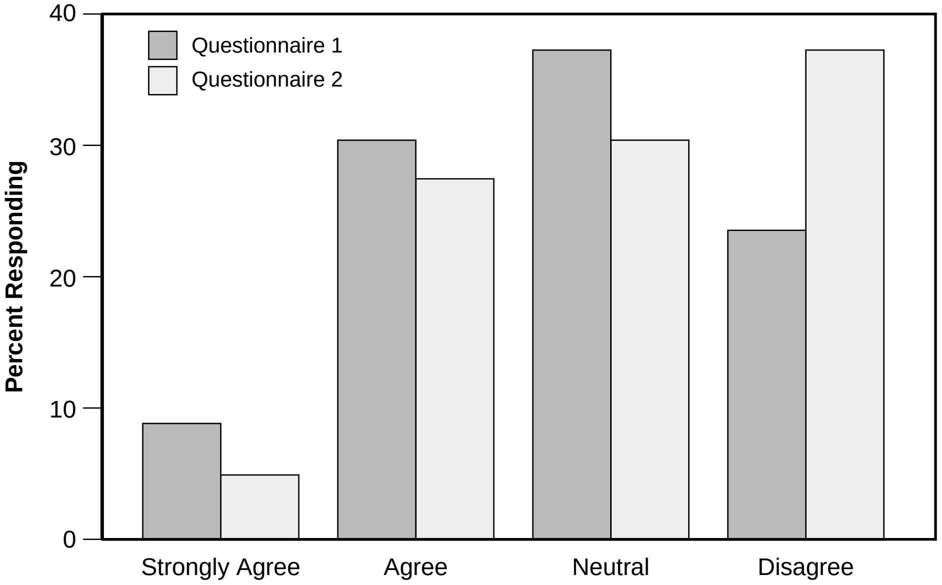


Phase 2

Phase 1	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Row Total
Strongly Agree	**2**	2	1			**5**
Agree	1	**11**	9	2		**23**
Neutral	1	6	**23**	13	2	**45**
Disagree		1	4	**13**	3	**21**
Strongly Disagree			1	1	**3**	**5**
Column Total	**4**	**20**	**38**	**29**	**8**	**99**

Source: U.S. National Aeronautics and Space Administration

Probe 13.:
"There is too much workload below 10,000 feet and in the terminal area."

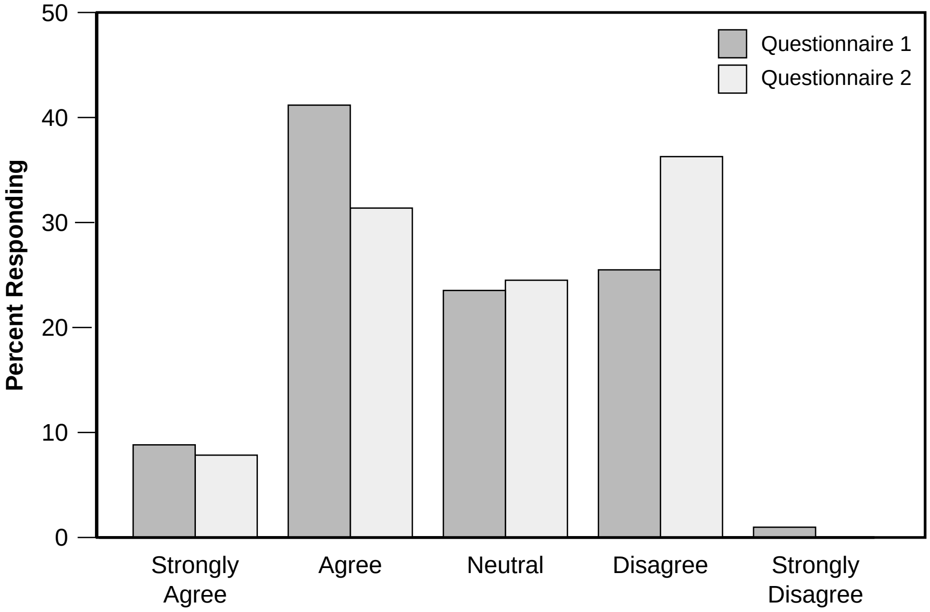


Phase 2

Phase 1	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Row Total
Strongly Agree	**1**	7		1		**9**
Agree	3	**15**	8	5		**31**
Neutral	1	5	**16**	16		**38**
Disagree		1	7	**16**		**24**
Strongly Disagree					**0**	**0**
Column Total	**5**	**28**	**31**	**38**	**0**	**102**

Source: U.S. National Aeronautics and Space Administration

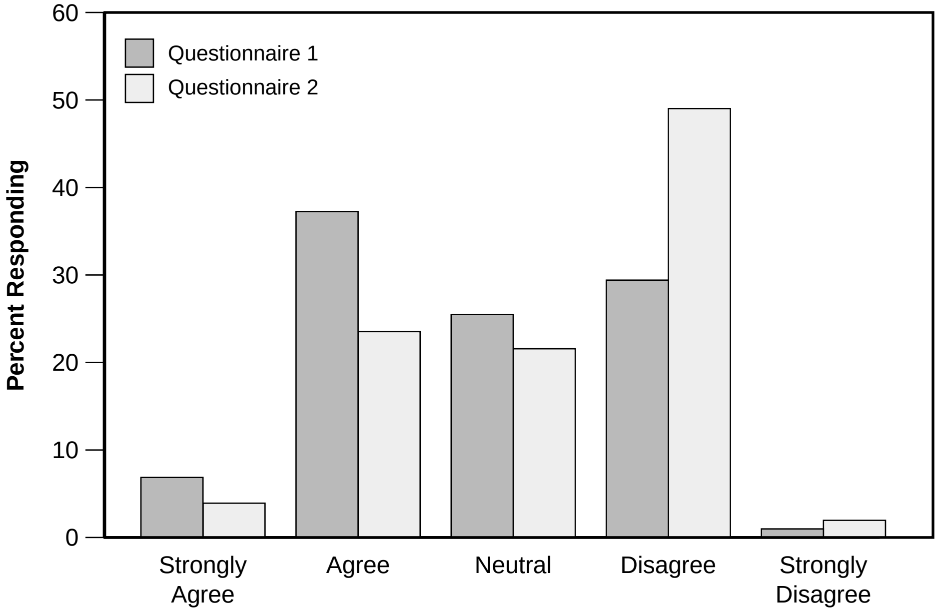
Probe 15:
"It is easy to bust an altitude in today's environment."



		Phase 2					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Row Total
Phase 1	**Strongly Agree**	**4**	4	1			**9**
	Agree	4	**18**	11	9		**42**
	Neutral		5	**6**	13		**24**
	Disagree		5	7	**14**		**26**
	Strongly Disagree				1	**0**	**1**
	Column Total	**8**	**32**	**25**	**37**	**0**	**102**

Source: U.S. National Aeronautics and Space Administration

Probe 17:
“I am concerned about the lack of time to look outside the cockpit for other aircraft.”



		Phase 2					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Row Total
Phase 1	**Strongly Agree**	**1**	4	1	1		**7**
	Agree	2	**14**	9	13		**38**
	Neutral	1	5	**7**	12	1	**26**
	Disagree		1	5	**23**	1	**30**
	Strongly Disagree				1	**0**	**1**
	Column Total	**4**	**24**	**22**	**50**	**2**	**102**

Source: U.S. National Aeronautics and Space Administration

Appendix D

Questionnaire Forms — Q1, Q2 and Q3

The following pages contain the three questionnaire forms (known as Q1, Q2 and Q3), from the three phases of the study (P1, P2, and P3). For brevity, the three are not shown in their entirety, since there is considerable repetition of attitude probes lists and answer forms, as well as repetition in Q2 and Q3 of open-ended questions.

NASA/CAL Questionnaire No. 1

Date you started 757 transition: ____ ____ ____
MM DD YR

Name ______________________________ Capt., F/O, S/O ____________________

Home Address ____

City ____

State ______________________________ ZIP ____________________

Present Base ______________________________ Base after 757 transition ____________________

Home Phone: Area Code and number: (   ) ____________________

Make up an ID code for yourself and enter it below. Use any combination of letters and numbers (up to a max of 6). Do not use your Social Security or company pay number, birth date, etc. Insert it in the blank below. The characters in the last two positions are reserved for our purposes. The full eight characters make up your ID (e.g., ELW86815). If you use less than six characters, still include the last two (e.g., TOM415).

The red sticker is for you to keep a record of your ID. Please enter your full ID as written below onto the red tag and keep it some convenient place. We suggest a log book or Jep manual. If you have questions, please call the project director or your IACP Safety Committee. Remove and keep the red tag. It's yours!

Informed consent:

I have read and understood the material in the attached booklet, including the purpose and method of the study, and I consent to serve as a volunteer pilot.

Signed: ______________________________

ID Code: __ __ __ __ __ __ 1 5

I. Biographic Data and Aircraft Experience

This is our first effort to collect some information from you about your attitudes toward cockpit technology and your experiences. First we need some information about you, and about your flight experience.

1. Your present age to closest month:______ years _______ months

2. Gender (circle one): M F

3. We would like to know your past experience in CAL turbojet aircraft. Please consider your experience **only at CAL**. Place an "X" in the box for each seat on each aircraft that you have ever flown at CAL. **Do not put flying time**.

Aircraft	**Seat**		
	Captain	**F/O**	**S/O**
DC-9			______
MD-80			______
B-737-100/200			______
B-737-300			______
B-727			
A-300			
B-707/720			
DC-10			
B-747			

4. Which seat in which aircraft did you occupy immediately before going to 757 transition. If it is a B-737, please state model. How many months had you been in this seat?

   Aircraft _____________ Seat _________________Months _____________

5. Approximate total flying hours **at CAL** (include S/O)

   ______________ hours

6. Approximate total flying hours, all aircraft (airline, military, general aviation etc.)

   ______________ hours

7. When did you attend, or when do you plan to attend B-757 transition training?

   Month _________Year _________

8. List in the space below any glass cockpit (EFIS) aircraft that you have flown (airline, commuter, military, corporate)

9. What do you consider the most advanced aircraft (with respect to instrumentation, avionics, automation etc.) that you have flown? Include military or other employers:

   Answer: ________________________________

10. Do you use a personal computer at home? (Y/N) Ans: _________

11. If yes, when you are at home, how often do you use it? (check one)

Daily ____ Several times a week ____ Less than weekly ____

12. Approximately how many actual Cat II approaches did you make (as PF or PNF) last calendar year? Autolands?

Cat II ________ Autolands __________

13. Approximately how many non-precision approaches (as PF or PNF) did you make last calendar year?

VOR_________ LOC ________ ADF ________

14. If the money and quality of trips were all the same, and base assignment were not a factor, what would be your first choice of plane to fly in CAL's fleet? (Include B-737-500 and B-757 as present fleet.)

Aircraft: ________________________________

II. Attitude-Toward-Automation Scale

This is a 20-item attitude scale. It is called an "intensity scale" because you can indicate not only your agreement or disagreement with the statements, but the extent to which you agree/disagree. Note that the statements can be positively or negatively stated. The scale is straight-forward — there is no attempt to be "tricky." The next page is the answer sheet .

Answer all questions based on your present experience and opinions with CAL aircraft. For the purpose of these questions, consider the word "automation" to mean autopilots, autothrottles, flight directors, etc., as well as the more advanced flight guidance and controls that you are familiar with.

1. Flying today is more challenging than ever.

2. I am concerned that automation will cause me to lose my flying skills.

3. Automation leads to more efficient, safer operations.

4. It is important to me to fly the most modern plane in my company's fleet.

5. As I look at aircraft today, I think they've gone too far with automation.

6. Automated cockpits require more cross-checking of crewmembers' actions.

7. In the aircraft I am presently flying, it is easy for the captain to monitor and supervise the first officer.

8. I am very apprehensive about going through this transition.

9. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "managing" the flight.

10. I am not concerned about making errors, as long as we follow procedures and checklists.

11. I look forward to more automation — the more the better.

12. I have no trouble staying "ahead of the plane."

13. There is too much workload below 10,000 feet and in terminal areas.

14. Automation does not reduce total workload.

15. It is easy to bust an altitude in today's environment.

16. I am concerned about the reliability of some of the automation equipment.

17. I am concerned about the lack of time to look outside the cockpit for other aircraft.

18. CAL’s CRM training has been helpful to me.

19. Sometimes I feel more like a “button pusher” than a pilot.

20. I regularly maintain flying proficiency by turning off automation and hand flying.

Attitudes-Toward-Automation Answer Form

Referring to the 20 statements, place an “X” in the box that best represents your feeling about the statement. Answer quickly — your first impression is the best. Be sure that you respond to all 20 statements.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

NASA/Continental Human Factors Project

Questionnaire No. 2

Project ID Code *

						1	5

* If you have forgotten your project ID code, please write your name on the top of the page — we will remove it and write in your ID code, and send you the code.

This is the second in the series of NASA questionnaires. Please fill it out and return it to us in the enclosed envelope. You should receive the next one about a year from now. We will take a random sample of our volunteer pilots for face-to-face interviews in Houston and may see you then. Again, our thanks for participating in the study.

Note that the questionnaire has three parts.

1. Some information about your present status (on this page).

2. A 24-item questionnaire on your attitude toward automation.

3. Four open-ended questions where we ask you to give us some answers in your own words.

Total flying time in B-757: _______ hours. Current base: ________

Following your training and IOE, were you assigned to your former plane, or the 757?

______________ 757 Former plane, which was _______________

If it was former plane, how long was it before you returned to 757? ______ months

If it was the former plane, did you experience any problems when you returned to the 757?

_____ No _____ Yes (please describe)

Open-ended Questions — Q2 and Q3

Please answer the following questions. If you need more space, please write on the back of the page.

---

1. What did you think of your training for the 757? Did you have trouble with anything? What topics should receive more or less emphasis? Please comment on the training aids and devices.

2. Describe in detail an error which you have made, or have seen someone else make, with the automation, that might have led to some undesirable consequence. How could it have been avoided? (equipment design, training, CRM, procedures?)

3. What can you say about crew coordination and procedures in the 757? In what way are they different from previous planes you have flown? What areas can use improvement?

4. How would you compare the overall workload in the 757 compared to your previous plane? Please mention anything that you feel should be changed to help you manage workload (procedures, ATC, training, etc.).

The first four questions were repeated on Questionnaire 3, and the following two were added:

5. Please tell us your strategy for selecting the various HSI modes. Do you always use the map mode? For what maneuvers, if at all, do you use the compass rose mode? The expanded VOR or ILS mode?

Can you also give us an estimate of the percent time for each?

Map ______ Expanded ILS ______ Expanded VOR _______ Rose _______

Question is not open-ended. It was added at the request of the 757 fleet manager.

6. Note: this question for those who have left the 757.

After you left the 757 and went to another aircraft, what was your reaction? What did you miss about the 757 avionics and automation? What did you like better about the older technology plane? Why did you bid off of the 757?

Plane and seat you went to: Aircraft _______ Seat ________

Additional Attitude Probes on Questionnaires 2 and 3

Four attitude probes that were not appropriate for Q1 were added to Q2 and Q3. The attitude probes on Q2 and Q3 were identical.

Additional Probes:

21. The 757 works great in today's ATC environment.

22. Training for the 757 was as adequate as any training that I have had.

23. Electronic flight instruments ("glass cockpits") are a big advance for flight safety.

24. There are still modes and features of the 757 automation that I do not understand.

NASA/CAL Human Factors Project

Questionnaire No. 3

Project ID Code *

						1	5

* If you have forgotten your ID code, please write your name on the top of this page — we will remove it and write in your ID code, and send you the code.

This is the third and final in the series of NASA questionnaires in this project. Please fill it out and return it to us in the enclosed envelope. Again, our thanks for participating in the study.

Note that the questionnaire has three parts.

I. Some information about your present status (on this page).

II. A 24-item questionnaire on your attitude toward automation.

III. Some open-ended questions where we ask you to give us some answers in your own words. There is a special question for those of you who have left the 757 for another aircraft.

I.

Current aircraft and seat: Aircraft ___________ Seat __________

Total flying time B-757: ________ hours. Current base: _________

Do you "feel comfortable" in the 757 now? Yes ____ No _____

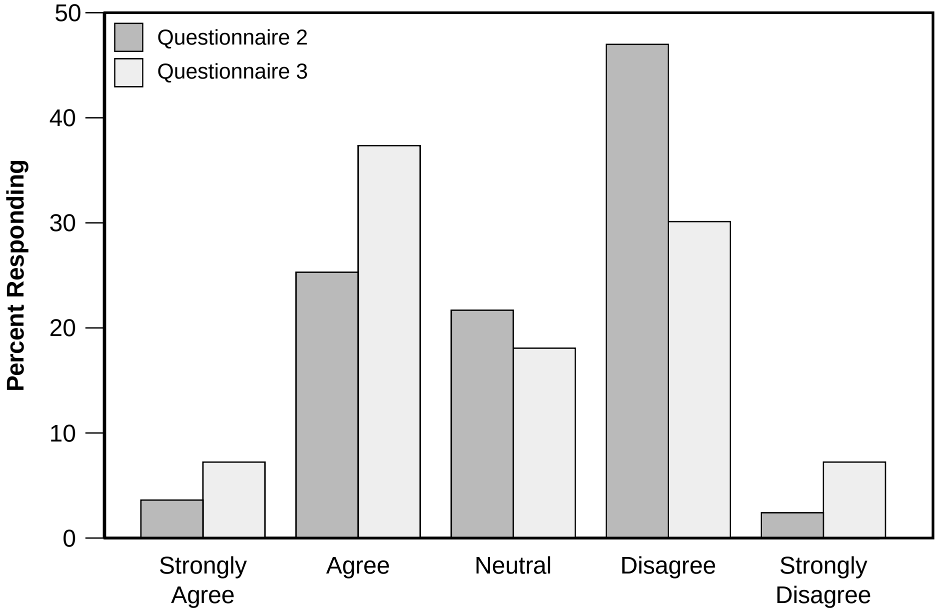
If yes, how long after you went on the line did it take? _________ months:

Appendix E

Marginal Homogeneity Tests: Q2 vs. Q3

For explanations, see page 111.

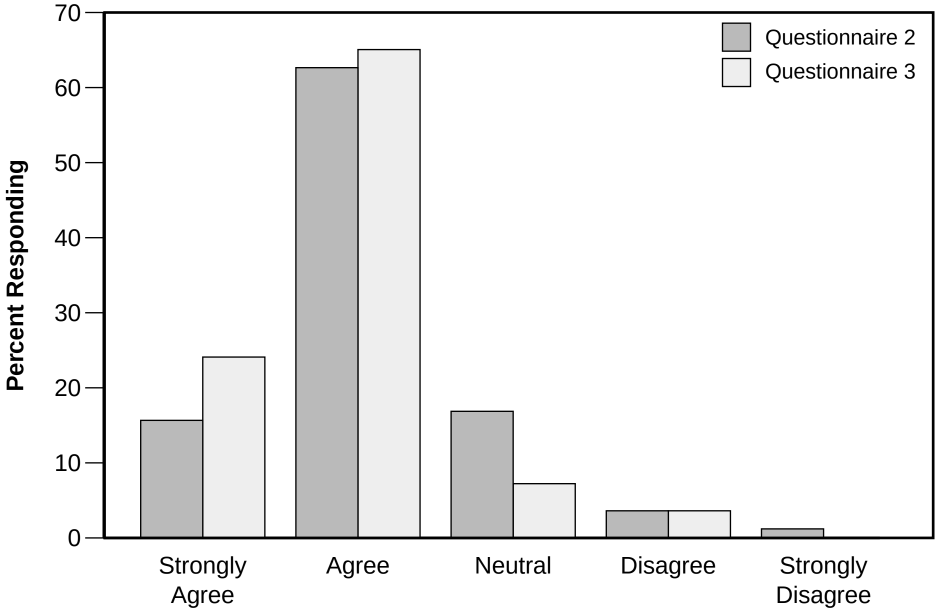
Probe 17:
"I am concerned about the lack of time to look outside the cockpit for other aircraft."



				Phase 3			
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Row Total**
Phase 2	**Strongly Agree**	**1**	2				**3**
	Agree	3	**12**	6			**21**
	Neutral	1	5	**6**	6		**18**
	Disagree	1	12	3	**18**	5	**39**
	Strongly Disagree				1	**1**	**2**
	Column Total	**6**	**31**	**15**	**25**	**6**	**83**

Source: U.S. National Aeronautics and Space Administration

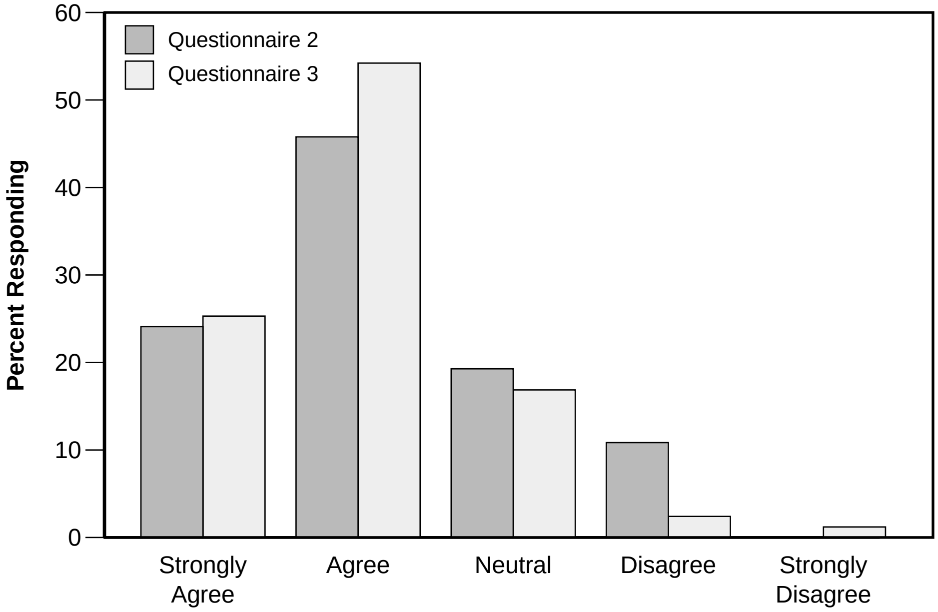
Probe 18:
"Continental's CRM training has been helpful to me."



		Phase 3					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Row Total
Phase 2	**Strongly Agree**	**10**	3				**13**
	Agree	9	**41**	1	1		**52**
	Neutral		8	**5**	1		**14**
	Disagree	1	2		**0**		**3**
	Strongly Disagree				1	**0**	**1**
	Column Total	**20**	**54**	**6**	**3**	**0**	**83**

Source: U.S. National Aeronautics and Space Administration

Probe 23:
"Electronic flight instruments ('glass cockpits') are a big advance for flight safety."

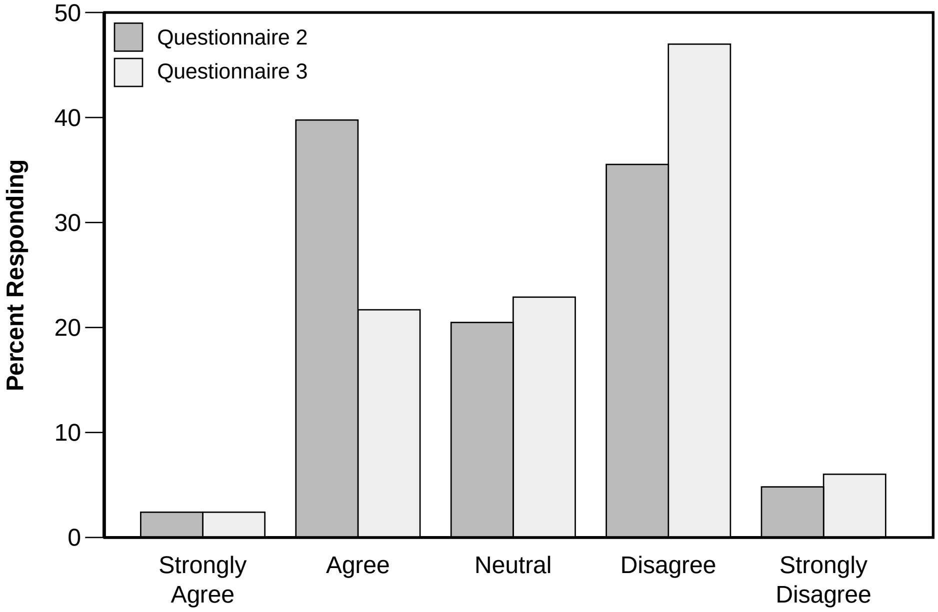


Phase 3

Phase 2	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Row Total
Strongly Agree	**13**	6	1			**20**
Agree	6	**29**	3			**38**
Neutral	1	8	**6**	1		**16**
Disagree	1	2	4	**1**	1	**9**
Strongly Disagree					**0**	**0**
Column Total	**21**	**45**	**14**	**2**	**1**	**83**

Source: U.S. National Aeronautics and Space Administration

Probe 24.:
“There are still modes and features of the 757 automation that I do not understand.”



		Phase 3					
		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Row Total**
Phase 2	**Strongly Agree**	**1**	1				**2**
	Agree	1	**10**	9	12	1	**33**
	Neutral		6	**5**	6		**17**
	Disagree		1	4	**21**	1	**27**
	Strongly Disagree			1		**3**	**4**
	Column Total	**2**	**18**	**19**	**39**	**5**	**83**

Source: U.S. National Aeronautics and Space Administration

Appendix F

Continental's Automation Philosophy Statements

CAL's Automation Philosophy Statement (1994)

The purpose of enhanced autoflight and flight guidance systems in our current and future generation of aircraft is to improve precision and reduce workload.

The pilot must be well versed in utilizing the full capabilities of the automated systems in the aircraft. Standard operating procedures for each aircraft have been developed to establish conventional methods for utilizing automated functions in any given phase of flight. However, it is ultimately up to the judgment of the pilot as to how the automation is employed.

If an automated function improves precision and/or reduces workload in a given situation, then its use may be desirable. If an automated function does not complement the situation, the use of a more basic mode displays good judgment.

CAL expects its pilots to match the level of automation to the flight dynamics of the moment. Automated functions are tools. The pilot's judgment is the master of those tools. If automation helps, use it. If it hinders, go back to basics. Match the resource to the situation.

Automation Committee's Recommended Format

The Automation Committee recommended a more graphic format, so that the levels stood out in their relative vertical position in the automation-to-manual stack. This design was never adopted.

CAL's goal for automation is to increase safety and efficiency, and improve situational awareness, while reducing pilot workload. Pilots must be proficient in all capabilities of their aircraft including the automated systems and must use their judgment as to how those systems are employed. Standard operating procedures for use of automated features have been developed for each of CAL's fleets and may be found in respective flight manuals.

Levels of Automation

I	Hand Flown	Raw Data
II	Hand Flown	Flight Guidance
III	Autopilot/Autothrottle	Flight Guidance
IV	LNAV/VNAV	Flight Guidance

Flight Operations Manual Version (rev. 1998)

This version is included in all flight operations manuals (FOMs):

The goal of automation in our aircraft centers around safety and efficiency. The purpose of enhanced autoflight and flight guidance systems in our current and future generation of aircraft is to improve precision, reduce workload, and contribute to situational awareness.

The pilot must be proficient in utilizing all capabilities of the systems in the aircraft from the most basic hand flown mode to the full use of the aircraft's most automated function. Standard operating procedures for each aircraft have been developed to established conventional methods for utilizing automated functions in any given phase of flight. However, it is ultimately up to the judgment of the pilot as to how automation is employed.

The third and fourth paragraphs are the same as in the 1994 philosophy statement.

Appendix G

Continental Human-centered Automation Training (H-CAT)

Simulator Check Airmen CRM Briefing Outline (proficiency check [PC]/recurrent training [RT]/LOFT)

Standardized Briefing Guidelines

The following outline will be incorporated into all simulator PCs, RTs and LOFTS. The intent is to:

1. Inform crews of the recent increase in incidents that have occurred in the past 12 months and the resulting FAA surveillance program.
2. Heighten the emphasis on crew resource management throughout the airline.
3. Elevate CRM from a "nice to know" to a "need to know" status.
4. Ensure that pilots are routinely exposed to a baseline of standard CRM briefing items.
5. Introduce CRM elements and outline the role they play in all facets of our operation.
6. Enhance the uniformity of training, i.e., take one step closer to seamless training.

It is extremely important to include the entire crew in the CRM brief. Instructors working with three-man crews will present the CRM brief before splitting up to discuss particular PC or RT maneuvers. Active participation by all crewmembers is critical to the success of the program. Utilization of facilitation and reverse briefing techniques is encouraged wherever possible.

Reference: *Enhancing Flightdeck Safety*. CAL Quarterly Standards Meeting, April 14, 1994.

Appendix H

A Sample of U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) Reports on Automation and Training

1. At approx 90 miles south of SNS on J88 given FL240. Approx 50 miles south of SNS given clearance to cross 55 miles south of SJC VOR at or below 17000', 25 miles south of SJC VOR at and maintain 8000'. F/O at this time figure new waypoints to make these restrictions and entered them into CDU. Aircraft started to descend automatically following instructions given from FMC. Approx SNS VOR, OAK Center asked what our altitude was. At that point we were going through 22000, way above our clearance of at or below 17000' 55 south of SJC. During this narrative with ATC the aircraft started to turn left and manually turned back toward GILRO intersection. Cause of altitude incursion: descend waypoints entered into computer at wrong spot on legs page. Circumstances: Captain checked on aircraft two months prior to flight. No flight time given in aircraft. Deemed qualified in aircraft by FAA standards. First flight in aircraft since checkout. PC check in simulator next day. F/O had approx 1000 hours in aircraft. Was not aware of mistake in waypoint insertion in FMC due to lack of experience in aircraft. Conclusion: FAA deems pilot qualified on aircraft A model with short course on differences between aircraft B. No recent experience qualifications. This aircraft is not the same. The aircraft in question should have a distinct type rating for a pilot to be considered qualified. Along with this the currency requirements. At present, once a pilot completes differences training, he is considered qualified. He might not fly the aircraft for a year or more but still be deemed qualified by the FAA. Recommendation: separate type rating for this aircraft and the associated training and currency requirements. [Supplemental information from Accession Number: 71794.] We missed the crossing restriction by 5000'. I believe we began the descent too late and to complicate the situation further, the computer was programmed incorrectly for the crossing restriction. I also feel an experienced Captain would have caught the discrepancy between the VHF navigation DME and the information given by the computer. (Accession Number: 71850)

2. Experienced failure of one flight management computer (FMC) and had requested clearance toward Boston and started in that direction. We then contacted Dispatch to find out if they wanted the aircraft at BOS or JFK to replace the failed FMC. We knew that if one FMC failed prior to the oceanic gateway, we had to land. But Dispatch had another answer, and that was that the flight was legal to continue. They mentioned another flight had the same problem a few nights earlier, and our event was even agreed to by our maintenance people in Tulsa. They both concurred the MEL requirement for 2 FMC's for extended range (ER) operations was for dispatch purposes only. So we proceeded across to Paris. We looked in the operating manual, Pilot Operating Handbook, MEL, and could not find any requirement to land if one FMC failed prior to the oceanic gateway. Upon arrival at DFW from Paris a few days later, we were met by a flight manager who pointed out the references as to the fact that we should have landed. But they were not in the abnormal procedures section, as they should have been, but buried in the normal section where we did not look for a problem. This procedure has now been moved to the proper section, and the MEL will be changed to reflect this. Dispatch and maintenance have been corrected on this matter. Contributing to this incident is the fact that the international ground school can lead you to believe that the aircraft has 3 long range navigation systems. When in fact you only have two. Three inertial reference systems (IRS) and 1 FMC equals 1 long range navigation system. Those same 3 IRS's and the other FMC equals the other long range navigation system. Failure of either FMC brings you down to one long range navigation system. This is not emphasized in the ground schools as we are so used to flying with 3 INS, or Omega systems. I am going to recommend that this be emphasized in the schools. (Accession Number: 75956)

3. Our medium-large-transport (non-EFIS) was cleared: 'MUSEC 4 departure, TRM transition at or below 3000 ft until 6 DME, maintain 4000', expect FL370 after 10 minutes.' We set up the cockpit and briefed the departure in accordance with our company operations manual for the Santa Ana noise abatement 'normal cutback' procedure. Distractions were as follows: New captain (first non-checkride line departure from Santa Ana), new first-officer (first line trip ever), no APU (requiring airstart at gate, and decision from captain to perform noise abatement procedure bleeds on (normally it is bled off, with APU for pressurization), unfamiliar aircraft (neither of us had much time in the non-EFIS medium-large-transport), unfamiliar clearance (specifically the 'below 3 until 6 DME' part). Our company procedure calls for a maximum performance takeoff, flaps 15 degrees (normally reduced thrust, flaps 5), 28 degree nose up body angle to 1000 ft, then a radical thrust reduction, simultaneous flap retraction to 5 degrees, and a shallow climb at 1 / 2+15 to 6 DME, on autopilot (vertical speed mode +200 fpm, engaged after thrust cutback). It is a challenging procedure even with practice, but for 2 new

guys, no APU, new cockpit ... it starts to add up. Now consider the very heavy GA activity at and around Santa Ana on a Sat, and you start to get the picture of the scene in this flight deck. I made the takeoff and cutback (to 77.6 % N1 based on an extremely light weight of 88000 lbs) and attempted to engage the autopilot at 1000 ft as per procedure. Rate of climb at this point was well in excess of 6000 fpm (VSI needle pegged). At that moment, we were handed off to departure by ATC, and advised to watch for VFR traffic 12 o'clock at 3000 ft (typical). I lowered the nose and told my first-officer to ' stay outside and keep your eyes open.' The autopilot would not engage, and in the 2–3 secs I spent trying to figure it out (unfamiliar cockpit), the altitude horn went off. I thought it was the first alert (2000 for 3000 ft), but in the initial climb we both missed that one, and it was the second alert (you blew it!). We were at 3300 ft and our ballistic path carried us to 3500' at about 4.5 DME. I briskly lowered the nose and reduced thrust. ATC asked, 'what was your assigned altitude?' My first-officer replied ' 3000 ft..' I added, 'We 're correcting.' ATC answered crisply, 'Roger.' He then cleared us to 13000 ft, and advised us again of Traffic 12 o'clock, 3 miles, northbound along the coast at 3000 ft. In my opinion the Santa Ana noise abatement procedures are an extreme menace to aviation safety and should be abandoned at once. This flight had all the necessary ingredients for disaster: new crew (both captain and first-officer), new aircraft (in the fleet for quite some time but both pilots relatively unfamiliar), radical, one-of-a-kind, maximum performance, totally nonstandard departure procedures (well practiced in simulator, but done only once before by captain on company line check), heavy GA traffic, extremely busy flight deck, high deck angle (28 degrees) making see and avoid a complete farce, unfamiliar departure clearance. I strongly recommend the following actions: a thorough review of all non-FAA imposed noise abatement regulations and procedures. A spotlight on Santa Ana in particular (that airport is an accident waiting to happen, ground operations ramp, are just simply crazy). Scheduling guidelines that preclude the new captain/new first-officer scenario any time the flight is into severe weather or into particularly difficult airports. Standardization of airline cockpits, or assignment of flight deck crew to only one variant (medium-large-transport A or medium-large-transport B or medium-large-transport B EFIS only). Advising ATC to simplify departure clearances as much as possible at all times, but particularly when extra conditions (weather noise abatement rules, etc.) are imposed. (Accession Number: 99595)

4. We were cleared to cross 40 nautical miles west of LINDEN VOR to maintain FL270. The captain and I began discussing the best method to program the CDU to allow the performance management system to descend the aircraft. We had a difference of opinion on how to best accomplish this task (since we are trained to use all possible on-board performance systems). We wanted to use the aircraft's capabilities to its fullest. As a result, a late descent was started using conventional autopilot capabilities (vertical speed, max indicated mach/airspeed and speed brakes). Near the end of descent, the aircraft was descending at 340 kias and 6000' fpm rate of descent. The aircraft crossed the fix approx 250–500' high. Unfortunately, we made no call to ATC to advise them of the possibility of not meeting the required altitude/fix. This possible altitude excursion resulted because: 1) Captain and F/O had differences of opinion on how to program the descent. 2) Both thought their method was best: the captain's of programming (fooling) the computer to believe anti-ice would be used during descent, which starts the descent earlier; the F/O's of subtracting 5 miles from the navigation fix and programming the computer to cross 5 miles prior to LINDEN at FL270. 3) A minor personality clash between the captain and F/O brought about by differences of opinion on general flying duties, techniques of flying and checklist discipline. 4) Time wasted by both Captain and F/O (especially F/O) in incorrectly programming CDU and FMS for descent, which obviously wasted time at level flight, which should have been used for descent. Observation: as a pilot for a large commercial carrier at its largest base, we seldom fly with the same cockpit crewmember. This normally does not create a problem. I do, however, feel that with the "new generation" glass cockpits being on the property approx 6 years; this can cause a bit more difficult transition than, say month to month cockpit crew change on a 727 or pre-EFIS DC-9. I have flown commercially for 10 years, and have flown 2-man crew aircraft for 8 of those 10. The toughest transition for me is to determine who shares PF and PNF duties. This historically (3 years) has been most difficult when the other crewmember has transferred from a 3-man cockpit to a 2-man "glass cockpit." This is especially pertinent when the crewmember has been on a 3-man crew aircraft for a # of years. As F/O, when you are the PNF, you accomplish your normal duties. However, often times when one is the PF, he also has to do the PNF duties because the other crewmember has not been used to doing PNF duties to the extent that it is required on 2-man cockpits, whether they be conventional or EFIS. This obviously can lead to a myriad of probs. Add weather problems or an airport such as Washington National, LGA or Orange county, and problems can accelerate with alarming rapidity. (Accession Number: 122778)

5. Situation: failure to make crossing restriction on Arrival route. The captain was flying and I was handling the radios and FMC work. After programming the ATC crossing restriction in the FMC we still had about 40 miles before reaching the fix. At this time, I told the captain that we were high on the profile and he acknowledged. I then began to prepare our landing data and complete the required company

communications. The captain took over ATC until I could complete my other duties. At some point during this process, I noticed that we were still high and I again said "we look high to me" and repeated the crossing restriction to the captain. He acknowledged and deployed the speed brakes. When I finished the landing data we had about 5 miles before reaching the restriction and I then realized there was no way we would make the crossing altitude. I told the captain and then informed ATC. One factor involved was the captain was new with only 35 hours on the narrow body/widebody. I have over a year on the widebody, but this was my first [narrow body] trip. While the narrow body/widebody are considered to be one "type" by the FAA and my company, they have many differences. One of these being performance, so when I thought we were high, we were really very high, and the action taken by the captain to correct the descent path, which I thought would be adequate, wasn't. Along with this, the training I received for the [narrow body] was inadequate. Ground school consisted of 6 hours of [narrow body] differences that was nothing more than "filling the squares" for the FAA. We didn't even have all of the [narrow body] revisions for our widebody manuals at the time, and there wasn't any required flight or simulator training for the first officers. Other factors include my distraction away from the descent profile in the form of company communication, preparation of the landing data and informing the cabin crew of our position so they could prepare the cabin for landing. At the time I thought I was still in the "loop" enough to be aware of what was going on, but obviously I wasn't. Also maybe if I had told the captain that it didn't look like we would make the crossing restriction instead of saying we looked high he might have made a greater effort to get down. (Note: after years of operating widebody aircraft, my company has just started adding the [narrow body] to the fleet). (Accession Number: 124072)

6. Departed SFO on runway 01L and tracked SFO 350 degree right per SID. Checked in with departure control per Tower. Departure Control cleared us to 210 degree heading and 4000 feet. F/O (PNF) misunderstood heading and a few seconds attention over the correct heading was taken by both pilots, the captain (PF) did not hear the new altitude and did not notice F/O reset altitude in mode control panel from previous cleared altitude of FL230. The aircraft was climbing at approx 4000 fpm and by the time altitude deviation was noticed by F/O an altitude of 4400 feet was momentarily attained before return to 4000'. 2 factors, I believe, underlie this deviation. The first is that this was my first trip in the aircraft since "shotgun." I am also new to the "glass cockpit" and feel that a certain amount of my attention is occupied in interpreting the glass cockpit instrument presentation, in this respect, I feel that having only had 4 simulator rides in training with the glass cockpit is insufficient, although it is FAA approved. This does not develop enough proficiency to apply in the real world with the multiplicity of contingencies that can and do occur. The second factor is that just prior to the altitude and heading clearance, I had called for an infrequently used but SOP autoflight function. This caused the F/O to stop and consider his response and thereby interrupt his "flow" during this busy time of aircraft configuration cleanup, frequency changes and reception of communications. My last remaining thought is that I should be more decisive during my preflight and brief the F/O more thoroughly on what to expect from me in the way of post takeoff procedures. (Accession Number: 125079)

7. While climbing after takeoff to 13,000' we "overshot" the assigned altitude by 500' (13,500) and immediately leveled back to 13,000. Related factors: both pilots type rated [narrow body] widebody. Both pilots initially trained on and experienced on widebody. [Narrow body] and widebody flown interchangeably by same crews. In that [narrow body] and widebody are common type rating, once having the initial check out in one no further aircraft checkout required for the other. It's possible for a legal [narrow body] crew to have never flown the aircraft and be assigned a revenue flight! This was my 4th leg in the [narrow body]. This was the captain's 1st! While it is extremely common [narrow body] to the widebody there are subtle differences that are distracting if it's your first encounter with the [narrow body]. In this case I missed my 1000' before level off call because I was distracted by either being assigned or mis-selecting the appropriate radio frequency. Keeping in mind that the light [narrow body] is climbing at 500 fpm. I'm not used to this. The captain surely wasn't. And for his first flight in the airplane to be climbing at 400 fpm in clouds and snow with copilot that is also new to the aircraft, is only stacking the deck against yourself. In essence I was "given" the job of "checking out the new guy" but I don't have enough experience in the [narrow body] to do this and watch everything else. I would most strongly urge that we return to the policy of sending a check airman with each Captain for a few legs. Let the new guy work out the kinks with someone on board that is trained, comfortable and familiar with watching the whole operation and the other pilot should the need arise. (Accession Number: 129814)

8. At cruise altitude captain went to restroom. Clearance was given to cross a fix at 19,000' and to change to another frequency. The frequency and 18,000 were read back. At this time the captain returned to the cockpit. The changeover freq. was dialed in but the new controller was not contacted. With the help of the captain the crossing restriction was loaded in the FMC and it was determined that speed brakes were needed to make the

restriction. On level off at 18,000 we were told to return to 19,000 and contact the controller as originally instructed. We were in VFR conditions and were informed by the controller that no other aircraft were in the area at 18,000. The F/O just completed IOE on the [wide body] and was an engineer for 4 1/2 years prior to this. I feel that an instructional tape describing dos and don'ts of 2-man crew everyday operation might have some assistance for a crewmember transition from a 3-man crew. (Accession Number: 132083)

9. Check airman in right seat of glass cockpit aircraft, instructing on Captain's IOE, was trying to maximize instruction time in all phases of flight. During later stages of descent, discussing descent in VNAV and other modes, ATC issued a clearance to cross SEAGO waypoint at 11000 ft and 250 knots. Shortly thereafter, we received an off course vector and, after another brief period, a vector to intercept the Arrivals route. Check airman, as PF, did not arm LNAV for the intercept as it was close to 90 degrees, which would result in a rapid course capture and a more radical turn than one might wish. The plan was to turn to intercept using heading mode and capture LNAV when closer to track. Further discussion about the aircraft distracted both pilots and they flew through the Arrivals route. The vectors had also interrupted the descent profile. The ATC controller called to ask whether we intended to intercept and with this 'wake up' call we did reverse and intercept, abeam SEAGO descending through 13000 ft. Instructing in the niceties of the aircraft had taken our attention from the business of flying the clearance. After landing on the west side of DFW, we were cleared to cross the inbound parallel runway, cross a bridge and contact ground control on freq. xxxx. We crossed the runway, crossed the bridge, but check airman got busy again and didn't call ground control until about half way to a distant gate. Fortunately, this was a low traffic period and there were no apparent conflicts. The moral is obvious: pay attention to the business at hand. The luxury of the third crewmember is no longer available in recent aircraft (excepting long haul) and more diligence is required of both pilots. It is much too easy, and not uncommon, for instructors to become involved in extolling the virtues of 'gee whiz' airplanes versus 'no whiz' ones and not devote the necessary attention to precise operation. (Accession Number: 184917)

10. Aircraft was discovered off course to the north. A turn south was made. Shortly thereafter, I checked the 'cross-track' on #2 INS and found it to be 20 miles left. I would estimate total off course error was 25–30 miles. Intending course at the time was westbound from 57 degrees north 30 degrees west to 55 degrees north 40 degrees west. Autopilot was discovered to have defaulted from 'nav' mode to 'heading' mode. Heading bug was set approx 30 degrees right of intended course. Aircraft was plotted on course at a position of approx 56 degrees 40 min north 32 degrees 00 west about 10 mins prior to incident. Autopilot will default from 'nav' to 'heading' during a course transfer on EFIS course/heading panel, but this function wasn't accomplished, so I have no idea how autopilot got to heading mode. Normal procedure calls for one INS to remain in 'course' page for a readout of track error (distance from track centerline) I was conducting IOE training at the time and going over various functions of both INS units; catalogs, data pages, etc., so neither INS was in course page. On analog type aircraft HSI needle would be full-scale deflection before being 10 miles off course. On EFIS presentation in 'map' mode and 600 miles scale 20 miles off course is hardly noticeable. My flight director was showing a command to turn left, but this is not unusual when the opposite side INS is controlling the autopilot. On analog aircraft if the autopilot defaults from 'aux nav' (INS controlling autopilot) it goes to 'turn nob' — which maintains current heading. On EFIS aircraft a default goes to 'heading' which, depending on bug setting, can cause a rapid departure from intended course, as happened to us. I believe increasing crew awareness to the fact that an 'off-course' situation will not be displayed in the same dramatic fashion on EFIS aircraft as on analog type displays is important. I also believe crews transitioning to EFIS equip should be aware of the importance of scanning ADI nav mode displays which show what is controlling the autopilot. My own inexperience on EFIS aircraft (approx 100 hours) contributed to this incident. (Accession Number: 223697)

11. I was on the first leg of my IOE on a widebody. (My first flight of the aircraft.) The flight was LAX/ATL. As we began the Rome Arrival, ATC asked us to cross 50 northwest of Rome at FL290, descend to FL240. I tried unsuccessfully to enter the restriction in the FMS. After 3 attempts, the captain tried unsuccessfully and tried to explain why it wouldn't take it. Meanwhile, no descent was started. Captain said 'just descend manually, I'm going for the ATIS.' However I descended, it wasn't fast enough, especially with a 70 kt tailwind. As we neared the 50 NW point from Rome, the controller became more concerned and asked if we understood the clearance, and what our DME was. I said we understood, but didn't reply regarding to DME because I wasn't sure what he meant, from where. As I was calculating distances, he came back and asked if we could be out of FL290 in 30 seconds. We were just under FL 310 at the time and I said yes. We made it, continuing down to FL 240. We had the conflict aircraft in sight for about 43 seconds to a minute, as we went by 1500 ft–2000 ft above us at about 11–1 o'clock. The captain was back in the loop at about the '30 second' request, and Captain also set FL240 in the MCP, as that was missed when the clearance was first received. It is very clear to me what the problem was here. A big part of it was my first leg flying the airplane, but also, we

are flying an airplane, not a computer. My focus on the FMS got in the way of my doing a very simple aircraft descent profile. I will be focusing on flying first, programming second. [Supplemental info from Accession Number: 259900]. When I diverted my attention to getting the ATIS we had approx 30 miles to go to the crossing fix and to lose 6000 ft this was not a problem. However, a very slow descent occurred due to the F/O's unfamiliarity with the descent features in the FMS. One problem here is the training in ground school and the simulator doesn't always give a pilot a good knowledge of descent features of the FMS due to the fact that most of the simulator work is pattern altitudes. To the extent possible, this check airman from now on forward will not assume that the new pilot will yet have a good operating knowledge of the equipment and when those times that require diversion of attention to other duties to keep a closer eye on the aircraft. (Accession Number: 259889)

12. This was my first trip on this aircraft without training people aboard. This is still a brand new aircraft and none of us pilots have had much exposure or experience flying in it. We were on the CIVET profile descent to runway 25L at LAX. Our crossing restriction was 14000' to CIVET. We misinterpreted our instruments and began descent to 10000', believing we were inside CIVET. At about 13000' the LAX approach controller told us that we started down early and needed to maintain 14000' until CIVET. We immediately climbed to 14400', the assigned altitude to CIVET. After rechecking our instrument we realized that our DME reading was based on FUELER intersection instead of the LAX localizer DME. I feel this was an easy mistake to make considering our very limited exposure to this aircraft. I find the glass cockpit a very difficult system to master and a frightfully easy way to make critical mistakes—at least when the pilot is new to it. The problem occurred when both of us mistook the DME for FUELER intersection displayed on the nav display for the LAX DME, a smaller font image on the primary flight display. The fix for this problem, I believe, is more training for the crews. Checkouts have become extremely costly forcing airlines to make them in the shortest time possible, which is understandable. However, I think more training would help pilots with this extremely complex new flight system. [Callback conversation with reporter revealed the following: reporter cites that this was first trip w/o a check airman on board. Also states that this flight crew was very low on combined experience as the captain had only 30 hours of experience. That is counting the 25 hours obtained on IOE time. Reporter also states that the 15 hours he had as operating experience was 3 takeoff's and landing's and the rest of the time was logged from the jump seat. Reporter feels that this is too little exposure to the real world of operating a $125,000,000 aircraft and that he was overworked in the Arrival and got confused as the captain started the descent prematurely. He was of no assistance in preventing the deviation. This event occurred in spite of 3 years and 9 years operating time on standard 747's for F/O and Captain. It could be suggested that if at all possible, 2 low time pilots should not mixed together as a flight crew. The coordinated crew concept suffers from the composite low experience level and exposes the aircraft, crew, and passengers to an unnecessarily high risk of incident, deviation, or accident. The economics as practiced in this low training hours approach cannot be justified considering the possible results from a mix of unfortunate circumstances being thrown to a set of low in type pilots in an ever changing and ever increasingly complex environment. Providing the best in hands on experience and training should be the goal and it is considered, from a historical viewpoint, that F/O's should obtain their operating experience in the seat that they would normally function and therefore be of more assistance to the PIC. Jump seat riding should not be considered for operating experience in this complex aircraft. Callback conversation #2 with reporter revealed the following: the primary flight display (PFD) was on "ILAX" showing ILS/DME distance from 25L at LAX. Nav display (ND) showed mileage to waypoint in stored route. Reporter could not explain why mistake was made when all the waypoints were in the stored route of the FMC. The FMC system auto selects the required radio for nav display with, in this case, the 25L "ILAX" ILS/DME being selected. The ILS/DME, according to reporter would not be auto-selected automatically until about 30 DME out unless "forced" through selection and activation of certain push buttons near the screen. The "time" attached to CIVET waypoint was not considered in the election for descent. The "bottom line" in the assessment of this event is training and the amount of technical expertise that is introduced to the student in that training atmosphere. There is a level of certainty in the future of the "glass cockpit" and its portrayal of valuable, usable data. This however comes about through repeated use and experience. Initial training that disallows hands on use in the "formative hours" can only be previewing another altitude deviation or misinterpretation that may have more serious considerations. The potential for error in a low time flight crew must be re-emphasized as an evaluation is made of further comments from reporter. On this aircraft there is no ACARS system thus requiring the PNF, in addition to his other duties to contact the company with landing ETA and gate info. Add to this, on a "CIVET STAR" the fact that LAX airport constantly uses the task inducing procedure of runway switching to facilitate aircraft departures. Consider the additional workload to re-program the FMC by getting into the pages of the CDU and selecting the newly assigned runway/ILS for approach. Proper crew coordination would then dictate another task induced approach plate review.] (Accession Number: 307372)

Advanced-technology Aircraft Safety Survey Report

’Department of Transport and Regional Development
Bureau of Air Safety Investigation
Australia

Contents

Summary

Jet transport aircraft equipped with basic automated-flight-control systems and electromechanical displays have given way to new generations of aircraft equipped with highly automated flight management systems and cathode-ray-tube or liquid-crystal displays.

The advent of new technology has significantly changed the work of airline pilots and has had implications for all elements of the aviation system, including safety regulators, air traffic services and air safety investigators.

Each new generation of aircraft has resulted in safer and more efficient flight; however, new technology also has the potential to introduce new challenges and potential operational difficulties. Air-safety investigators and researchers worldwide have witnessed the emergence of new human factors problems related to the interaction of pilots and advanced cockpit systems.

Several major airline accidents have been related to such difficulties.

The Australian Bureau of Air Safety Investigation (BASI) has a role to identify deficiencies before they lead to accidents, and has conducted this research into advanced-technology aircraft to proactively identify safety deficiencies.

With the cooperation of member airlines of the Association of Asia-Pacific Airlines (AAPA), formerly the Orient Airlines Association (OAA), BASI developed a survey designed to explore the safety issues of advanced-technology aircraft. The survey contained questions designed to evaluate pilot attitudes to advanced-technology aircraft and to give pilots the opportunity to provide written comments on their experiences with advanced-technology aircraft.

Five thousand copies of the survey were distributed within the Asia-Pacific region; 1,268 (approximately 25 percent) completed surveys were returned.

Pilots expressed strongly positive views about advanced-technology aircraft; however, several potential problems were identified.

Pilots reported some difficulties with mode selection and awareness on flight management systems. However, most pilots did not consider that too many modes were available.

Crew coordination on advanced-technology aircraft remains a potential problem and a significant proportion of respondents reported that they had experienced communication problems with another crewmember.

Many respondents gave examples of system work-arounds where they were required to enter incorrect or fictitious data in order to ensure that the system complied with their requirements. The most common reasons for system work-arounds were to comply with difficult air traffic control instructions and to compensate for software inadequacies during the descent/approach phase of flight. The continuing incidence of such work-arounds indicates that designers have not yet achieved optimal systems compatibility.

It is apparent that air traffic control systems do not always utilise the advantages of advanced aircraft to their fullest and sometimes impose requirements on advanced aircraft that are not easily achieved. There is scope for greater coordination between air traffic controllers and operators of advanced-technology aircraft. In particular, future air traffic control systems and procedures need to be designed to take account of the characteristics of advanced-technology aircraft. [For example,“communications, navigation, surveillanc/air traffic management” systems will be included in a new generation of flight management guidance system (FMGS).]

Pilot technical training, although frequently conducted using advanced computer-based methods, is not necessarily providing pilots with all the knowledge required to operate their aircraft in abnormal situations. The skills and training of instructors also emerged as an issue of concern to some pilots, particularly as many instructors have had no training in instructional techniques.

Traditional airline check-and-training systems, developed to maintain flight standards on earlier generations of aircraft, do not necessarily cover all issues relevant to the operation of advanced aircraft. For example, the survey identified that there is the potential for pilots to transfer some of the responsibility for the safety of flight to automated systems, yet problems such as this are not generally addressed by check-and-training systems.

The report concludes with recommendations addressing issues of system design, training, human factors and the interface between air traffic control and advanced-technology aircraft.

Introduction

Definitions

For the purpose of this study, advanced-technology aircraft, or automated aircraft, were defined as aircraft equipped with cathode-ray-tube/liquid-crystal displays and flight management systems, such as Boeing 737-300, 737-400, 767, 747-400, 777, and Airbus A310, A320, A330 and A340.

Automation is the allocation of functions to machines that would otherwise be allocated to humans. Flight-deck automation, therefore, consists of machines that perform functions otherwise performed by pilots (Funk, Lyall and Riley, 1996).

Background

Accident, incident and anecdotal evidence indicates that the introduction of new technology to aviation has generally resulted in benefits to safety and efficiency (Norman and Abbott, 1988), but has also resulted in a range of new human factors and operational difficulties. BASI's advanced-technology aircraft research project was begun in response to a number of perceived problems such as data-entry errors, monitoring failures, mode-selection errors and inappropriate manipulation of automated systems.

Phase 1 of this project included a literature review that identified major concerns with advanced aircraft, including pilot complacency, potential loss of skills and loss of situational awareness. There have been several previous surveys concerned with advanced-technology aircraft safety issues. Wiener (1989) surveyed errors made by pilots of Boeing 757 aircraft, and Wiener and others (1991) compared the DC-9 with the MD-80, looking at errors in the operation of both aircraft types. James and others (1991) surveyed over 1,000 pilots on their attitudes to advanced aircraft but focussed on opinions rather than error types. Lufthansa also surveyed A310 pilots (Heldt, 1988) with an emphasis on opinion regarding cockpit layout and design. Although advanced systems have the potential to reduce errors and to make the systems more error-tolerant, they can also introduce new forms of error. U.S. National Aeronautics and Space Administration (NASA) researchers have suggested that advanced systems have the potential to elicit more severe errors than electromechanical systems (Wiener, 1989). While reliability has not been a major issue with advanced systems, there have been occasional instances of system irregularities.

Previous international surveys have identified that although pilots have a generally positive view of new technology, some system-interface difficulties are occurring with advanced systems. This is reflected in systems behaving in unanticipated ways, pilots inappropriately manipulating automated systems, and "user errors." These concerns have also been reinforced by the recent study conducted by the U.S. Federal Aviation Administration (FAA, 1996). Rather than laying the blame for these problems at the feet of the pilots alone, it is useful to see such difficulties as system-induced abnormalities. Although the term "error" is used throughout this report, it is not intended to imply blame or culpability.

Issues are not necessarily being identified by existing government and airline safety systems for the following reasons: human factor incidents tend to be under-reported; there is often a resistance to reporting for fear of adverse consequences; and, perhaps most importantly, pilots may perceive errors as very minor, perhaps not recognising that they may be indicators of larger problems.

The second phase of the project was commenced with the belief that aviation safety will benefit from the collection and dissemination of information on specific operational problems.

Scope

This report deals with information supplied by respondents to the Advanced-technology aircraft Safety Survey and provides a detailed analysis of answers to both the "open" and "closed" questions.

The accompanying analysis does not include responses to closed questions by second officers or McDonnell Douglas pilots due to their disproportionately low representation within the sample. However, all written comments made by all respondents have been included and analysed.

The survey covers a range of technologies from the early 1980s to the present. However, the survey sought pilots" perceptions of the technology that they were using. Despite any differences in technology, the Bureau believes that the survey results are applicable to aviation in the Asia-Pacific region.

Objectives

The objectives of the phase-2 study were to:

- Determine specific types of human-system interface problems that are occurring on advanced aircraft in service within the Asia-Pacific region;
- Collect information on flight-deck errors;
- Assess the severity of errors;
- Identify design-induced errors; and,
- Identify areas where pilots inappropriately manipulate automated systems.

Method

Phase 2 included the drafting and distribution of a questionnaire. Questions were based on:

- Personal interviews with flight crew;
- Flight deck observation; and,
- Personal interviews with airline management.

The draft questionnaire was trialed within two Australian airlines, and the results were published in a BASI report (1996). The questionnaire was then modified on the basis of comments provided by respondents via a survey critique. Details of the survey questionnaire are included as the final section of this report.

Five thousand and twenty-three survey forms were distributed through the flight safety departments of participating member airlines of the AAPA.

One thousand two hundred and sixty-eight surveys were returned by the specified reply date, representing a 25.24 percent return. Completed questionnaires were returned in sealed envelopes to BASI via the flight-safety departments of participating airlines, or for Australian Airlines, via a prepaid envelope.

The survey contained 42 attitude probes or Likert-scale items designed to elicit pilot opinion on seven topics.

> A Likert scale is a standard tool in attitude assessment. It is a form of "intensity scale," whereby not only the direction but intensity of the response is measured. An item consists of a "probe," which is a positive or negative statement with which the respondent was asked the degree of agreement/disagreement. The response scale contains an odd number of possible responses, ranging from agree through neutral to strongly disagree. The center response is somewhat ambiguous: it can mean "no opinion," "undecided" or a truly neutral position on the probe. In this study, five response levels were employed: "strongly agree," "agree," "neutral," "disagree" and "strongly disagree" (Wiener, 1989).

Open-ended questions gave respondents the opportunity to provide detailed comments regarding their opinion on specific subjects.

The results of the "closed" (Likert-scale) questions were recorded in a database before being statistically analysed using the Statistical Package for the Social Sciences (SPSS Version 6 for Windows). The "hand-written," or "open," responses were similarly recorded in a database before being manually analysed by a team of six raters.

Participation was voluntary and no incentives were provided to any of the respondents to complete the survey form.

Confidentiality

All volunteers were assured of confidentiality. The survey cover included the following statement:

> As this survey does not require you to identify yourself, all information supplied is COMPLETELY CONFIDENTIAL.

The survey form contained no codes that would allow researchers to identify an individual. Survey responses were entered into a database as they were received and no attempt was made to order surveys returned from any particular flight-safety department.

Archiving

All survey forms were retained in accordance with the Australian Government Public Service General Disposal Authority No. 14.24.2.1.

Statistical Analysis

All results contained in this report relating to differences between demographic categories (e.g., pilot rank, age, nationality or aircraft manufacturer) are statistically significant. An alpha level of 0.05 was used for all statistical tests.

Report – Figure and Table Numbering

Numbering of figures and tables in the report does not follow the standard. Beginning at chapter 1 of the Analysis, the numbers allocated to figures and tables reflect those allocated to the corresponding questions in the survey form. For example, fig. B2.4 graphically depicts the distribution of the answers to question 2.4 in part B of the survey form.

The Sample – Summary

The following information summarises the demographic data provided in response to questions in part A of the survey.

The accompanying analysis does not include information pertaining to second officers or pilots of McDonnell Douglas aircraft due to their disproportionately low representation within this sample. However, written comments made by all pilots have been included and analysed.

Table 5.1 (page 146) shows demographic data for respondents according to pilot: rank, age, gender, average experience in type, and average total aeronautical experience.

Table 5.2 (page 146) indicates the current aircraft type flown by respondents at the time of the survey.

- The majority of respondents (68 percent) were line pilots. The remaining 32 percent of respondents were represented by management pilots (5 percent), check pilots (8 percent), training pilots (8 percent), supervisory pilots and company test pilots (1 percent). One hundred and thirty pilots (10 percent) did not provide their rank.

- Approximately 42 percent of respondents flew international long-haul routes. International long-haul routes were defined as flights crossing more than one international boundary, e.g., Manila, Philippines, to London, England; Tokyo, Japan, to Los Angeles, California, United States; Jakarta, Indonesia, to Jeddah, Saudi Arabia.

- Pilots reported their nationality as Australian (51 percent), Singaporean (12 percent), New Zealander (11 percent), British (10 percent), Malaysian (5 percent), Canadian (3 percent), Korean (3 percent), Indonesian (2 percent), and other (3 percent).

- The majority of pilots recorded their first language as English (90 percent), and most (66 percent) indicated

Table 5.1
Summary of Demographic Data by Pilot Rank

	Captain	1st Officer	2nd Officer	Unknown	Total
Respondents	699	457	89	23	1,268
Average age	46	35	32	41	–
Male	697	448	87	6	1,238
Female	1	7	1	0	9
Unspecified gender	1	2	1	17	21
Average experience in type	2,776	1,829	958	2,409	–
Average total aeronautical experience	12,662	6,262	4,396	10,358	–

Source: Bureau of Air Safety Investigation

Table 5.2
Current Aircraft Type

Airbus		Boeing		MD		Other	
A320	87	B747/400	524	MD-11	18	Unknown	11
A310	42	B767	299	DC-10	1		
A340	29	B737	222				
A330	27	B777	2				
A300-600	6						
Total	191		1,047		19		11

Source: Bureau of Air Safety Investigation

that they did not speak a second language. This figure is influenced by the large number of Australian English speakers in the sample.

Analysis

Introduction

The following analysis has been organised into 12 topical chapters. Each chapter commences with an introduction, followed by an analysis of those elements of the questionnaire that fall under the topic area. Chapter 13 contains recommendations that arise from the preceding analysis, and chapter 14 contains a general conclusion.

Organisation

For the purpose of analysis, each of the closed questions contained in the questionnaire was allocated to one of the following 10 groups (see table 1, page 147):

Air Traffic Control

Introduction

During the questionnaire-design phase, some airline managers expressed concern that the safe operation of advanced-technology aircraft could be threatened by potential incompatibilities between aircraft automation and air traffic control (ATC) procedures, systems and airways design.

The ATC environment in which advanced-technology aircraft operate has become increasingly complex. Some ATC systems have undergone technological change comparable to that of the aircraft they are designed to manage. Within the Asia-Pacific region, most ATC centres have made technological changes, or have plans in place to adopt new technologies that include modern radar facilities, remote very high frequency (VHF) communications and computer-aided ATC management systems.

This chapter contains a discussion based on pilot perceptions of the relationship between ATC and advanced-technology aircraft, together with an analysis of specific events in which pilots had difficulty operating their aircraft in accordance with ATC instructions.

Using the Capabilities of Advanced-technology Aircraft

Approximately 60 percent of respondents considered that ATC did not make use of the capabilities of their aircraft to the fullest (see fig. B2.1, page 147).

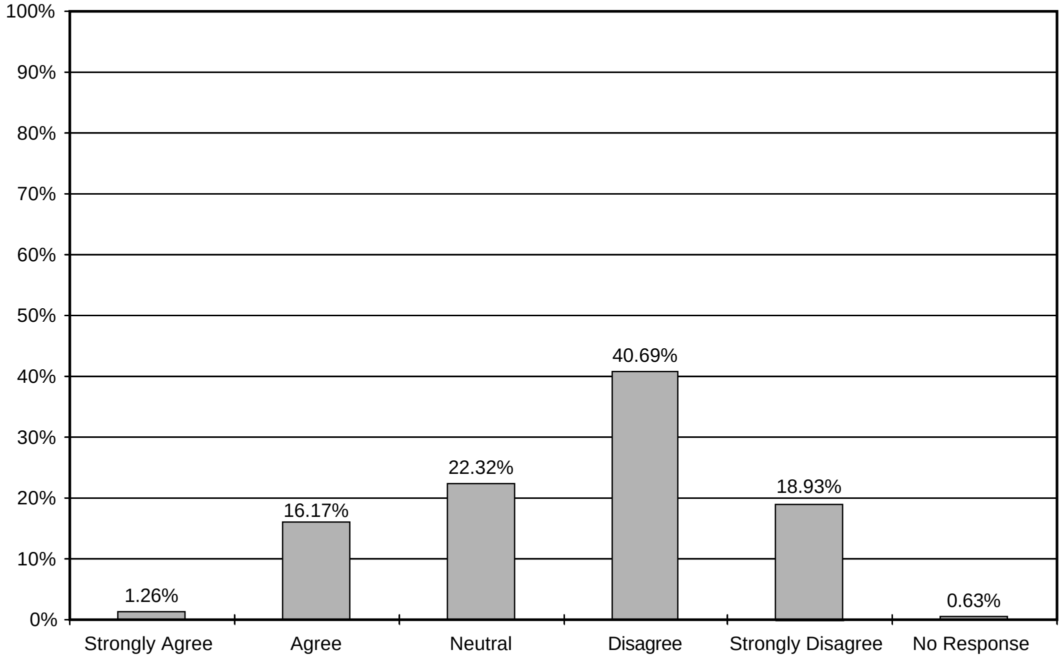
First officers were observed to be more positive in this respect than captains. Airbus pilots (58 percent) were more positive than Boeing pilots (61 percent).

Table 1
Organisation of Data Analysis

Chapter	Question number
1. Air traffic control	2.1, 2.2, 2.3, 2.4, 2.5
2. Automation	1.5, 1.6, 1.7, 7.4
3. Crew resource management	7.1, 7.2, 7.3, 7.4
4. Flying skills	5.1, 5.2
5. General	9.1, 9.2, 9.3, 9.4, 9.5, 9.6
6. Mode	1.10, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8
7. Situational awareness	4.1, 4.2, 4.4, 4.5
8. System design	1.1, 1.2, 1.3, 1.4, 1.8, 1.9, 5.3
9. Training	8.1, 8.2, 8.3, 8.4, 8.5, 8.6
10. Workload	6.1, 6.2, 6.3, 6.4

Source: Bureau of Air Safety Investigation

"Air Traffic Control make use of the capabilities of this aircraft to their fullest."



Source: Bureau of Air Safety Investigation

Figure B2.1

The capabilities available to pilots of advanced-technology aircraft include precision flight in both the vertical and lateral planes, enhanced situational awareness through computer-generated map displays, and enhanced awareness of other air traffic via the airborne collision avoidance system (ACAS). Hazardous-weather avoidance has also been enhanced by the overlay of airborne weather radar on computer-generated map displays. This is particularly important considering that many modern ATC radar displays filter out hazardous-weather information.

Vertical and lateral navigation systems allow the pilot to program a flight from takeoff to landing in accordance with actual, or expected, ATC clearances. Once the autopilot and navigation modes are engaged, the aircraft can follow the programmed route with minimal pilot input or ATC intervention.

The airways system is a complex environment that caters to many different aircraft types and operations. Air traffic controllers are often unable to use the capabilities of advanced-technology aircraft to their fullest because they are restricted by other flow-control and separation considerations.

On the other hand, some advanced-technology-aircraft functions do not permit adequate compliance with ATC requirements. For example, anecdotal evidence revealed that some air traffic controllers are aware of the limitations of advanced-technology aircraft and have devised their own system "work-arounds" to ensure timely flow control. During interviews with ATC personnel at Sydney, Australia, several staff mentioned that advanced-technology aircraft take a longer time to enter and exit holding patterns, compared with earlier-model aircraft. Some ATC staff now compensate for this lag in response time by modifying the instructions they issue to these aircraft. For example, if holding is no longer required, ATC may issue the instruction "cancel holding track direct to." The aircrew are required to make several keystrokes on the flight management computer (FMC) to exit the holding pattern and program a track to the next waypoint. To ensure this process is completed in a timely manner, some ATC staff may issue specific instructions, such as "cancel holding, turn onto a heading of." Once the aircraft is established towards the next desired waypoint they will instruct the aircraft to "track direct to."

ATC Familiarity with Modern Aircraft Aerodynamics

Figure B2.2 shows that 40 percent of respondents were satisfied with the level of ATC familiarity with their aircraft, and 36 percent were not satisfied. The results were evenly distributed across pilot ranks, although Airbus pilots were less satisfied than Boeing pilots.

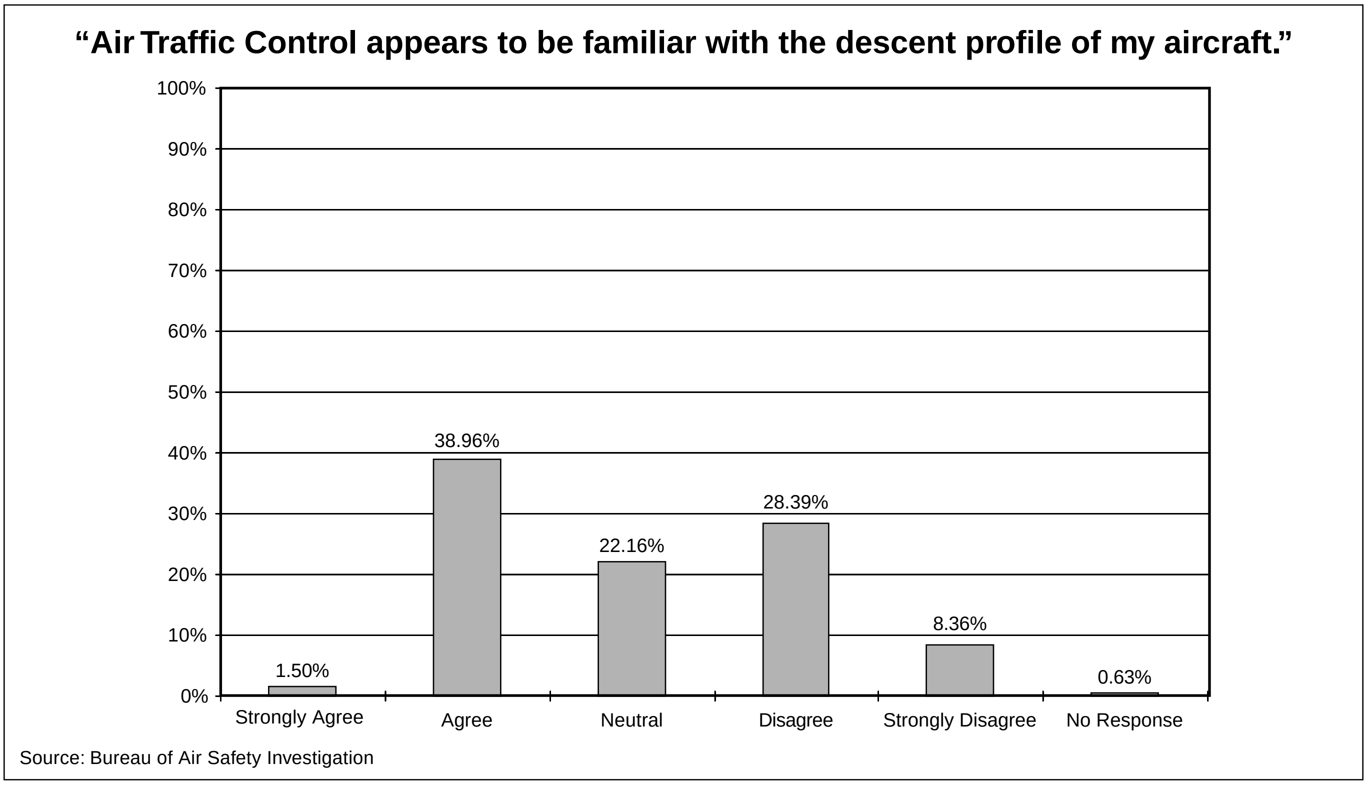
Pilots commonly pointed out that the aerodynamics of modern jet aircraft did not always allow them to reduce airspeed and descend ("slow down and go down") simultaneously. The design and execution of ATC flow control measures needs to take into account the performance and operational characteristics of modern jet aircraft.

There appears to be a general lack of appreciation by both pilots and ATC staff regarding the requirements of each other's operation. Past familiarisation/observation activities have been of limited value, mainly due to the lack of an integrated program in which participants are required to observe and report on specific aspects of an operation.

Automation's Response to ATC Requests for Information

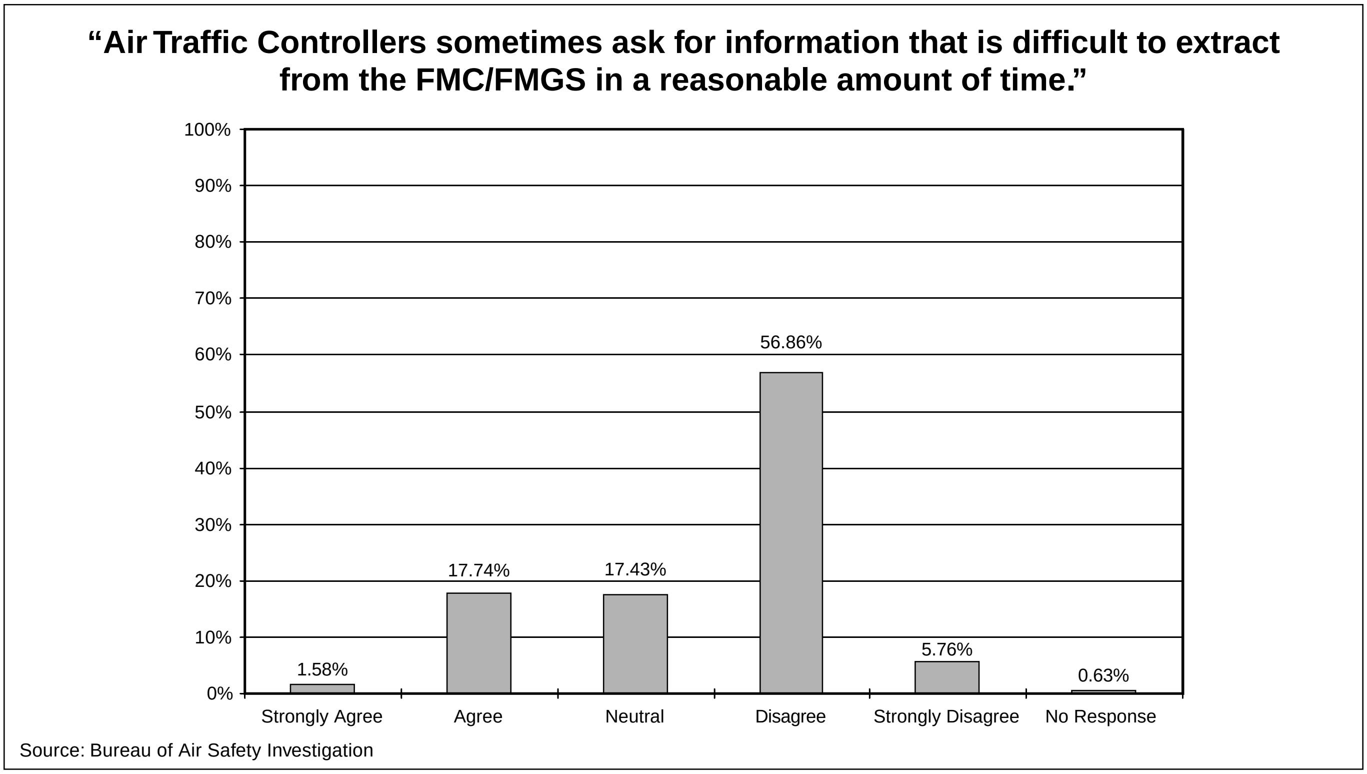
Figure B2.3 (page 149) indicates that most crew did not agree that air traffic controllers sometimes asked for information that is difficult to extract from the FMC/FMGS in a reasonable amount of time.

This finding proved to be contrary to information received during flight deck observations, where pilots expressed their concern that not all air traffic controllers were aware of what the crew were required to do to extract information from an FMC/FMGS



Source: Bureau of Air Safety Investigation

Figure B2.2


“Air Traffic Controllers sometimes ask for information that is difficult to extract from the FMC/FMGS in a reasonable amount of time.”

Source: Bureau of Air Safety Investigation

Figure B2.3

in response to ATC queries. Pilots reported that sometimes the most difficult queries to answer relate to time/distance/altitude information while at low altitude following takeoff. There is no suggestion that such requests for information are not justified; however, whereas the response from the crew of an older aircraft may be no better than an educated guess (based on the existing performance of the aircraft), the crew of modern aircraft are more likely to rely on the calculations of the FMC. Difficulty may arise when the crew are required to use data outside the programmed flight-planned data.

The Ability of Automation to Cope with Changes Imposed by ATC

Figure B2.4 (page 150) shows that approximately 50 percent of crew agreed with the statement that the current level of automation did not cope well with the last-minute changes imposed by ATC. Aircrew expressed the concern that what once may have been a relatively simple task (such as a change of runway, standard instrument departure (SID), or standard terminal arrival route (STAR) may now be much more complicated.

Modern aircraft operate most efficiently when subjected to minimum disruption to ATC clearances (for example, changes to STARs). The intervention service provided by ATC does not seem compatible with the safe and efficient operation of modern automated aircraft. The response to this question highlights the fact that aircraft and airspace/procedures design have not advanced at the same pace.

Programming Below 10,000 Feet

Some pilots (36.75 percent) were concerned that there was too much programming activity below 10,000 feet (see fig. B2.5, page 152).

This question related directly to the way in which ATC processed aircraft, especially during the arrival phase, and the methods by which pilots controlled their aircraft. It also reflected on the familiarity of both pilots and controllers with the complexities of each other’s operation.

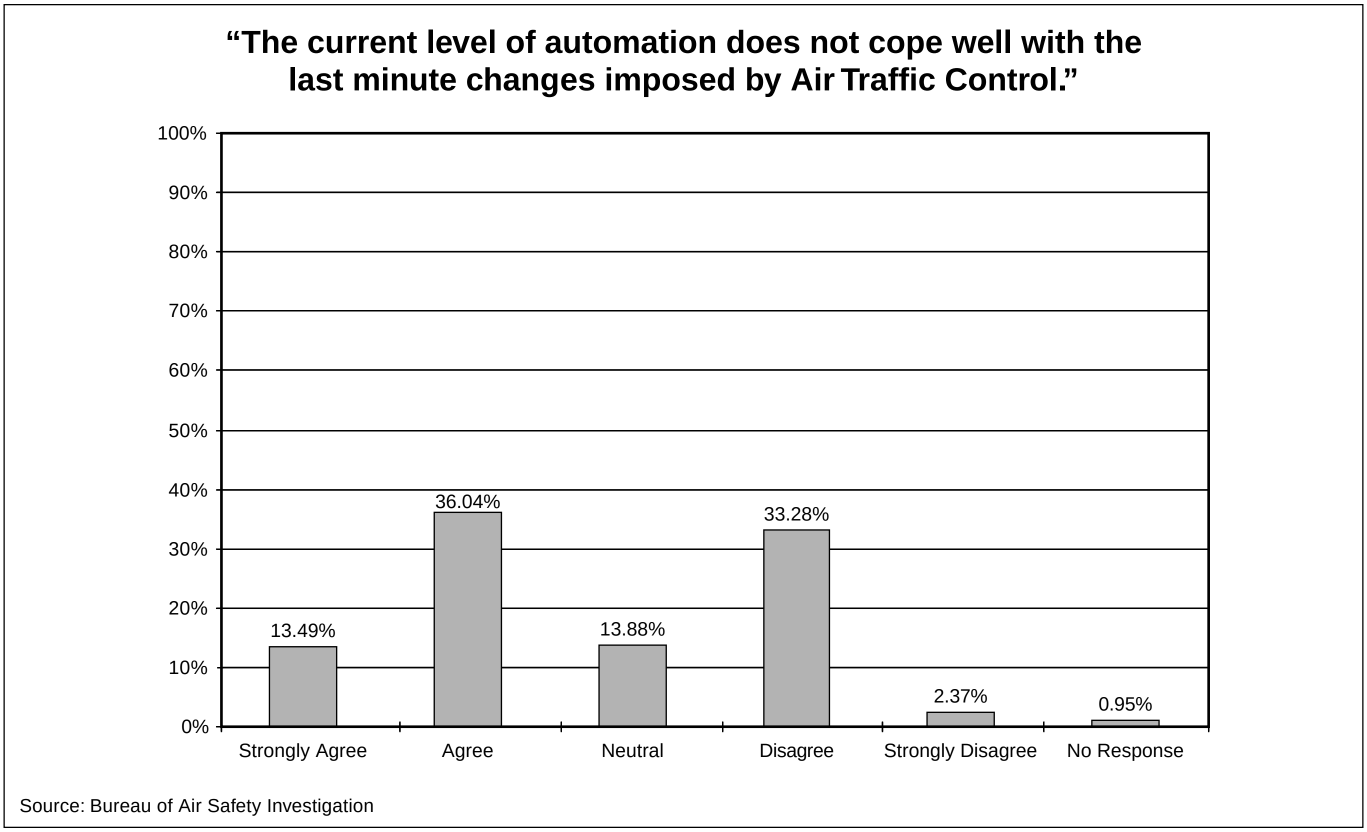
ATC Procedures by Geographical Area

Approximately 50 percent of respondents indicated that they were concerned about ATC procedures within a specific geographical area (B2.6).

Respondents were grouped into one of seven categories according to their response to question A2, which asked pilots to nominate which routes they flew. Pilots were free to nominate any geographical location for which they had a concern. This led to a certain amount of overlap as some respondents may have nominated several different ports (for example, Sydney, Melbourne and Perth), whereas others may have nominated a country (for example, Australia).

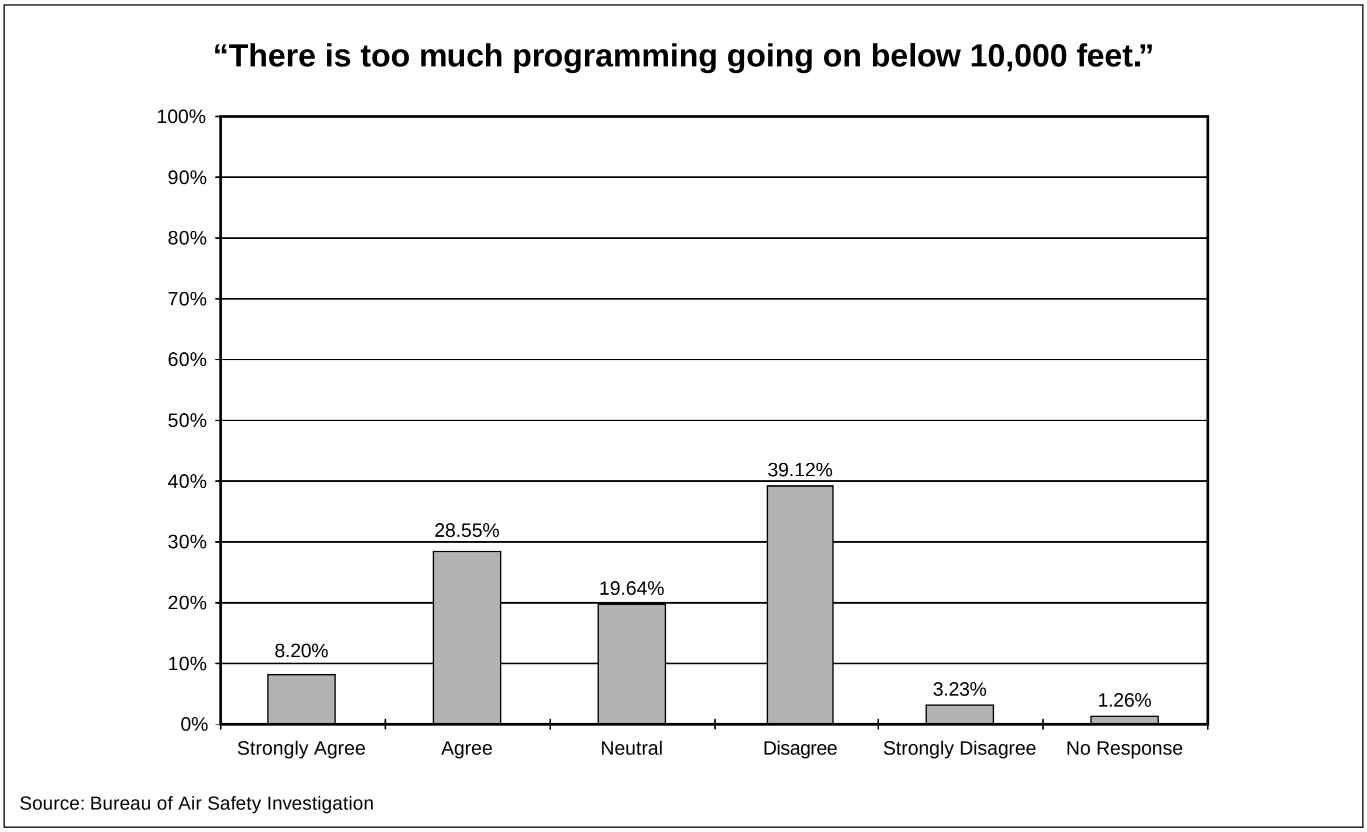
Table 2.6 (page 151) summarises the most frequent responses by pilots in each category.

(continued on page 151)



Source: Bureau of Air Safety Investigation

Figure B2.4



Source: Bureau of Air Safety Investigation

Figure B2.5

Table B2.6
Most Frequently Nominated Geographical Region by Routes Flown

Route Flown	Summary of Responses
Domestic routes	Sydney, Australia
Domestic & international short-haul & international long-haul routes	Indonesia
Domestic & international short-haul routes	Sydney
International long-haul routes	India
International short-haul routes	Sydney, China
International short-haul routes & international long-haul routes	India, China and Indonesia

Domestic routes = Flights which do not cross international borders, e.g., Sydney to Melbourne, Australia.

International short-haul routes = Flights to adjoining airspace, e.g., Australia to New Zealand; Singapore to Jakarta, Indonesia; Hong Kong to Taipei, Taiwan.

International long-haul routes = Flights crossing more than one international boundary, e.g., Manilia, Philippines, to London, England; Tokyo, Japan, to Los Angeles, California, United States; Jakarta to Jeddah, Saudi Arabia.

Source: Bureau of Air Safety Investigation

The high proportion of Australia-based respondents could account for the prominence of Sydney in three of the seven categories.

Some degree of concern was reported from within all seven categories regarding the relationship between the operation of advanced-technology aircraft and ATC procedures in various geographical locations. Sixty-one locations were nominated by pilots responding to question B2.6.

These locations incorporate various levels of ATC services, ranging from the most advanced to purely procedural ATC environments. The responses to this question would seem to indicate that advances in technology do not necessarily guarantee better or safer operations.

It should be noted that this survey was conducted prior to the 1996 midair collision near New Delhi, India.

Specific Events

When asked to outline a specific event in which they had difficulty operating an advanced-technology aircraft in accordance with an ATC instruction, pilots nominated the following:

- Runway change / late runway change (27 percent)
- Speed changes / late speed changes (24 percent)
- STAR / Changes to STAR (17 percent)

Box 2.7a provides examples of pilot comments concerning programming a change of runway and/or receiving late advice of a change of runway from ATC. This would appear to confirm the responses to part B, question 2.4, where pilots indicated that the current level of automation did not cope well with the last-minute changes imposed by ATC.

The following boxes contain examples from each category.

Change of Runway and/or Receiving Late Advice of a Change of Runway

Box B2.7a. Examples of written responses relating to a change of runway and/or receiving late advice of a change of runway

> *Arrive into Bangkok, [Thailand,] where a request/requirement to change from runway 21R to runway 21C was made. The altitude was 2,000 ft and intercept from the east required a slight "S" turn to capture the ILS [instrument landing system]. Some difficulty was encountered changing ILS frequency.*
>
> *Four runway changes arriving into London on a B-747-400 (though it would probably have been difficult in an analogue aircraft). The last two changes were, with localiser captured and the last with both localiser and glide slope captured and autopilot engaged.*
>
> *Several occasions with change of runway and hence SID or STAR in either take-off or arrival situations.*
>
> *On arrival to Sydney the assigned runway is given too late, as is speed control. These things need to be known before descent begins. Also I believe once a STAR is cancelled it should not be resumed.*
>
> *Weather at Sydney included heavy rain and low cloud. ATC advised change of runway from 16R ILS to 16 LOC/DME with 18 miles to run. Heavy rain and light/moderate turbulence. Several returns on aircraft radar requiring some manoeuvring. Different runway and approach had to be programmed into FMGC and briefed.*
>
> *Change of runway in poor visibility at SFO [San Francisco, California, United States], from runway 28R to runway 28L. I was new on the fleet and took a long time to change the ILS frequency, new route/overshoot etc. The B-747-300 was definitely faster and easier.*

Speed changes, and/or late speed changes were nominated by 24 percent of respondents, followed by STARs, and/or changes to STAR procedures (17.57 percent) as the next most difficult events (see box B2.7b).

Speed Changes and/or Late Speed Changes

Box B2.7b. Examples of written responses relating to speed changes and/or late speed changes

> *Last minimum speed and height restrictions. FMC can cope aircraft cannot. ATC knowledge not 100 percent*
>
> *The B-737-300 does not like to go down and slow down. ATC issue too many speed restrictions, too late.*
>
> *Speed reduction on descent being given after descent commenced with a restrictive altitude requirement of 8,000 ft. Some difficulty meeting this requirement as VNAV [vertical navigation] had been programmed for optimum descent profile.*
>
> *In San Francisco they require us to slow down, descend to a lower altitude and expect an early turn to final approach. On top of this a change in runway occurred while we were intercepting the initial runway. The workload had increased a lot and the FMC took a long time to be reprogrammed, e.g., stand-by mode kept popping up.*
>
> *Being required to maintain 250 kts for separation on descent then required to expedite descent. The two are incompatible.*
>
> *Requested 350-kt descent to initial approach fix by ATC, input info into FMC, descent commenced. Halfway down radar instructed us to contact approach. Upon change-over told to reduce airspeed to 250 kts putting us very high on profile.*

STARs and/or Changes to STAR Procedures

Box B2.7c. Examples of written responses relating to STARs and/or changes to STAR procedures

> *STAR arrival Sydney — three changes to STAR in 10 minutes.*
>
> *Reloading STARs, with last minute changes due poor ATC.*
>
> *Last minute changes, STAR or descent speed changes especially if involving new track and or altitude crossing required as STAR has to be entered into FMC and verified.*
>
> *Arriving into Melbourne, [Australia], on the new STARs (20 June 1996) the speed control changes made, make the altitude requirement difficult.*
>
> *Late changes to a STAR clearance into Sydney, require a new entry in the FMGS then a confirmation from the Jeppesen chart that the correct procedure is inserted. This takes both pilots to confirm the entry. Meanwhile the new STAR requirements still have to be met and you are not aware of them at this point.*
>
> *Arrival in Tokyo STAR was pre-programmed and we were cleared via a different arrival. This made for some heads down. On an older plane you would just track to the appropriate VOR [very-high-frequency omnidirectional radio] or WPT [waypoint].*

To a lesser degree, pilots nominated the following as also being difficult to comply with:

- Changes to instrument approaches (7 percent);
- Holding patterns (4 percent);
- Unanticipated navigational requirements (4 percent);
- Low altitude level-off (3 percent); and,
- Changes to SIDs (3 percent).

Pilot Comments

Changes to Instrument Approaches

Box B2.7d. Examples of written responses relating to changes to instrument approaches

> *Direct to VOR then told to intercept 9 DME (distance measuring equipment) ARC for a VOR approach (Perth). Aircraft not programmed for that approach and too difficult to program at late stage.*
>
> *Landing New Delhi, delayed descent way above ILS GS (glideslope), late clearance into LOC (localizer), very late frequency changes with no response on first contact with ATC.*
>
> *An instruction to discontinue an ILS approach (LOC and GS captured) due conflicting traffic and then a parallel runway side step, to another ILS in marginal (IMC [instrument meteorological conditions]) weather. Equipment not user-friendly and workload high.*
>
> *Changes of instrument approach of runway at very late notice.*
>
> *When an aircraft on final approach is "logged on or captured" on runway 20C and glide slope and ATC requires a change of runway or side-step to a parallel runway.*
>
> *When fully established on an ILS approach, asked to change over to another runway at short final.*

Unanticipated Navigational Requirements

Box B2.7e. Examples of written responses relating to unanticipated navigational requirements

> *Instruction to intercept a radial which is not expected. The only sure and safe method is to use raw data and once on the radial use the direct intercept to and then engage LNAV [lateral navigation].*
>
> *Intercepting a VOR radial is sometimes a little difficult on the B-767.*
>
> *Inbound to Sydney on LETTI STAR. At around 40 NM from Sydney, told to track to CALGA and be at or below 7,000 ft by 20 DME. It took us a while to program CALGA (which is not a waypoint but an NDB). Also descent profile was shot to bits by re-route. (Perhaps this is more a case of ATC asking us to do things which exceed quick execution in an FMC aircraft.)*
>
> *Given direct tracking to a point not in FMC while in terminal area. Had to ask for vectors. Problem with CAA [Australian Civil Aviation Authority] not supplying Jeppesen with new way-points.*
>
> *Intercepting and track outbound on a VOR radial. Requires a lot of button pushing to fly in LNAV. As there is no VOR LOC mode, only other alternative is increased workload of flying and intercept in HDG [heading] mode.*
>
> *Intercepting a VOR radial is almost impossible on short notice. The aircraft has to be flown in heading select up a fix line or a waypoint and a track built.*
>
> *When given a "direct to" clearance to a point I am not familiar with or not on my flight plan, without ATC HDG steer I have to look for the point and enter it into the FMS. I am uncomfortable with the length of time to do it. I have had to ask for initial HDG steer while ascertaining the position.*

Low-altitude Level-off

Box B2.7f. Examples of written responses relating to low-altitude level-off.

> *Low altitude level-off, e.g., 1,500 ft, 2,000 ft, 3,000 ft.*
>
> *On departure from a short runway requiring high power, we were given a very low initial level-off altitude. Just after rotation the aircraft captured the assigned altitude but the thrust stayed in THRUST HOLD. Some quick MCP [mode control panel] selections were required to stop an overspeed of the flaps occurring.*
>
> *Level-off after takeoff is an area of concern for me as this causes problems with speed control.*
>
> *Low altitude level-off after takeoff during turning departure.*
>
> *ATC runway heading maintain 2,000 ft. Must be very quick with AT [autothrottle], CAB commands to overspeeds/excursions.*
>
> *Departure Cairns (B-767) ATC, maintain 2,000 ft, after takeoff to level off, and keep speed within limits that was beyond the capability of the automatics.*

Changes to SIDs

Box B2.7g. Examples of written responses relating to changes to SIDs

> *Change of departure SID on line up, request to immediate roll, also change of level restriction.*
>
> *ATC changed the ATC clearance during initial take-off phase.*
>
> *Sudden last minute changes to departure clearances at Brisbane [Australia]. Low level altitude restrictions, sudden changes to headings all at odds with initial departure clearance.*
>
> *Taxiing for departure Sydney with runway change. Figures extracted prior to engine start are now calculated under increased pressure with most cases the captain not checking the figures. Runway change below 10,000 ft Sydney. 8 NM final with runway change from runway 16L to 16R, this requires the support pilot head down in the box for a while.*
>
> *On departure from Shanghai [China] Airport, given last minute different SID with take-off clearance. Too many changes to FMC.*
>
> *Frankfurt [Germany], last minute change of departure runway to one with minimal taxi time. ATC expected us to be able to just "line up and go" and were not aware of need to re-calculate data and then reprogram the FMC.*

The common theme among these comments appears to be that pilots can at times experience difficulty changing a preprogrammed component of the flight. The later the pilot receives the advice of the change, the more difficult it becomes to program the particular change, assimilate new information, accommodate changes and maintain situational awareness. The degree of difficulty may be greater when these changes are carried out in adverse weather conditions. Several situations were reported where it was impossible for the pilot to reprogram the FMC prior to landing. In these cases, the pilots elected to go around or hand-fly the aircraft.

Summary and Conclusions

Aircraft and ATC systems have undergone significant advances in recent decades. However, the results of this survey suggest that some of these developments have occurred in an uncoordinated fashion and that issues of system compatibility between airborne and ground-based systems have not always been addressed.

Many pilots considered that air traffic controllers do not take full advantage of the capabilities of modern aircraft and sometimes impose unrealistic requirements on pilots. It appears that the design philosophy and aerodynamic characteristics of advanced-technology aircraft have not always been considered by the designers of ATC procedures.

Of particular concern are the reports that pilots are sometimes required to disconnect automated systems to comply with ATC requirements, particularly on approach. Automated systems have the potential to improve the safety and efficiency of flight and unnecessary reversions to manual operation are not desirable.

Some individual air traffic controllers appear to be unfamiliar with the descent profiles of advanced-technology aircraft. A program of controller familiarisation flights on the flight decks of advanced-technology aircraft (or in full-flight simulators) could help to provide this knowledge.

The survey identified the most frequent situations in which pilots had difficulty complying with ATC instructions. These were late changes of runway, speed changes, STARs and changes to STARs, changes to instrument approaches, difficulties with holding patterns, unanticipated navigational requirements, low altitude level-offs and changes to SIDs. As can be seen, most of these difficulties occurred on approach rather than departure. When considering potential improvements in ATS procedures, designers would do well to give particular attention to making approach procedures more compatible with the characteristics and capabilities of advanced-technology aircraft.

When asked to identify a location where ATC procedures were of concern, pilots nominated a large range of geographical areas, including regions with advanced ATS systems and regions with less advanced systems. These results will to some extent reflect the pilots” familiarity with various regional ATC systems and the frequency with which they fly in these regions. Nevertheless, the responses to this question seem to indicate that advances in ATC technology do not necessarily guarantee a higher level of pilot satisfaction with the system.

Contrary to anecdotal evidence, the majority of pilots do not agree that controllers sometimes ask for information that is difficult to extract from the FMC/FMGS in a reasonable amount of time. This may reflect the nature of the initial inquiry and the pilot’s skill in retrieving information from the FMC. Pilots revealed that their main concerns related to any non-essential requests shortly following takeoff, and requests involving off-track waypoints or navigation aids. These involved considerably more input into the FMC than when pre-programmed data was queried.

There are many aspects of flight operations that affect the analysis of question B2.6 (“I am concerned about the ATC procedures within the following geographical area”), for example, the frequency of flights and familiarity with ATC procedures. Notwithstanding these considerations, the results are not as clear-cut as might be expected. The responses to this question would seem to confirm that advances in technology do not necessarily guarantee a better or safer operating environment.

By nominating specific events in which they had difficulty operating their aircraft in accordance with an ATC instruction, pilots have identified several areas in which potential mistakes can be made:

- Programming a change of runway and/or receiving late advice of a change of runway from ATC;
- Speed changes, especially late speed changes;
- STARs, and/or changes to STAR procedures;
- Changes to instrument approaches;
- Difficulties with holding patterns;
- Unanticipated navigational requirements;
- Low altitude level-off; and,
- Changes to SIDs.

Developing an “automation policy” by airline operators and ATC, or addressing these difficulties through clear and concise standard operating procedures, may minimise the risk of errors.

Recommendations

The Bureau of Air Safety Investigation recommends that Airservices Australia (R980024) and the Civil Aviation Safety Authority (R980025):

Review their airways and procedures design philosophies to:

(a) ensure that STAR, SID and airways design is compatible with aircraft FMS programs;

(b) allow a ±10-knots range with respect to descent speed below 10,000 feet to allow for the tolerances of FMS-equipped aircraft, with the aim of reducing the requirement for system work-arounds;

(c) provide ATC personnel with the information on aerodynamic and performance characteristics of advanced-technology aircraft; and

(d) seek the cooperation of airline operators for a program of advanced technologies flight-deck observation for all ATC personnel during both their initial and recurrent training.

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980026):

Consider a program of flight crew observation of ATC operations during both initial and recurrent flight crew training. Such a program could be incorporated into the syllabus of training and include subjective elements requiring observation and assessment.

Automation

Introduction

Since 1910, aircraft systems have become progressively more automated. Major developments in automation have included the gyroscopic stabiliser, coupled navigation (DC-6), flight management systems (B-767), and fly-by-wire with envelope protection (A320).

This chapter analyses the results relating to the current level of automation in advanced-technology aircraft and considers the evidence for the existence of cases where the flight crew was not aware of the mode characteristics or aircraft response (automation surprise) and the unconscious transfer of aircraft control and command (passive control) to automation.

The Extent of Automation

Contrary to anecdotal evidence, only 10 percent of respondents agreed that "they've gone too far with automation" (see fig. B1.5).

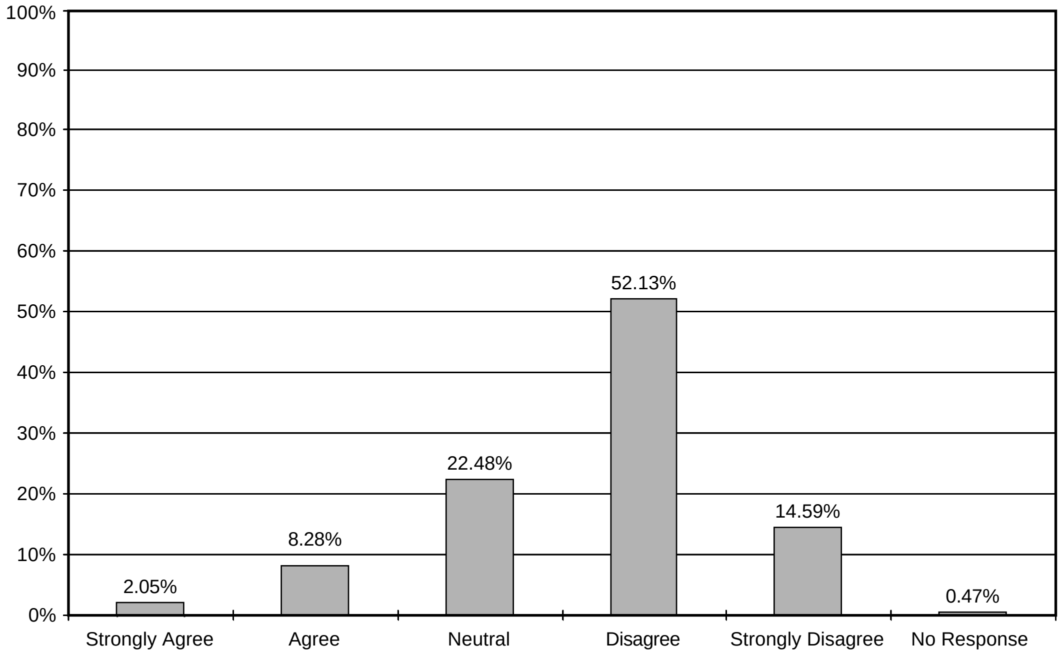
These results are in accordance with the findings of Wiener (Wiener 1989, see chapter 11) and are also consistent with responses received to question B3.5 ("There are too many modes available on the FMC/FMGS"), where only 9 percent of respondents felt that there were too many modes available on the FMC/FMGS.

Table B1.5 (page 156) indicates the proportion of pilots who agreed that "they've gone too far with automation." A statistically significant difference was observed between the response of first officers and captains, with captains being more likely than first officers to consider that automation had "gone too far."

Automation Surprise

Figure B1.6 (page 156) shows that 61 percent of respondents agreed that with automation there are still some things that took them by surprise. Automation surprise can be defined as a weakness in a pilot's mental model of the automated environment that results in the pilot being "surprised" by the difference between the expected and actual performance of the aircraft. For example, subtle mode reversion (commonly between Vertical Speed mode and Flight Level Change mode)

"They've gone too far with automation."



Source: Bureau of Air Safety Investigation

Figure B1.5

Table B1.5
“They’ve gone too far with automation.”

	Captain	First officer
Airbus	16%	8%
Boeing	11%	7%

Source: Bureau of Air Safety Investigation

may result in an unexpected change in aircraft performance from what was expected by the pilot. Common verbal responses to automation surprise are “What is it (the aircraft) doing now?” and “Why did it (the aircraft) do that?” This weakness has been attributed to a lack of mode awareness and inadequacies in training. Sarter and Woods (1995) have discovered weaknesses in the mental models pilots had developed of how the FMS functions in specific situations. They concluded that training must go beyond teaching how to operate the automated systems to teaching how the automated systems operate. Ongoing learning programs are also needed to help pilots refine their mental models of how automation works.

Table B1.6.1 (page 157) summarises the responses of those pilots who agreed with the statement, “With automation there are still some things that take me by surprise.” A statistically significant difference was observed between the responses of Airbus and Boeing pilots. Airbus pilots were more likely to report experiences of automation surprise than Boeing pilots. It should be noted that Boeing pilots had considerably more experience in type than Airbus pilots (see table B1.6.2, page 157), and this may account for some of the differences between groups.

Altitude Capture

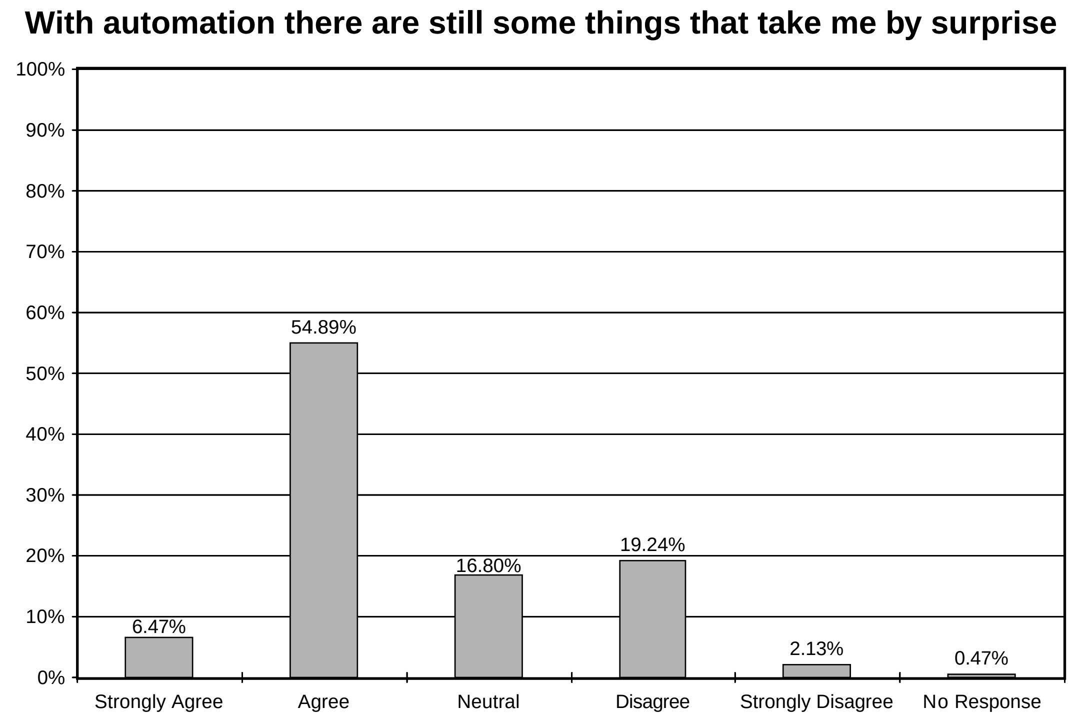
The weakness in the mental model is not necessarily the fault of the pilot. Poorly annunciated mode changes can leave the pilot several steps behind the aircraft. The pilot anticipates that the aircraft will respond to the last selected mode, whereas the aircraft may have reverted to a sub-mode and will behave in a different manner than expected.

As in the previous question (B1.6), this also provides evidence of a weakness in the pilot’s mental model, particularly in relation to mode awareness. Fifteen percent of respondents indicated that the FMC/FMGS sometimes fails to capture an altitude as they expect (see fig. B1.7, page 157).

Passive Command

The development of automation has also produced instances in which the crew has unconsciously relinquished command responsibilities momentarily to the automated systems. In such situations, pilots may unconsciously become “observers” rather than “controllers” of aircraft systems.

Figure B7.4 (page 158) indicates that while most respondents did not have a problem with passive command, 16 percent had experienced this phenomenon during flight.



Source: Bureau of Air Safety Investigation

Figure B1.6

Table B1.6.1
“With automation there are still things that take me by surprise.”

	Captain	First officer
Airbus	68%	73%
Boeing	55%	65%

Source: Bureau of Air Safety Investigation

Table B1.6.2
Hours in Type by Aircraft Manufacturer

	Mean hours in type	Minimum recorded hours in type	Maximum recorded hours in type
Airbus	1,789	5	6,800
Boeing	2,379	10	9,999

Source: Bureau of Air Safety Investigation

Analysis of this result revealed that this phenomenon is apparent across all aircraft types, pilot ranks, age categories and experience levels.

Automation Policy

This chapter has outlined several comments made by respondents in relation to the quality of training staff, manuals, simulator instruction, line training and the quality of training. Several pilots requested greater standardisation and expressed the need to discuss automation philosophy prior to their simulator training. Investigation revealed that very few airlines have addressed automation philosophy in their company manuals. The lack of specific policy has promoted a plethora of personal opinion and may cause check-and-training staff to avoid making comment during initial and recurrent training activities.

Aviation safety could be improved by incorporating specific policy guidelines regarding the operation of automated aircraft. Such policy should be incorporated into standard operating procedures and become a reference document for all operational staff.

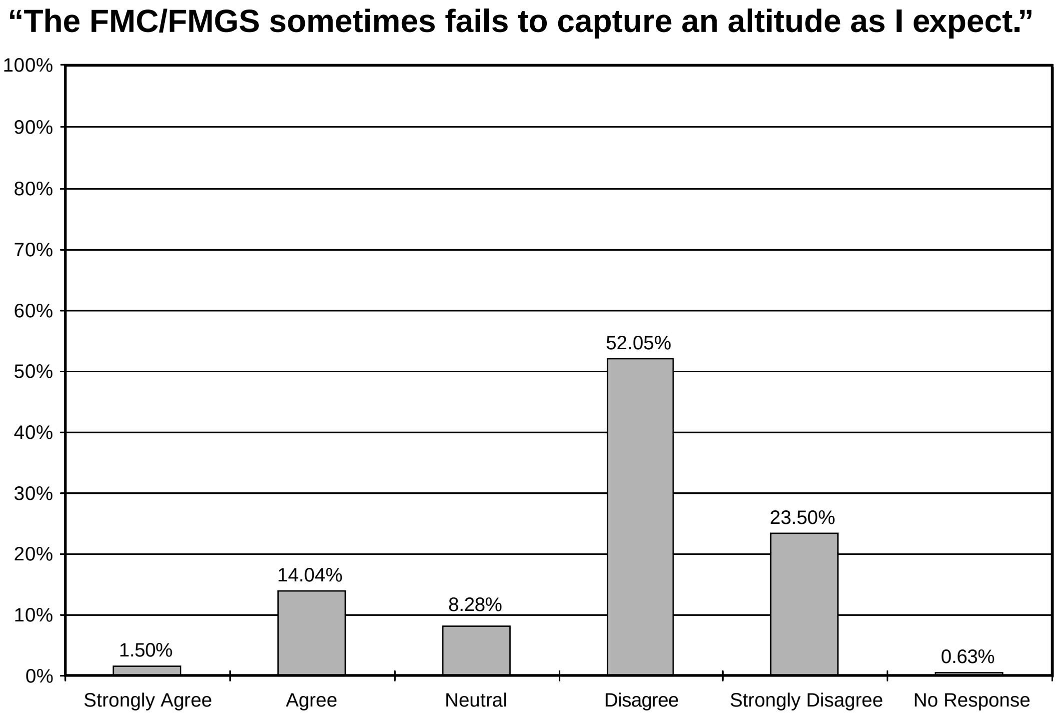
The following information is provided as an example of the results of two airlines” efforts to formulate an automation policy:

1. Delta Air Lines Inc.

The following is taken from the Delta Air Lines, Inc. Flight Operations Manual, Chapter 4: “General Policy,” page 8:

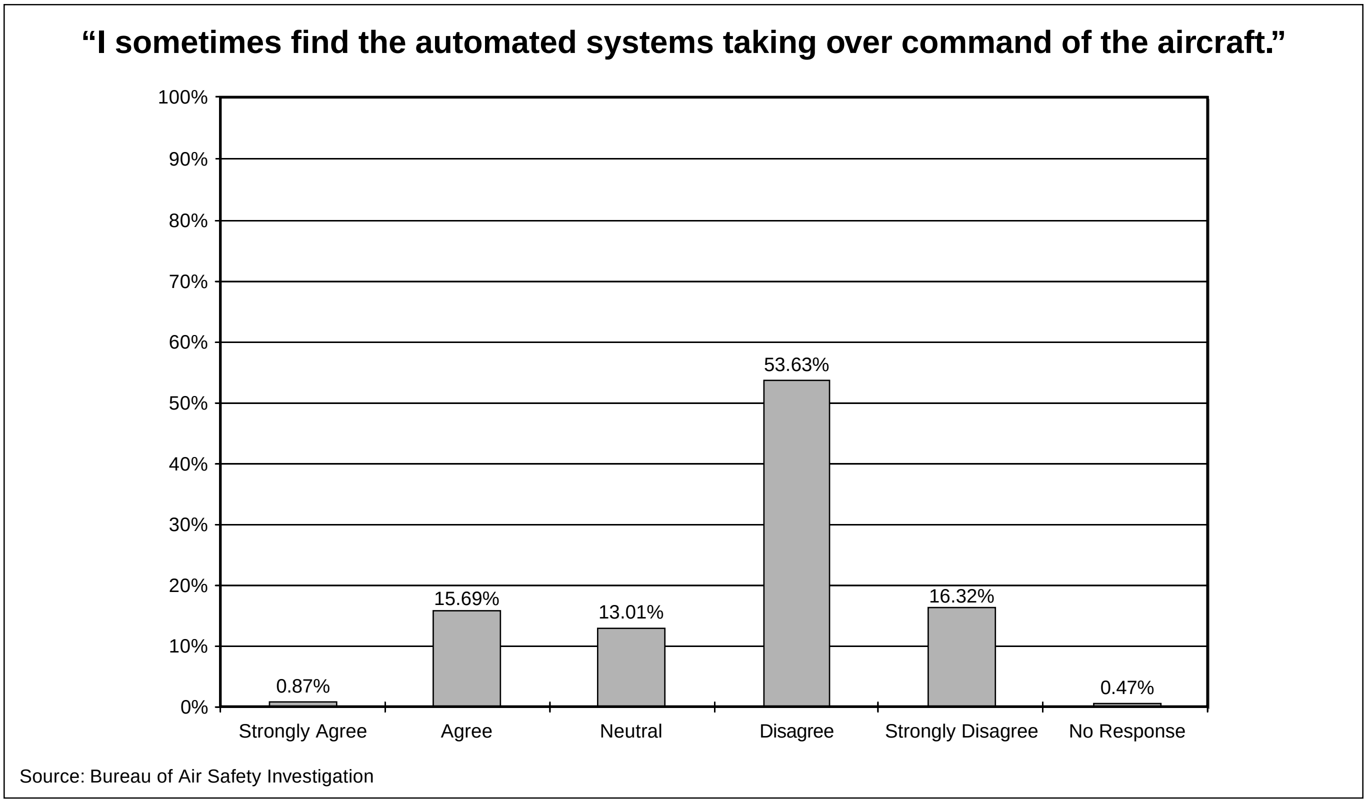
General

> Automation is provided to enhance safety, reduce pilot workload and improve operational capabilities. Automation should be used at the most appropriate level.



Source: Bureau of Air Safety Investigation

Figure B1.7



Source: Bureau of Air Safety Investigation

Figure B7.4

> Pilots will maintain proficiency in the use of all levels of automation and the skills required to shift between levels of automation. The level used should permit both pilots to maintain a comfortable workload distribution and maintain situational awareness. The following guidelines apply to the use of automation:

- If any autoflight system is not operating as expected, disengage it.
- All pilots should be aware of all settings and changes to automation systems.
- Automation tasks should not interfere with outside vigilance.
- Briefings should include special automation duties and responsibilities.
- The PF must compare the performance of the autoflight systems with the flight path of the aircraft.

2. Cathay Pacific Airways Limited

Automation policy is mentioned in Cathay Pacific's Flight Training Manual, vols 1, 3 and 7, part 1:

> It is Cathay Pacific Airways policy to regard Automation as a tool to be used, but not blindly relied upon. At all times, flight crew must be aware of what automation is doing, and if not understood, or not requested, reversion to basic modes of operation must be made immediately without analysis or delay. Trainers must ensure that all CPA flight crew are taught with emphasis how to quickly revert to basic modes when necessary. In the man-machine interface, man is still in charge.

Conclusions

These results establish the existence of an unacceptably high degree of "automation surprise." Of concern is the number of pilots who completed their engineering course prior to 1993 and still report that they experience this problem. Most airline recurrent training and checking programs do not adopt a holistic approach to consolidating, or developing, a pilot's knowledge and understanding of aircraft operation. Often such programs are restrained by regulatory requirements. Future research should identify specific instances of "automation surprise" in order to minimise occurrences. The fact that most pilots indicated that "the FMC/FMGS captures an altitude" as they expected may reflect the routine nature of this manoeuvre. However, this result should not mask the importance of the pilot maintaining a correct mental model of the aircraft environment at all times.

Similarly, these results confirm the subtle phenomenon of "unconscious transfer of command to automation" or "passive command." Airlines should take appropriate action to alert pilots to the existence of this phenomenon. Further research should identify the stage of flight in which this occurs and assess the risk to safe flight operations.

Recommendations

The Bureau of Air Safety Investigation recommends that airline operators (R980027):

1. Ensure that flight crew of advanced-technology aircraft are educated in the concept, and safety implications, of Passive Command Syndrome.

2. Include a comprehensive statement of automation policy in their general operations manual and/or airline policy documents.

Crew Resource Management

Introduction

Crew resource management (CRM) may be defined as "the management and utilisation of all people, equipment and information available to the aircraft. It is in principle no different from the management and utilisation of people in any other workplace involving skilled activities in a technological environment."

CRM was first seriously considered within the aviation industry in 1972 following an accident involving Eastern Airlines Flight 401 (Florida Everglades, United States). In 1975, IATA (International Air Transport Association) held its landmark Human Factors Conference in Istanbul, Turkey, and in 1977, KLM Royal Dutch Airlines (KLM) developed the KLM Human Factors Awareness Course (KHUFAC) following the fatal accident involving KLM and Pan Am aircraft at Teneriffe, Canary Islands.

CRM concepts have developed significantly since the early training courses of the 1970s.

Helmreich (1996) has identified five generations of CRM encompassing the initiation of CRM programs, team building, focusing on specific skills and behaviours, integrating CRM into technical training and focusing on the management of human error and training in the limitations of human performance.

This chapter addresses the role of the pilot, crew communication, and crew management on automated aircraft, and their effect on CRM.

Well-defined Roles

Figure B7.1 (page 160) shows that 82 percent of respondents felt that the roles of the pilot flying (PF) and the pilot not flying (PNF) are always clear. Analysis of the negative responses (*n* = 102) revealed no statistically significant results.

Communication

Thirty-seven percent of respondents reported that there had been times when the other pilot had not told them something they needed to know for the safe conduct of the flight (see fig. B7.2, page 160).

A statistically significant difference was observed between the responses of Australian and Singaporean pilots (on the basis of nationality). Singaporean pilots were more satisfied with the level of communication than Australian pilots. This may reflect differences in cultural traits between Anglo-Europeans and Asian groups (see Hofstede 1980).

Table B7.2 (page 161) suggests a trend toward a significant difference (0.07522) between pilots with different first languages. Captains who spoke English as their first language tended to perceive more communication difficulties when compared to captains who spoke an Asian language. The reasons for this difference are not clear; however, the difference in the sample size may have affected the reliability of this result.

Crew Management

Most of the respondents reported that crew management was not a problem on advanced-technology aircraft (see fig. B7.3, page 161). Thirteen percent, however, had experienced difficulty with crew management. Table B7.3 (page 162) presents a breakdown of pilot rank and aircraft flown by those respondents who found CRM to be a problem on advanced-technology aircraft. More Airbus pilots (19 percent) reported a problem than Boeing pilots (12 percent).

The development of automation has also produced instances where the crew have unconsciously relinquished their command responsibilities momentarily to the automated systems. In such situations, pilots have unconsciously become "observers" rather than "controllers."

Figure B7.4 (page 158) indicates that 16 percent of respondents recognised the existence of this phenomenon during flight.

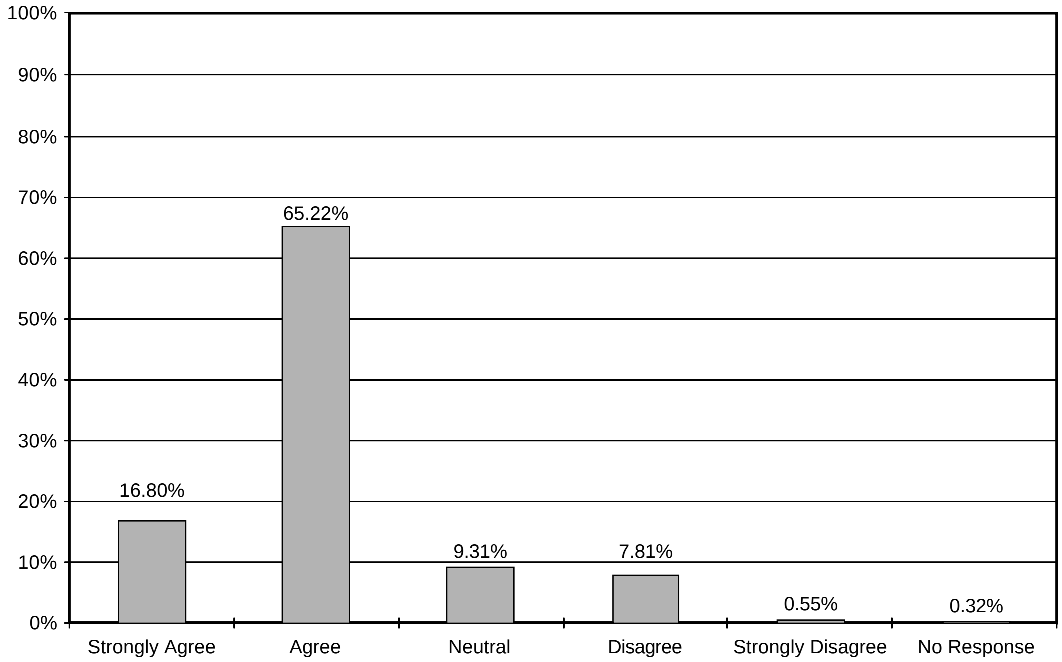
Analysis of this result revealed that this phenomenon is apparent across all aircraft types, pilot ranks, age categories and experience levels.

Table B7.4 (page 162) indicates a relatively even distribution across pilot ranks and aircraft manufacturers.

Conclusions

Pilots agree that their roles (pilot flying and pilot not flying) are well defined and that crew management is generally not a problem on advanced-technology aircraft.

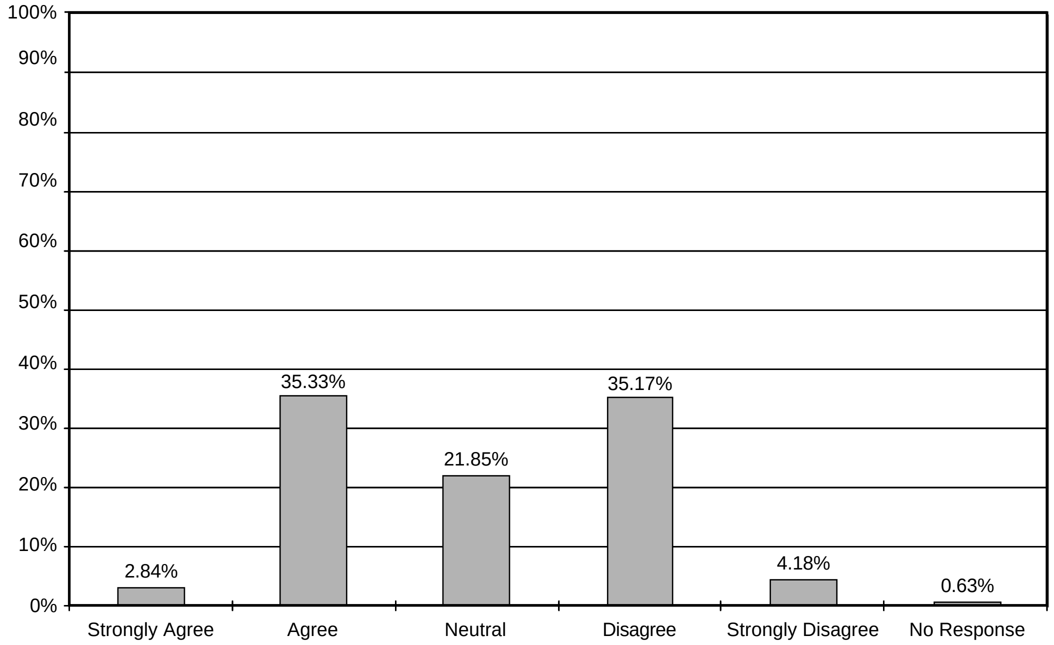
(continued on page 161)



“On this aircraft, the role of the pilot flying (PF) and pilot not flying (PNF) is always clear.”

Source: Bureau of Air Safety Investigation

Figure B7.1



“There have been times when the other pilot has not told me something I needed to know for the safe conduct of the flight.”

Source: Bureau of Air Safety Investigation

Figure B7.2

Table B7.2
“There have been times when the other pilot has not told me something I needed to know for the safe conduct of the flight.”

	English	Asian	European
Captain	41.5% (261/628)	25.6% (11/43)	52.6% (10/19)
First Officer	35.5% (148/417)	36.3% (12/33)	–

Source: Bureau of Air Safety Investigation

There is evidence of “passive command,” and while the percentage of pilots who reported this problem is relatively low (16 percent), this phenomenon requires continued monitoring. The topic deserves to be addressed in CRM courses and during conversion/recurrent training.

One of the aims of CRM training is to create a cockpit environment where both crew can communicate openly and effectively. The designers of CRM programs have recognised this and attempted to minimise the effects of cross-cockpit gradient (age, pilot rank and cultural differences between crew members) which may inhibit communication. The responses to question B7.2 (“There have been times when the other pilot has not told me something I needed to know for the safe conduct of the flight”) suggest that more effort needs to be put into the improvement of communications between crew. In the absence of historical data, we are unable to assess whether technology has specifically aided communication in the cockpit.

Recommendation

The Bureau of Air Safety Investigation recommends that airline operators (R9800028):

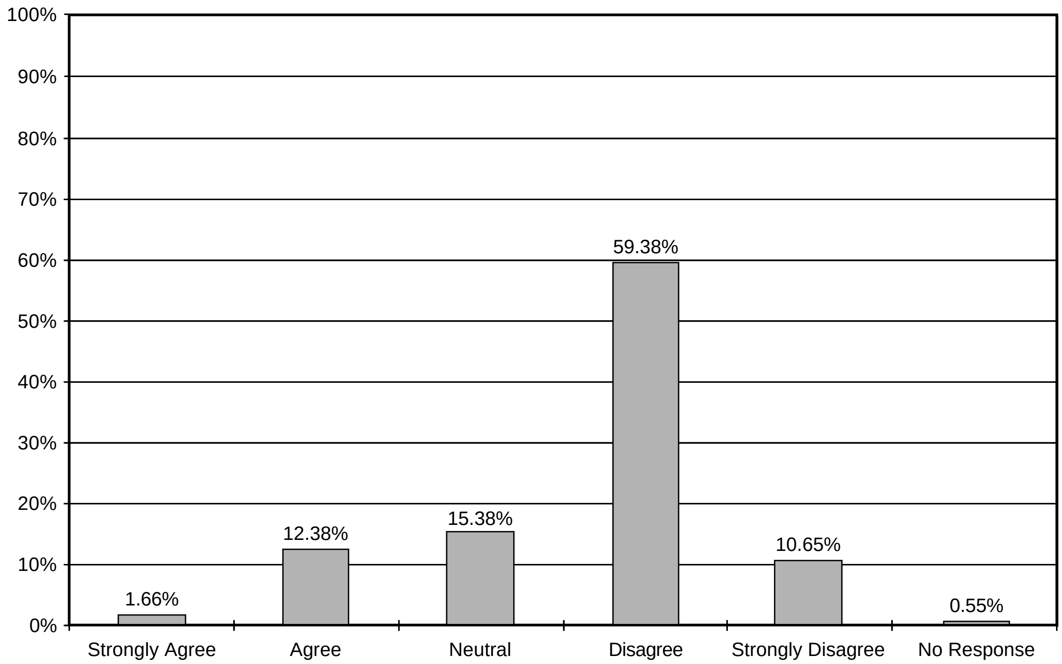
Employ appropriate methods and examples during initial and refresher CRM training to enhance the transmission of safety information between flight crew members during flight. Such training should stress the consequences of not communicating essential flight safety information.

Flying Skills

Introduction

The opportunities for pilots to maintain their manual flying skills have decreased significantly since the introduction of advanced-technology aircraft; for example, improvements in autopilot and autoland systems, airline policies, and long-haul operations have reduced the opportunities for hand-flying. Some airlines have introduced additional simulator sessions to allow pilots to practise their manual flying skills.

This chapter discusses how pilots perceive the effect of automation on their manual flying skills.


“Crew management is a problem on advanced-technology aircraft.”

Source: Bureau of Air Safety Investigation

Figure B7.3

Table B7.3
"Crew management is a problem on advanced-technology aircraft."

	Captain	First officer
Airbus	19.7%	18.2%
Boeing	12.9%	12.6%

Source: Bureau of Air Safety Investigation

Table B7.4
"I sometimes find the automated systems taking over command of the aircraft."

	Captain	First officer
Airbus	17.4%	14.8%
Boeing	13.7%	18.5%

Source: Bureau of Air Safety Investigation

Skill Retention

Figure B5.1 indicates that 85 percent of respondents prefer to hand-fly part of every trip to retain their skills. A statistically significant difference was noted between the responses of captains and first officers, with first officers more likely to prefer to "hand-fly part of every trip" than captains (see table B5.1).

Table B5.1
"I prefer to hand-fly part of every trip to keep my skills up."

	Captain	First officer
Airbus	85%	92%
Boeing	81%	90%

Source: Bureau of Air Safety Investigation

Skill Assessment

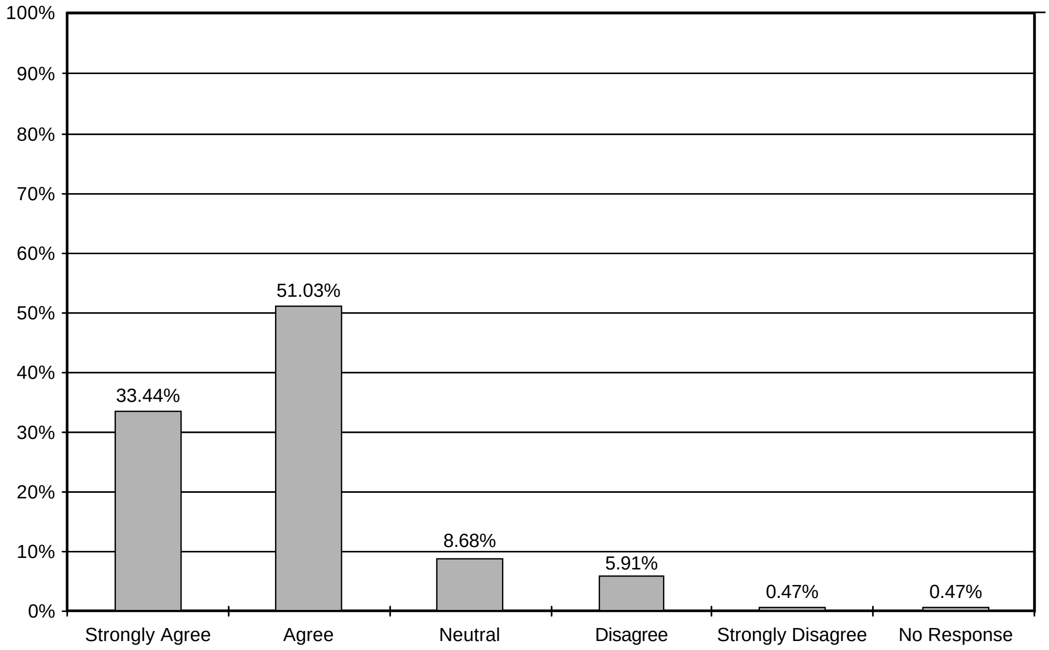
Forty-three percent of pilots considered that their manual flying skills had declined since they started flying advanced-technology aircraft (see fig. B5.2, page 163).

Table B5.2 (page 163) presents a breakdown by pilot ranks and aircraft types flown by those pilots who agreed that their flying skills had declined since they started flying advanced-technology aircraft. These results are relatively evenly distributed between pilot ranks and aircraft manufacturers.

Conclusion

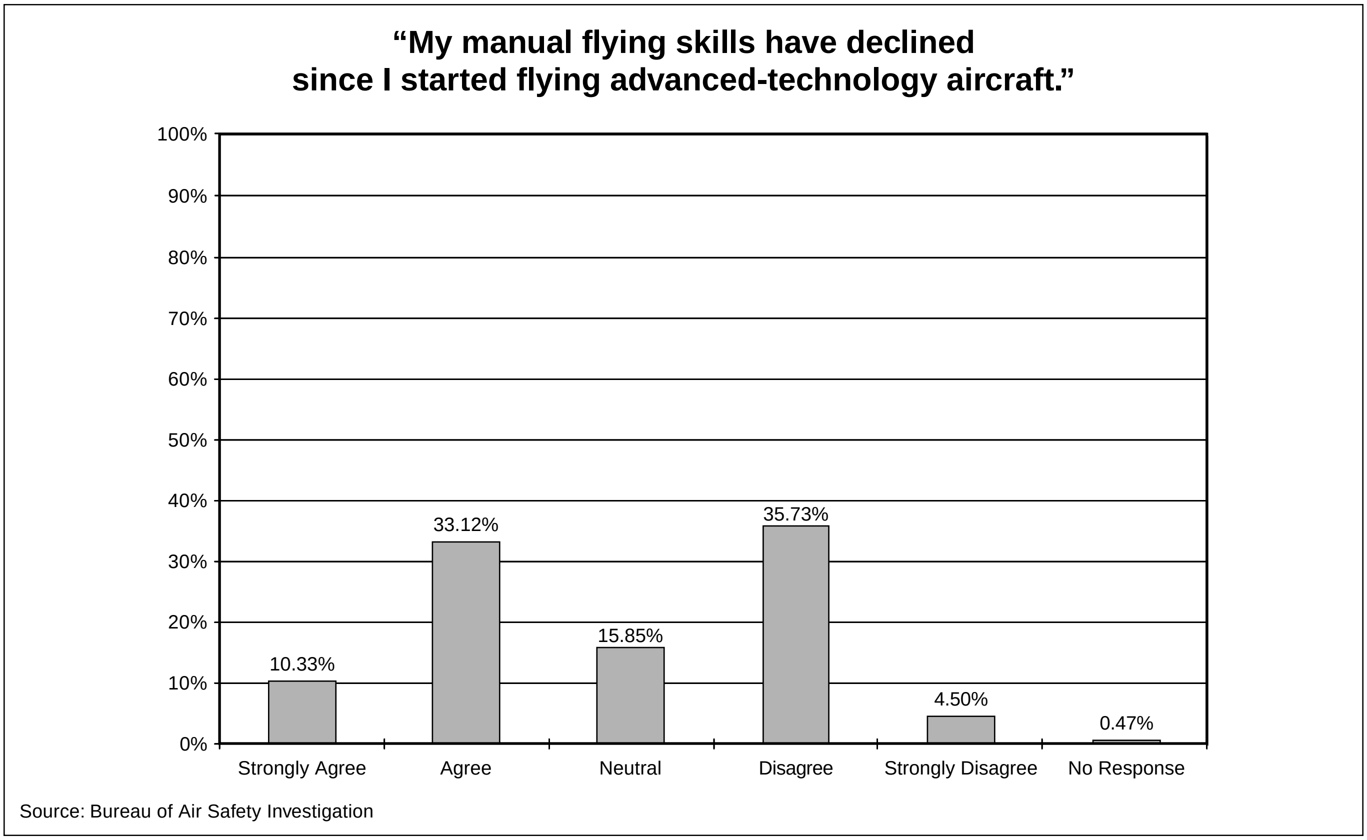
Most pilots hand-fly their aircraft at some stages of each flight to maintain an acceptable skill level. Anecdotal evidence indicates that the main reasons for this are a pilot's natural satisfaction in performing manual flying tasks, the requirement to perform manual flying exercises during simulator sessions (including

"I prefer to hand-fly part of every trip to keep my skills up."



Source: Bureau of Air Safety Investigation

Figure B5.1



Source: Bureau of Air Safety Investigation

Figure B5.2

Table B5.2
"My manual flying skills have declined since I started flying advanced-technology aircraft."

	Captain	First officer
Airbus	45.5%	48.2%
Boeing	40.5%	45.2%

Source: Bureau of Air Safety Investigation

recurrent training and licence renewal) and the need to be able to manually fly the aircraft should the automated systems fail to function as expected (see page 157, "Automation policy").

It would appear that the attempts of both the pilots and their airlines have not succeeded in maintaining a perceived level of manual skills. Of concern are pilots who continue to manually control an aircraft with a diminishing level of skill. This has been recognised by some airlines who have implemented supplementary simulator programs to compensate for a perceived loss of manual flying skills.

Some airlines have required pilots to demonstrate their manual flying skills during simulator exercises to fulfil the requirements set down by regulatory authorities. These requirements (for example, manually flown instrument approaches or emergency descents) are often outdated and thus not appropriate for the current level of technology.

Further research is needed to determine how pilots can best maintain their manual flying skills, the reliability of autopilot systems and the appropriateness of licence-renewal procedures.

Recommendation

The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (R980029):

Ensure that all recurrent and rating renewal simulator exercises are appropriate considering the level of automation fitted to the aircraft type. Such exercises should reflect the level of serviceability that the pilot may be expected to encounter during line operations.

General

Introduction

This chapter analyses the results of the General section of the survey, which comprised six unrelated questions addressing automation reliability, database errors, teaching techniques, flight-crew alertness, and perceived difficulties during conversion training. Five of these questions gave respondents the opportunity to give a written response.

Encountering Abnormal/Emergency Situations

Forty-eight percent of respondents had experienced an abnormal or emergency situation while flying their current aircraft in operations excluding simulator sessions and base training.

Analysis of the type of emergencies pilots had experienced reveals that flight control problems (17 percent) were mentioned most often, followed by engine failure/shutdown (13 percent), FMC/FMGS malfunctions (10 percent), emergencies involving engines other than failure/shutdown (10 percent), hydraulics (8 percent), electrical (7 percent) and in-flight emergencies involving warnings and messages (7 percent).

The percentage of pilots who indicated that they had encountered an abnormal or emergency situation was higher than expected.

The list of emergencies and abnormal situations provided by pilots answering this question included several situations which are unique to automated aircraft. These were FMC failure (including double FMC failures) and false electronic warnings. It could not be determined from the data provided whether the high percentage of flight control problems can be attributed to an automated system. Most flight control problems related to the flap system, with pilots reporting asymmetric, partial or flapless landings. For example:

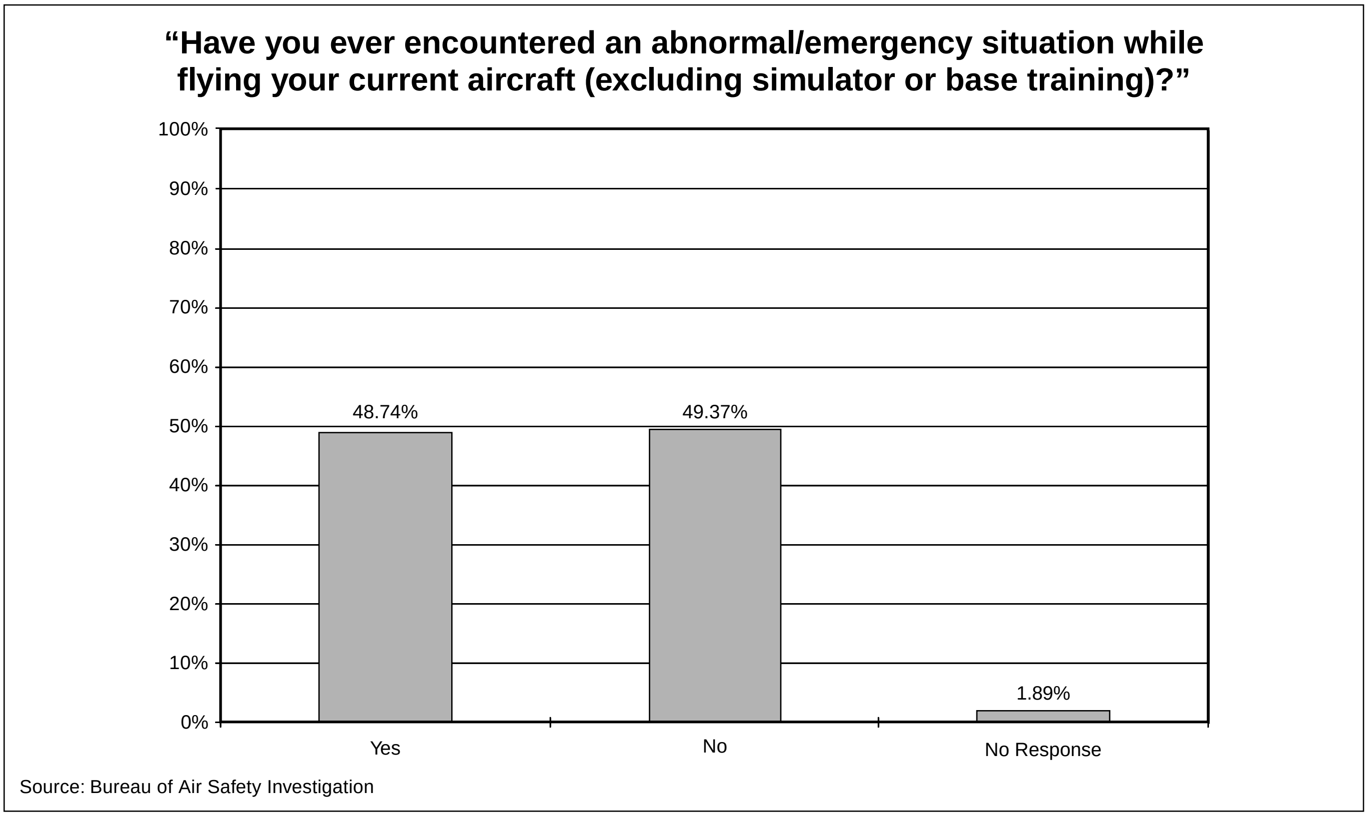
> "Asymmetric flaps on landing."
>
> "Flap failed to deploy below Flap 5, Flap 5 landing."
>
> "Flap malfunction, flaps locked, followed ECAM, landed with slats only."

Less frequent reports concerned navigation failures (Inertial Reference System), emergencies involving TCAS and problems attributed to personal electronic devices (PEDs). (PEDs include carry-on electronic items such as laptop computers and mobile phones, which may interfere with the aircraft's electronic systems. Most airlines restrict the use of PEDs to the cruise phase of flight.)

This information should be of special interest to training departments and regulatory authorities when formulating training requirements for initial and recurrent training exercises.

Database Errors

The integrity of the computerised navigation and performance systems rests on the quality of the FMC/FMGS database. Avionics and aircraft manufacturers and regulatory authorities have recognised the potential for entering incorrect data through the FMC/FMGS. Flight crew are therefore required to make minimal manual input to advanced systems, compared with navigation and performance systems of previous generations of navigation systems such as Inertial Navigation



Source: Bureau of Air Safety Investigation

Figure B9.1

System. Databases are updated on a regular basis (approximately every 28 days). If an error is detected in the database, the operator advises the pilots of the error and relies on them to manually correct those errors that apply to the route they are flying. Such errors may stem from an authority providing outdated or incomplete data to the aircraft manufacturer, from data-entry errors, or from electronic data transfer faults. Most airlines require the crew to cross-check the information in the database against printed information contained in en-route charts, instrument approach charts and NOTAMs. Currently, aircraft manufacturers are researching the concept of a "paperless" cockpit, wherein this cross-checking process may not be available.

Fifty percent of respondents reported that they had detected database errors.

Pilots reported that the most common database problems were errors in SID information, followed by incorrect waypoint information (latitude/longitude), and STAR information. Pilots also highlighted inconsistencies in route/track data, the use of outdated databases, and incorrect Navaid information. To a lesser extent, some information was missing from the database altogether or was at variance with chart information. Errors were also found in instrument approach data, aerodrome data (including gate position) and in holding pattern and runway information.

Pilot responses are summarised in fig. B9.2 below.

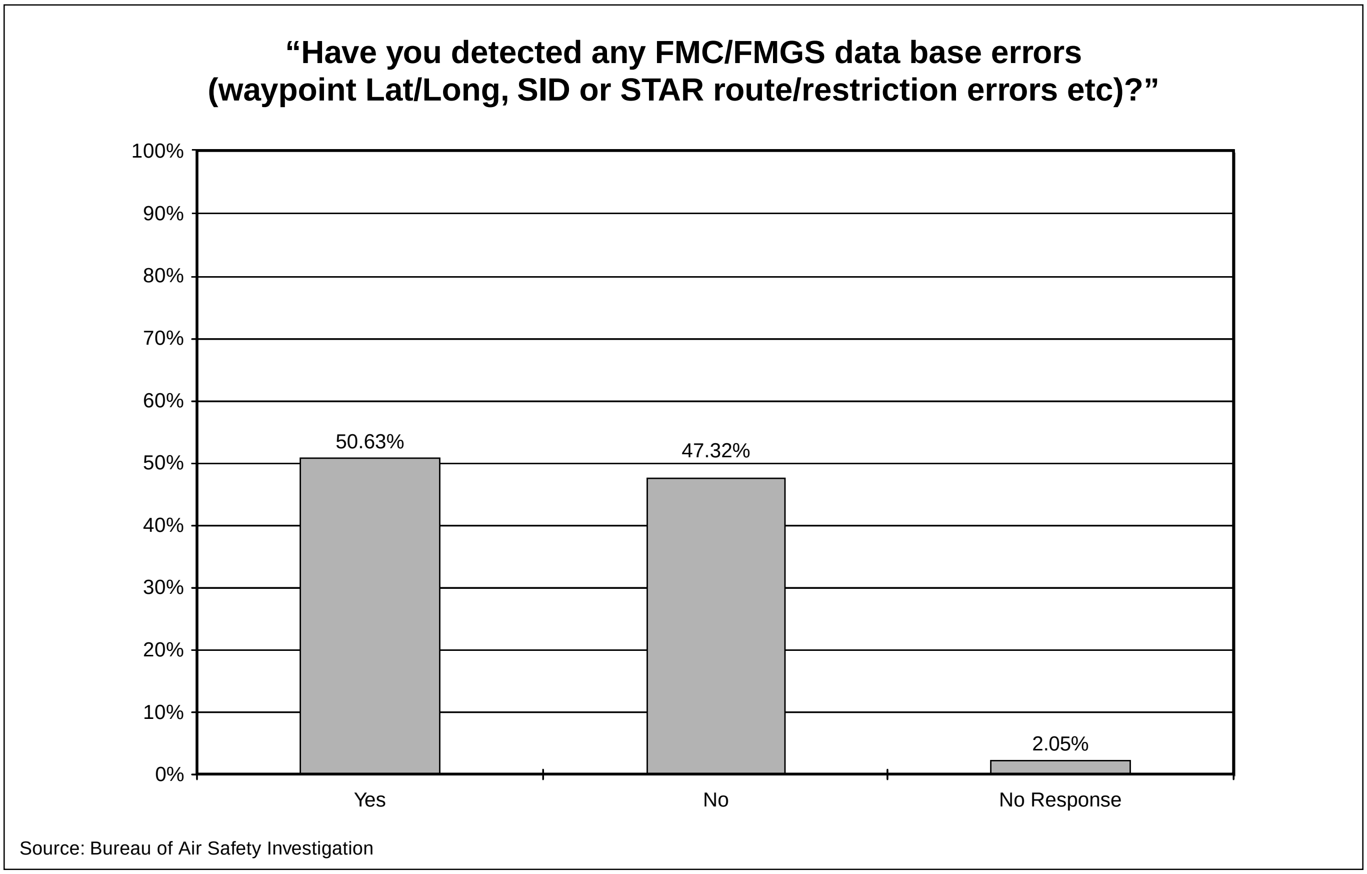
A majority of pilots have encountered errors in database information, including errors in aerodrome information, SID, en-route and STAR data.

The final safety net in the process of checking the accuracy of database information currently lies with the pilot, who should cross-check electronic data against printed data. Evidence suggests that human performance during such cross-checking tasks deteriorates over time; therefore, there is the likelihood that even with the best policy and intentions, this process could be compromised and database errors could be missed by the pilot. Furthermore, pilots have indicated (question B4.1) that they refer to their en-route charts far less on new-technology aircraft than on aircraft without an FMC/FMGS. This may further weaken the cross-checking process.

This deficiency needs to be addressed by both aircraft manufacturers and regulatory authorities if the goal of a paperless cockpit is to be attained.

Using Previous Accidents and Incidents as a Training Aid

Discussion with airline managers revealed that some airlines considered that they effectively used accident and incident



Source: Bureau of Air Safety Investigation

Figure B9.2

information in either initial endorsement training or during CRM refresher courses. Some respondents confirmed that they had discussed accident or incident scenarios during their recurrent/CRM training sessions. However, only 42 percent of respondents stated that they had ever discussed any advanced-technology aircraft accidents or incidents during their conversion training (see fig. B9.3).

When asked to list the accidents and incidents that were discussed during conversion training (see table B9.3), respondents listed a total of 28 identifiable accidents or incidents.

These results tend to confirm that some companies are discussing aircraft accident and incident data during conversion training programs, although more use could be made of the educational value of occurrences. Pilots are generally able to recall events which have been discussed during their training. Approximately 10 percent of pilots, however, recorded that they only had a vague recollection of accident or incident details, or that they had forgotten the details altogether.

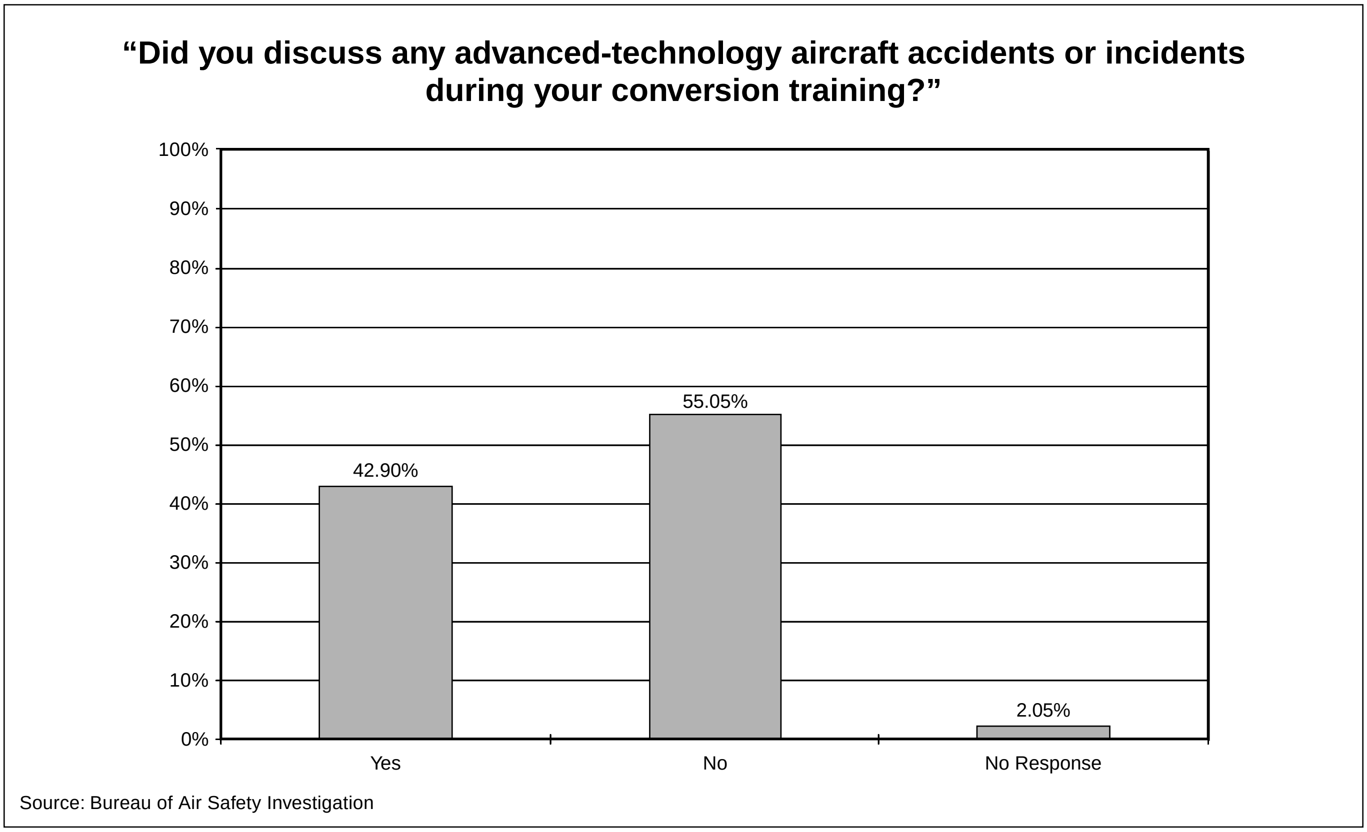
It also seems significant that very few pilots recorded the fact that they discussed accident and incident data pertaining to their own company, "company incidents — engine failures, hydraulic pump failures and fleet specific information," as one pilot stated. Another pilot stated that he had only discussed "other operators experiences."

Table B9.3
Most Commonly Listed Accidents and Incidents Discussed During Conversion Training

Category	Result
Accidents involving Airbus aircraft	20%
Bangalore, India (Airbus)	17%
Cannot recall details of discussion	9%
Nagoya, Japan (Airbus)	7%
Habshiem, France (Airbus)	7%
Kegworth, England (Boeing)	6%
Strasbourg, France (Airbus)	6%
Other (< 12 responses per category)	28%

Source: Bureau of Air Safety Investigation

Another aspect of these responses is that the accidents and incidents that have been nominated are now reasonably old. While the Nagoya, Japan, accident, which occurred on 26, April 1994, ranks fourth in discussion topics, only three pilots mentioned discussing the B-757 accident near Cali, Colombia (12 December 1995). This may confirm the notion that pilots seldom discuss accident and incident scenarios that are not related to the specific type of aircraft they are operating. There are no B-757 aircraft operating in the Asia-Pacific region. Often the same problem or scenario is repeated in various accidents



Source: Bureau of Air Safety Investigation

Figure B9.3

or incidents and reinforcement with new material can be an effective teaching tool. Also, as automated aircraft develop, new lessons may be learnt that need to be regularly presented to aircrew.

Flight-deck Fatigue

Figure B9.4 shows that 32 percent of respondents acknowledged that they had, at one time or another, inadvertently fallen asleep on the flight deck of an advanced-technology aircraft. This may relate to question B6.1 (“Times of low workload are boring”) in which 36 percent of respondents indicated that times of low workload in an automated aircraft were boring. Anecdotal evidence suggests that automation may make times of high workload more difficult and times of low workload even less arousing. However, in the absence of comparative figures for older-generation aircraft, it is not possible to conclude that fatigue is a greater problem on advanced-technology aircraft. Nevertheless, there is a clear message that airlines and regulator need to address the problem of pilot fatigue.

The focus of this question was on the concept of “inadvertent sleep,” as opposed to programmed rest or in-flight relief.

Some airlines have addressed this situation by installing pilot-alertness monitors. These systems monitor pilot input to the FMC, autopilot and radio transmissions. If the pilots fail to make inputs within a given period of time, the monitoring system will call for a response by the pilot such as responding to a message on the FMC screen. If a response is not made within a specified time, the level of response is increased, culminating in an aural alarm that must be cancelled by the pilot. Furthermore, in some airlines, cabin staff regularly visit the cockpit to check on the alertness of the pilots.

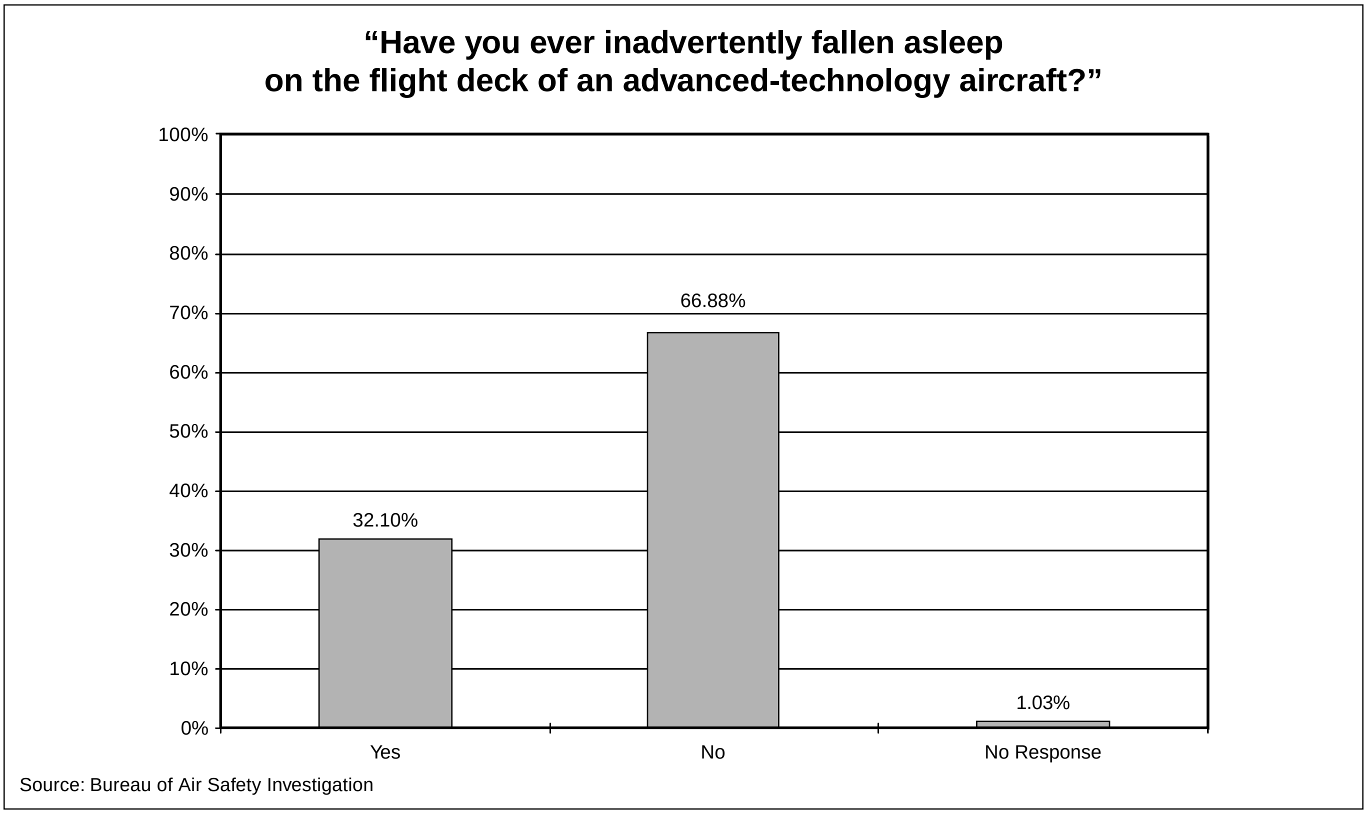
With developing automation, the level of activity during the cruise phase of flight is continuing to reduce. Navigation and communication tasks have significantly reduced, compared with the previous generation of aircraft.

Conversion Difficulties

Pilots were asked to nominate the most difficult part of their conversion to advanced-technology aircraft. A significant proportion (63 percent) of respondents answered this question. Their responses are summarised in table B9.5 (page 168) below.

To express their difficulties, pilots employed terms commonly used to describe a new learning experience:

- Accepting FMC data;
- Adapting to the FMC and MCP;
- Assimilating all the information;
- Becoming familiar with the FMC;



Source: Bureau of Air Safety Investigation

Figure B9.4

Table B9.5
Difficult Aspects of Conversion to Advanced-technology Aircraft

Difficulty	%
FMC/FMGS	42%
Autopilot / auto throttle mode selection	13%
CRT instrumentation / instrument scan	10%
Understanding automation philosophy	8%
Information overload	6%
Mode control panel	5%
Other	16%

Source: Bureau of Air Safety Investigation

- Coming to grips with (to terms with automation concepts);
- Finding information in the FMC;
- Getting used to the FMC;
- Learning different manipulative skills; and
- Understanding and operating the FMC.

Such language supports the hypothesis that the challenge faced by pilots during conversion training on an automated aircraft is largely conceptual rather than physical.

The areas in which pilots experienced most difficulty during their conversion training correlate closely with their responses to question B8.7, in which pilots were asked what could be done to improve the training they received on their aircraft. Of the respondents (*n* = 157) who specifically addressed automation, 58 percent stated that they would like more "hands-on" training and the provision of an FMC trainer or fixed-base simulator. They then suggested that in-depth training on automated systems (19 percent), teaching about automation philosophy (14 percent) and more training on mode characteristics would have improved their training.

The request for more hands-on training is not necessarily a request for more hands-on flying experience, but reflects the need to further explore, or consolidate, systems knowledge. Approximately 9 percent of pilots responding to question B9.5 commented upon the large amount of information they were expected to assimilate in such a short period of time.

It appears that much of the training provided to pilots is focussed on the physical skills needed to comply with standard operating procedures, with minimum emphasis being given to systems knowledge. Safety could be enhanced if, during the initial stages of training, pilots were provided with a thorough systems knowledge and an awareness of the design philosophies that guided the makers of automated systems.

Recommendations

The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (R980030):

Review the minimum standards for the quality of information provided in FMC databases with the aim of eliminating FMC database errors.

The Bureau of Air Safety Investigation recommends that airline operators (R980031):

1. Include in the ground-training phases of pilot endorsement courses:

   (a) sufficient technical knowledge of aircraft systems; and,

   (b) knowledge of the design philosophies employed by aircraft system manufacturers;

   to give the pilots sufficient systems understanding to permit analysis of system abnormalities and to determine appropriate responses in situations for which checklists are not available.

2. Consider the safety lessons from discussions of incident and accident scenarios during all initial, recurrent and CRM training programs.

The Bureau of Air Safety Investigation recommends that aircraft design authorities and airline operators (R980032):

Consider effective systems and procedures to ensure that flight crew of automated aircraft do not inadvertently fall asleep during flight.

Mode

Introduction

Automated aircraft provide pilots with a large number of functions and options for carrying out control tasks under varying circumstances. Appropriate mode selection should be underpinned by knowledge of systems operations (and the operation of the system) in order to satisfy new monitoring and attentional demands to track which mode the automation is in and what it is doing to manage the underlying processes. Failure to support these new cognitive demands may result in mode error (Sarter and Woods, 1995).

The modern automated aircraft may be controlled by the autopilot system from approximately 400 feet after takeoff to the completion of the landing roll following an automatic landing. Modes are selected via the MCP, while mode engagement is confirmed via the flight mode annunciator (FMA). Some vertical modes may be further defined through the FMC, for example VNAV SPEED.

This chapter discusses the responses of pilots in relation to mode selection, mode awareness, mode transition and indication. We also report responses regarding the number of available modes, whether there are modes that are not understood, and whether the airlines set clear guidelines for the selection of modes during line operations.

Mode Indication

Approximately 80 percent of respondents looked at the FMA when they wanted to know what the aircraft was doing (fig. B1.10). The FMA indicates to the pilot which mode is engaged. These annunciations also will confirm that the mode the pilot selected has actually engaged and secondly, will indicate mode reversion or transition.

Table B1.10 addresses pilot rank and aircraft manufacturer, and indicates the proportion of pilots who do not look at the FMA when they want to determine what mode the aircraft is in. Further analysis revealed a statistically significant difference between the responses of Boeing pilots compared with Airbus pilots, with Boeing pilots less likely to refer to the FMA than Airbus pilots. Also of concern are approximately 20 percent of respondents who either did not refer to the FMA or were unsure of the procedure they employed to determine what the aircraft was doing.

Mode Awareness

Approximately 11 percent of respondents reported that they did not always know what mode the autopilot, autothrottle and flight director was in (see fig. B3.1, page 170). Those respondents who did not know what mode the autopilot/autothrottle/flight director was in were relatively evenly distributed across pilot rank and aircraft manufacturers.

Table B1.10
"I do not look at the FMA when I want to know what the aircraft is doing."

	Captain	First officer
Airbus	10%	5%
Boeing	12%	8%

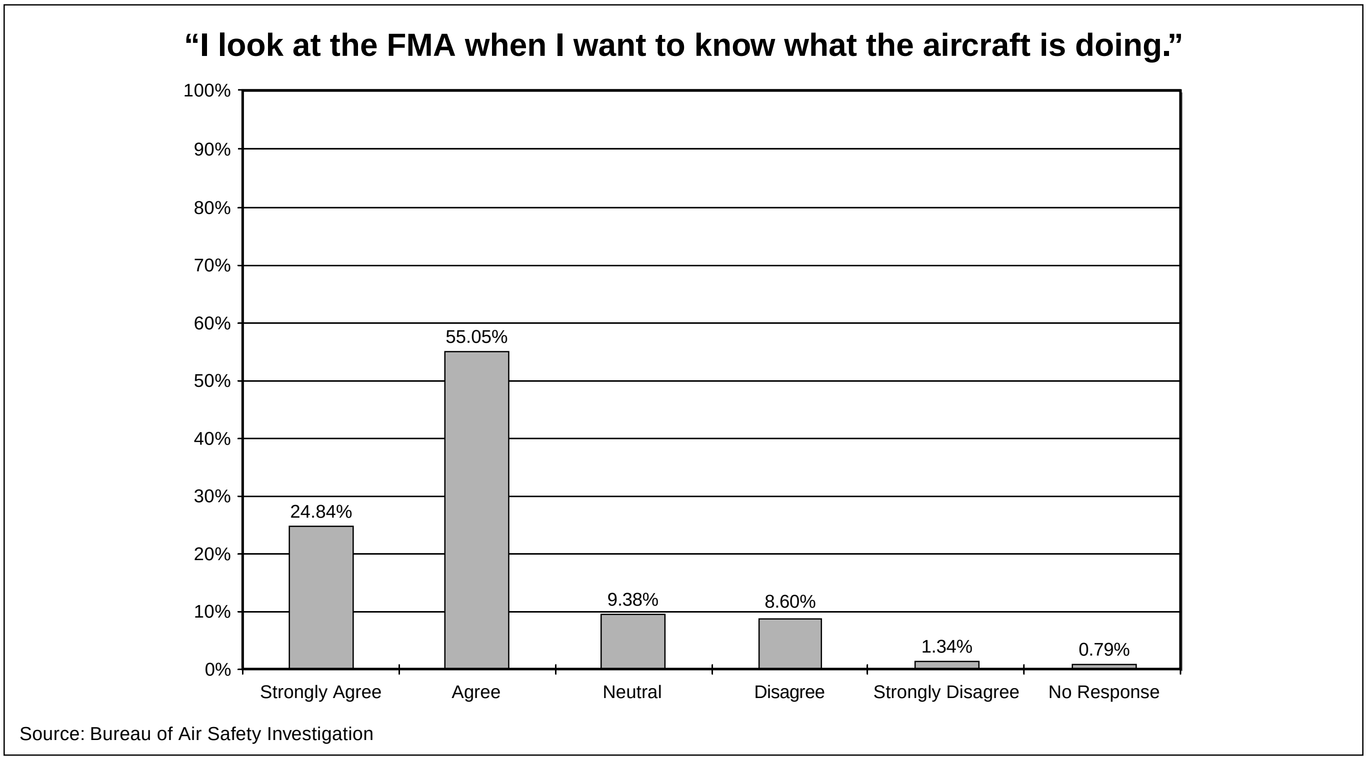
Source: Bureau of Air Safety Investigation

Of the 1,268 respondents, only 33 gave negative responses to both question B1.10 and B3.1 (2.6 percent), saying that they did not look at the FMA when they wanted to know what the aircraft was doing, and that they did not always know what mode the autopilot/autothrottle /flight director was in.

Mode Annunciation

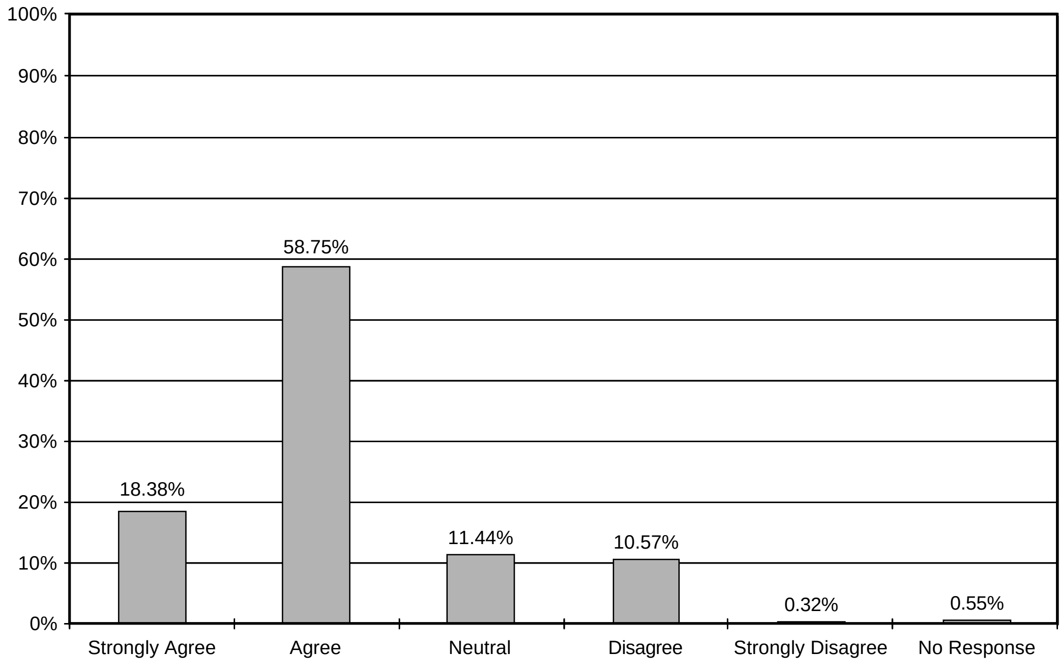
Twenty-one percent of pilots indicated that they were concerned that the automated systems might have been "doing something" they didn't know about (see fig. B3.2, page 170). Many functions which have, in the past, been controlled and monitored by the aircrew are now automatic, for example,

(continued on page 171)



Source: Bureau of Air Safety Investigation

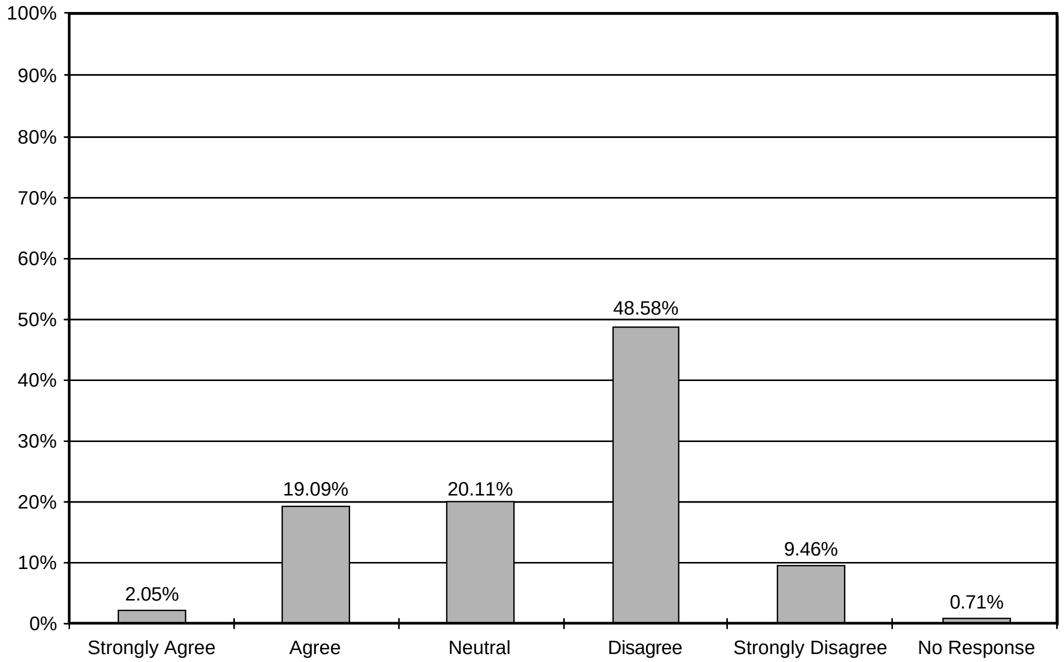
Figure B1.10



“I always know what mode the autopilot/autothrottle/flight director is in.”

Source: Bureau of Air Safety Investigation

Figure B3.1



“It worries me that the automated systems may be doing something that I don’t know about.”

Source: Bureau of Air Safety Investigation

Figure B3.2

the automatic transfer of fuel to maintain the optimum centre-of-gravity position and the automatic tuning of navigation aids. These functions may operate normally without warning or indication. Billings (1991) discusses the essential characteristics of human-centred automation:

> To command effectively, the human operator must be involved and informed. Automated systems need to be predictable and be capable of being monitored by human operators. Each element of the system must have knowledge of the others' intent.

Therefore, it is not surprising that such a significant percentage of pilots may be suspicious of systems over which the pilot has inadequate systems knowledge and little or no control.

Table B3.2 indicates the proportion of respondents who were worried that the automated systems might have been doing something that they didn't know about. Further analysis revealed that there was a statistically significant difference between the responses of Boeing pilots compared to Airbus pilots. Boeing pilots were less concerned about this issue than Airbus pilots.

Mode Selection

Figure B3.3 indicates that 73 percent of respondents had inadvertently selected a wrong mode.

Table B3.2
"It worries me that the automated systems may be doing something that I don't know about."

	Captain	First officer
Airbus	33%	35%
Boeing	16%	20%

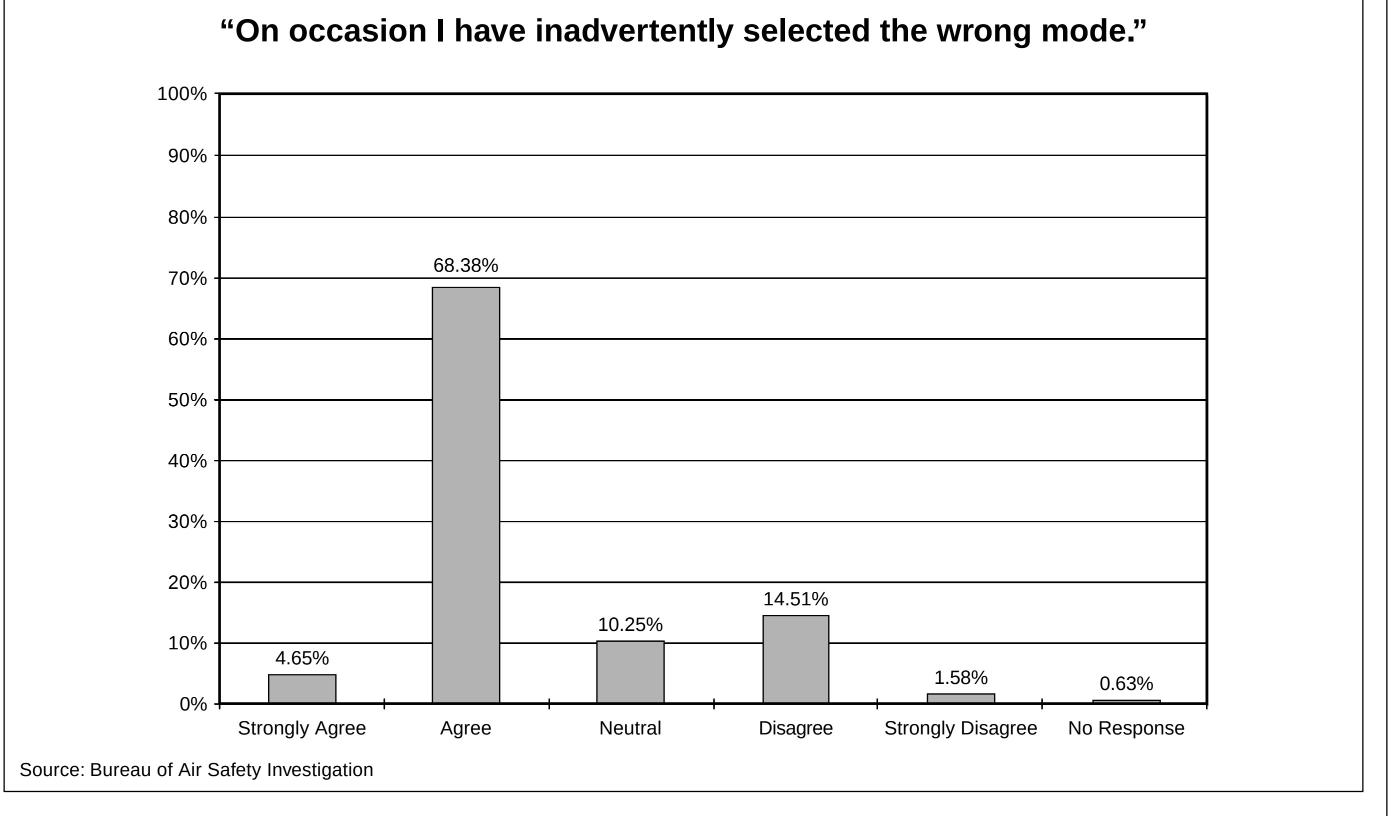
Source: Bureau of Air Safety Investigation

Table B3.3 (page 172) shows the proportion of respondents who had inadvertently selected the wrong mode, comparing pilot rank by aircraft manufacturer. Specifically, Airbus crews were more likely to report that they selected an incorrect mode than Boeing pilots.

Further analysis revealed that Asian-based pilots were less likely to have selected an incorrect mode than pilots based in Australia and New Zealand. This may correspond with the results of question B3.7 which noted that most Asian-based pilots reported that when it came to mode selection, their company set clear guidelines and procedures.

Subtle Mode Changes

Thirty-one percent of respondents reported that mode changes can occur without adequate indication (see fig. B3.4, page 172).



Source: Bureau of Air Safety Investigation

Figure B3.3

Table B3.3
"On occasion I have inadvertently selected the wrong mode."

	Captain	First officer
Airbus	76%	83%
Boeing	72%	74%

Source: Bureau of Air Safety Investigation

This relates to the adequacy of visual and aural warnings associated with mode changes. Pilots reported that mode changes in the vertical plane (e.g., V/S [vertical speed] to FLCH [flight level change]) were particularly subtle and often went unnoticed for long periods. For example, when asked to outline the details of a specific event where they had difficulty with mode selection, mode awareness or mode transitions, pilots made the following written responses:

> *Subtle changes from VNAV PATH to VNAV SPEED during descent.*
>
> *The subtle changes or noticeability of mode changes on the FMA.*
>
> *With VNAV path disconnect aircraft goes silently into control wheel steering mode.*
>
> *FMA annunciations on Saab better than on B-747-400. Saabs flash, where Boeing places a box around the changed mode.*
>
> *There are several situations in which the mode changes subtly causing annoyance, e.g., during descent in IDLE OPEN plus LNAV, an ATC instruction to adopt a HDG causes a reversion to VS, which was not a pilot instructed mode.*
>
> *Mode transition from VNAV PATH, SPEED to VNAV SPEED, idle if the aircraft leaves the path the FMC changes are subtle, e.g., VNAV PATH looks too much like VNAV SPEED.*
>
> *Sometimes a mode selection will inadvertently disconnect itself with no aural warning.*

Too Many Modes?

Authorities in the field of human/computer interaction (e.g., Norman) have warned that a large number of modes may work against the useability of automated systems. Yet contrary to this, only 9 percent of respondents agreed that there were too many modes available on the FMC/FMGS (see fig. B3.5, page 173).

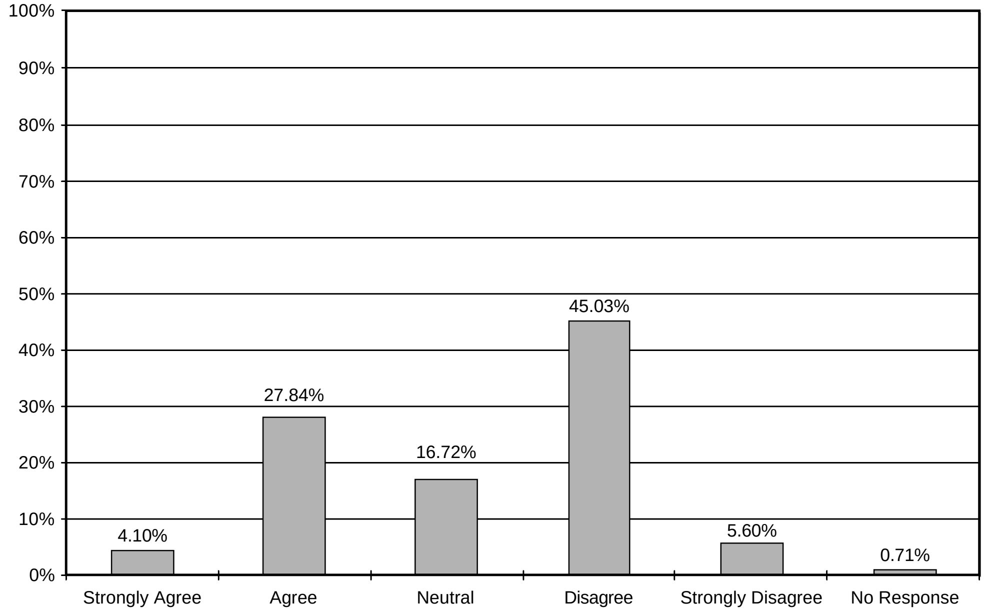
Understanding Mode Functions

Fifteen percent of respondents indicated that there were still some modes that they did not understand (see fig. B3.6. page 173).

Table B3.6a (page 176) shows that pilots operating Airbus aircraft were less satisfied with their knowledge of various modes than pilots operating Boeing aircraft.

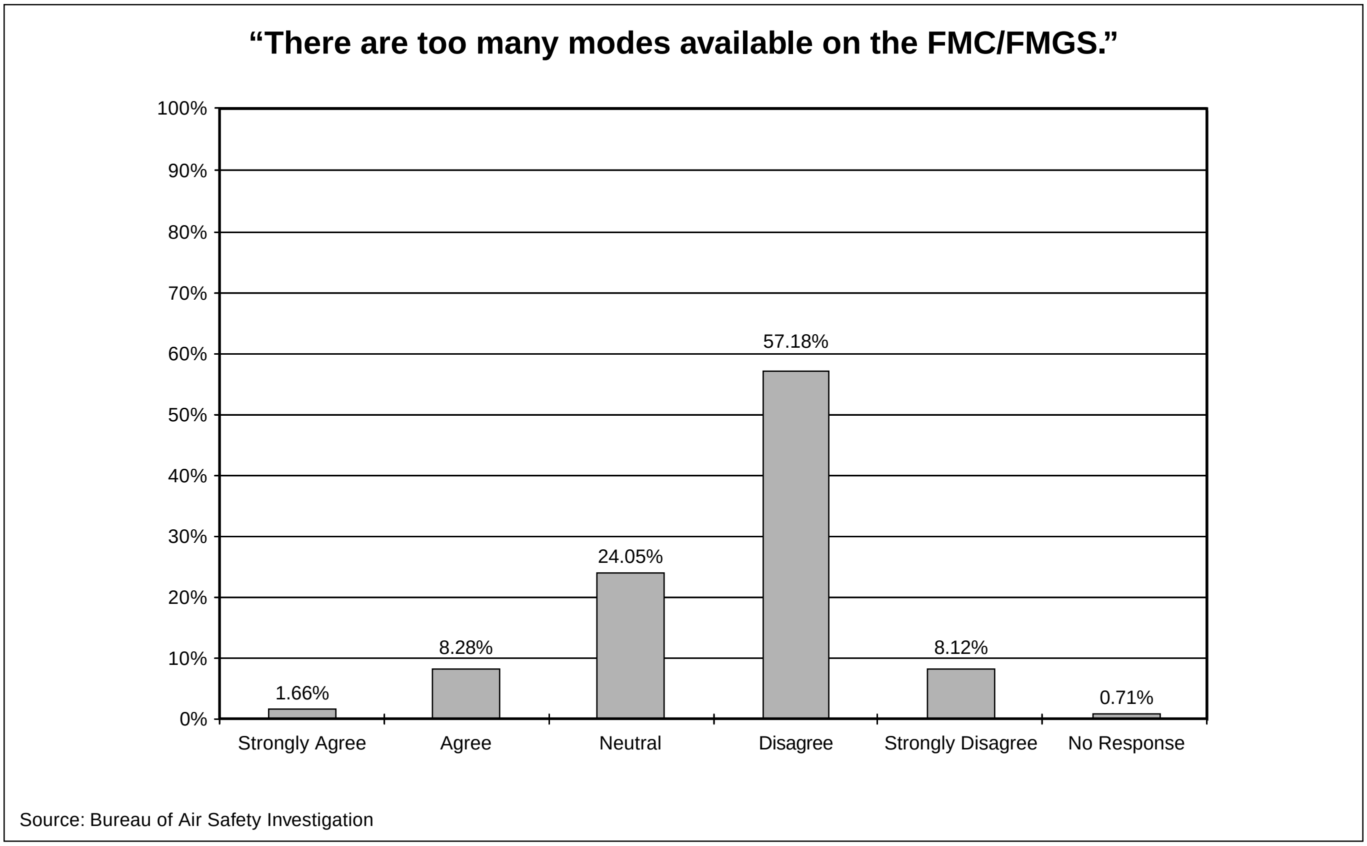
(continued on page 174)

"Mode changes can occur without adequate indication."



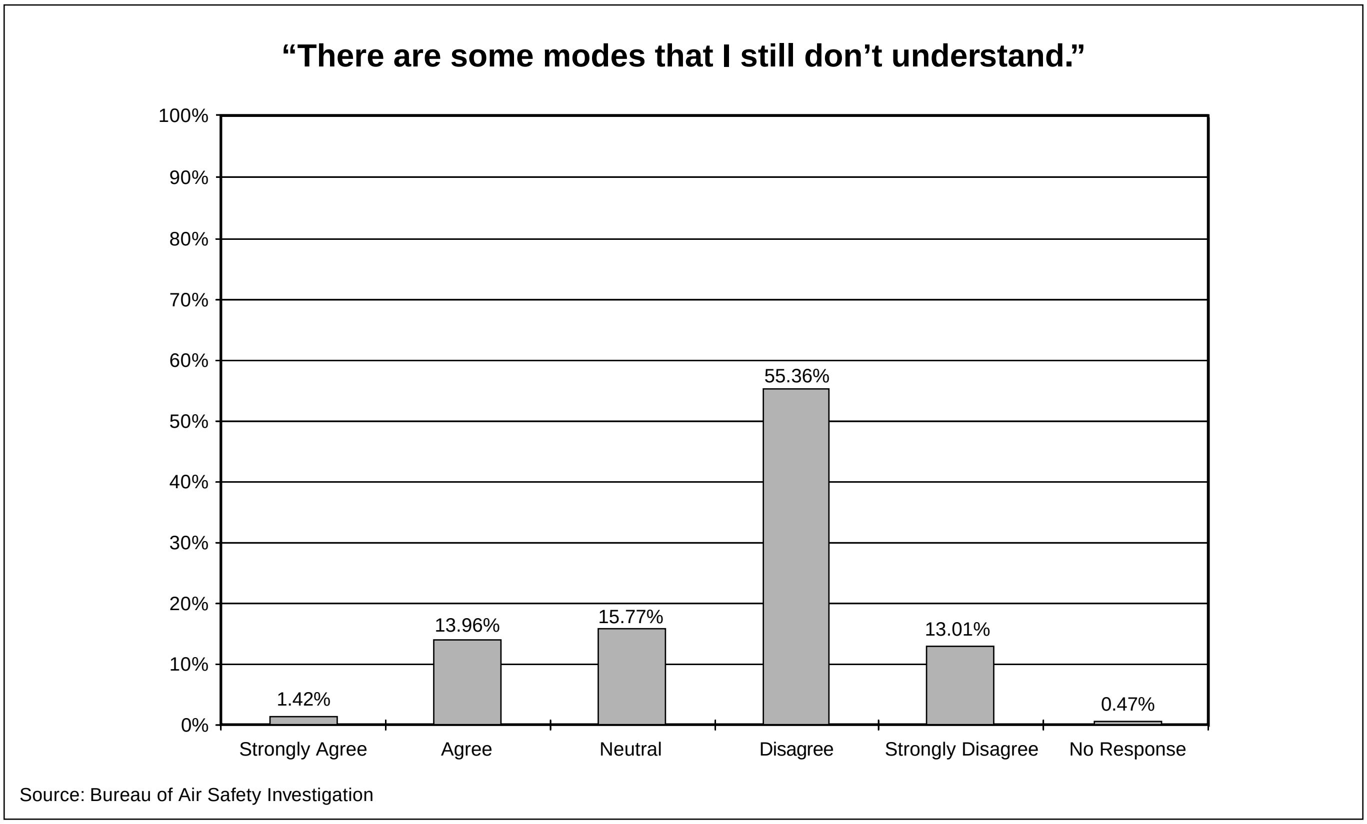
Source: Bureau of Air Safety Investigation

Figure B3.4



Source: Bureau of Air Safety Investigation

Figure B3.5



Source: Bureau of Air Safety Investigation

Figure B3.6

Table B3.6a
"There are some modes that I still don't understand."

	Captain	First officer
Airbus	22%	18%
Boeing	11%	15%

Source: Bureau of Air Safety Investigation

Further research needs to establish whether the modes that are not well understood by pilots are seldom used, or whether they are fundamental to the safe operation of the aircraft.

Table B3.6b lists 182 respondents (*n* = 195; valid cases for analysis = 182) who reported that there were still some modes that they didn't understand. The table shows that even pilots who had completed an engineering course prior to 1995 had gaps in their knowledge or understanding. Although these figures are relatively small, they may indicate deficiencies in recurrent training and line check programs.

Mode Selection Guidelines

Mode selection guidelines are a function of the aircraft manufacturer's and company's training philosophy. Interviews with airline management revealed that some airlines set rigid guidelines for mode selection, whereas others permitted pilots to make their own judgement about mode selection.

Eighteen percent of respondents were concerned that their company did not set clear guidelines and procedures for mode selection (see fig. B3.7, page 175).

Communicating Mode Selection

Twenty-four percent of respondents did not agree that a good crew briefing would always include what modes are to be used (see fig. B3.8, page 175).

These results are probably dependent upon the company's training philosophy; however, the importance of pre-planning and communicating intended mode selection is seen as a further safety net in the overall approach to safe operating practice. Mode selection is just as important as navigation aid selection. Incorporating this facet of the operation into the briefing structure reinforces the check and cross-check process.

Specific Events

Question B3.9 gave pilots the opportunity to outline the details of a specific event where they had difficulty with mode selection, mode awareness or mode transitions.

Three hundred and thirty-eight pilots (26 percent) provided a valid response to this question. Pilot responses were analysed against three criteria: the difficulty experienced, the mode and the phase of flight (see tables B3.9.1–3, page 176).

These results are of concern as the majority of accidents have been shown to occur during the final approach and landing phases of flight. As can be seen from table 3.9.3, descent and approach were the phases of flight in which most mode difficulties occurred.

Conclusion

A thorough theoretical and practical understanding of mode function is essential for the pilot of a modern automated aircraft.

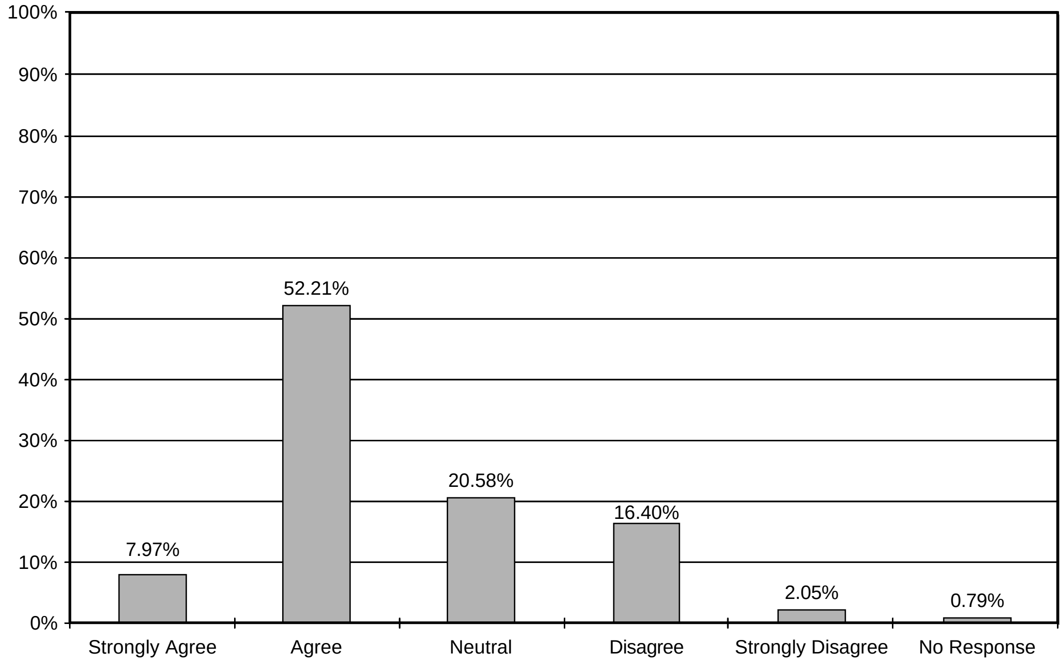
(continued on page 176)

Table B3.6b
"There are some modes that I still don't understand."

Engineering course completed	Captain		First officer		Second officer	
	Airbus	Boeing	Airbus	Boeing	Airbus	Boeing
1996	4	8	4	5	–	3
1995	8	6	3	22	1	12
1994	5	13	1	6	–	3
1993	–	6	1	9	–	–
1992	1	4	–	10	–	1
1991	1	7	–	2	–	–
1990	3	6	–	3	–	1
1989	4	4	–	1	–	2
1988	1	3	–	–	–	–
1987	2	1	–	–	–	–
1986	–	3	–	–	–	–
1985	–	1	–	–	–	–
1983	–	–	–	1	–	–

Source: Bureau of Air Safety Investigation

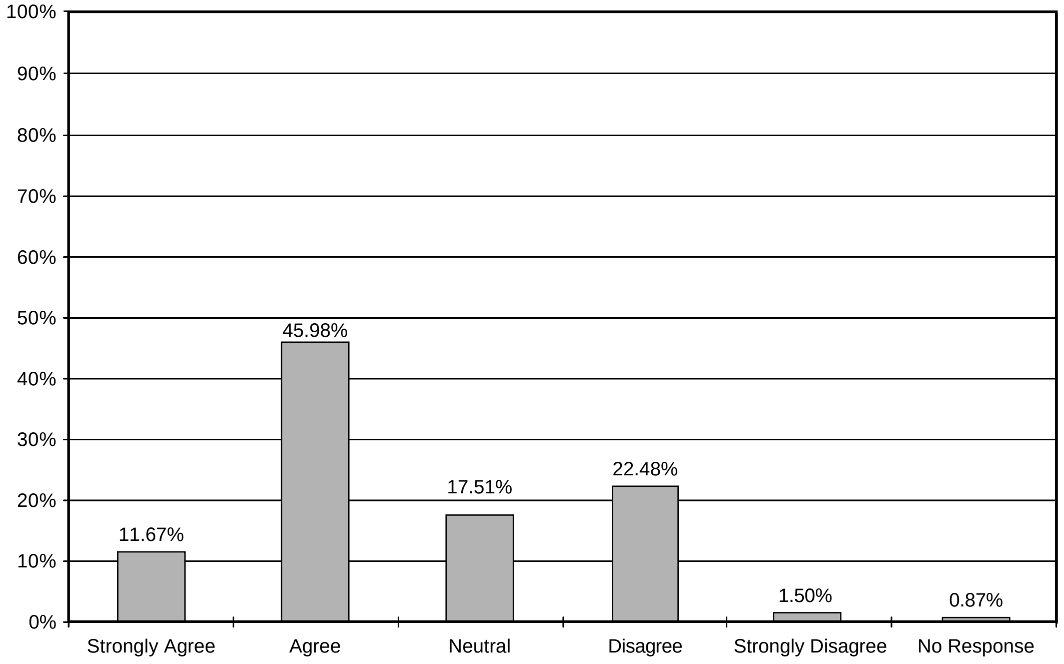
"When it comes to mode selection, the company sets out clear guidelines and procedures."



Source: Bureau of Air Safety Investigation

Figure B3.7

"A good crew briefing will always include what modes will be used."



Source: Bureau of Air Safety Investigation

Figure B3.8

Table B3.9.1
Nominated Difficulty

Difficulty	Response
Unaware of mode characteristics/ poor training/difficulty learning	28%
Mode reversion/not aware/subtle/ poor annunciation/uncommanded mode changes	21%
Pilot failed to select mode	6%
Other	35%

Source: Bureau of Air Safety Investigation

Table B3.9.2
Nominated Mode

Mode	Response
TOGA / max. continuous thrust	30.02%
Approach mode	25.73%
Vertical speed	20.32%
VNAV	13.09%
Other	10.84%

Source: Bureau of Air Safety Investigation

Table B3.9.3
Nominated Phase of Flight in Which Difficulty Was Encountered

Phase of Flight	Response
Descent	44%
Approach (precision)	18%
Go Around	16%
Approach (non-precision)	9%
Other	10%

Source: Bureau of Air Safety Investigation

This was highlighted in the report concerning the accident involving an A300B4-622R aircraft at Nagoya, Japan, in 1994 (Aircraft Accident Investigation Commission, 1996), which listed the following as two of the twelve causes of the accident:

(2) The crew engaged the autopilot while go-around mode was still engaged, and continued the approach; and

(6) The captain and first officer did not sufficiently understand the flight director mode change and the autopilot override function.

Survey results presented in this chapter have revealed various inadequacies in both aircraft design and training.

Over 30 percent of respondents reported that mode changes could occur without adequate indication. Aircraft manufacturers need to ensure that mode changes (especially automatic mode transitions) are adequately annunciated. Preferably, mode changes should be accompanied by a discrete audible tone.

Mode selection is an important aspect of controlling an automated aircraft. A comprehensive understanding of mode selection, mode function and the consequences of inappropriate mode selection are required by the crew. Traditionally, pilots have been required to obtain a 100 percent pass in the fuel, and weight and balance sections of the type-rating examinations. Failure to uplift sufficient fuel, or the incorrect loading of an aircraft, is potentially disastrous. Similarly, a lack of knowledge regarding mode usage is equally dangerous. Mode operation (both practical and theoretical) should be considered as important as fuel and loading calculations for a modern automated aircraft.

Some airlines do not set clear guidelines and procedures when it comes to mode selection. They view the setting of guidelines as contradicting the freedom of the operating pilot to use an appropriate mode for the in-flight situation. There are two important issues here. The first includes the recognition that guidelines, rules or policies are valuable aids to the pilot, especially when newly endorsed in type. The second includes the importance of a consistent policy that flows from the initial simulator training through to line operations. Similarly, it would appear that briefings could be improved by including the intended use of modes during any given phase of flight.

The written responses to question B3.9 ("Please outline the details of a specific event where you had difficulty with Mode Selection, Mode Awareness or Mode Transition") provide a valuable insight into the mode difficulties experienced by pilots. Those respondents who reported that they had been unaware of mode characteristics appeared to have either poor training and/or had difficulty in learning. Difficulty with the Take-Off Go-Around (TOGA) mode or maximum continuous thrust mode was the most commonly reported problem.

The following comment summarises one pilot's perception of an event.

> *The area that causes the greatest problem is a go-around. It is a real problem for two reasons: We never practice normal two-engine visual go-arounds, even in the simulator. It all happens so fast it is difficult to keep up with the FMA changes and level out at a low (2,000 ft) altitude.*

Possibly one remedy to this situation would be the extension of a "free play" simulator session in which pilots can practice or explore whatever event they wish. Alternatively, specific exercises could be included in line-orientated flight training (LOFT) exercises.

Recommendations

The Bureau of Air Safety Investigation recommends that aircraft design authorities (R980033):

Consider a requirement to ensure that all FMGS mode changes are visually and aurally annunciated.

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980034):

Review their procedures with regard to mode selection and consider:

(a) if flight crews should state intended mode selection during all flight crew briefings;

(b) if flight crews should announce and acknowledge all mode changes during flight;

(c) refresher training regarding mode mechanics and mode usage on a regular basis; and,

(d) clear and consistent guidelines regarding mode usage.

The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (R980035):

Review the achievement requirements for aircraft technical examinations with the aim of improving the knowledge pilots possess regarding mode characteristics and application.

Situational Awareness

Introduction

Helmreich and Foushee (1993) identify situational awareness as an "outcome rather than a specific set of mission management behaviours." They nominate preparation, planning, vigilance, workload distribution and distraction avoidance as key factors when considering effective situational awareness.

Orasanu (1993) describes situational awareness as the interpretation of "situational cues." The crew must analyse these cues to determine whether a problem exists that may require a decision or action. Successful interpretation relies on knowledge and experience. For example, airborne weather radar provides the crew with vital cues regarding en route weather. If an area of hazardous weather is indicated on the radar, the crewmembers must evaluate their situation with respect to their training and previous knowledge and make a decision. If they decide to track clear of the hazardous weather, they must also consider other information such as conflicting traffic and surrounding terrain.

In response to question B9.3 (concerning which advanced technology accidents were discussed during conversion training) pilots nominated many accidents that related to inadequate situational awareness. One such example was that of American Airlines Flight 965, which, during a scheduled service between Miami [Florida, United States] International Airport and Cali, Colombia, and operating under instrument flight rules (IFR), crashed into mountainous terrain during descent. The aircraft impacted terrain at approximately 8,900 feet above mean sea level (AMSL) near the summit of El Deluvio. One hundred and fifty-nine of the 163 passengers and crew sustained fatal injuries as a result of the accident. Colombian authorities (Aeronautica Civil of the Republic of Colombia, 1996) cite the following as the probable cause of the accident:

- The flight crew's failure to adequately plan and execute the approach to runway 19 at Cali and their inadequate use of automation;
- Failure of the flight crew to discontinue the approach into Cali, despite numerous cues alerting them of the inadvisability of continuing the approach;
- The lack of situational awareness of the flight crew regarding vertical navigation, proximity to terrain, and the relative location of critical radio aids; and,
- Failure of the flight crew to revert to basic radio navigation at the time when the FMS-assisted navigation became confusing and demanded an excessive workload in a critical phase of the flight.

This accident illustrates the dangers of poor situational awareness.

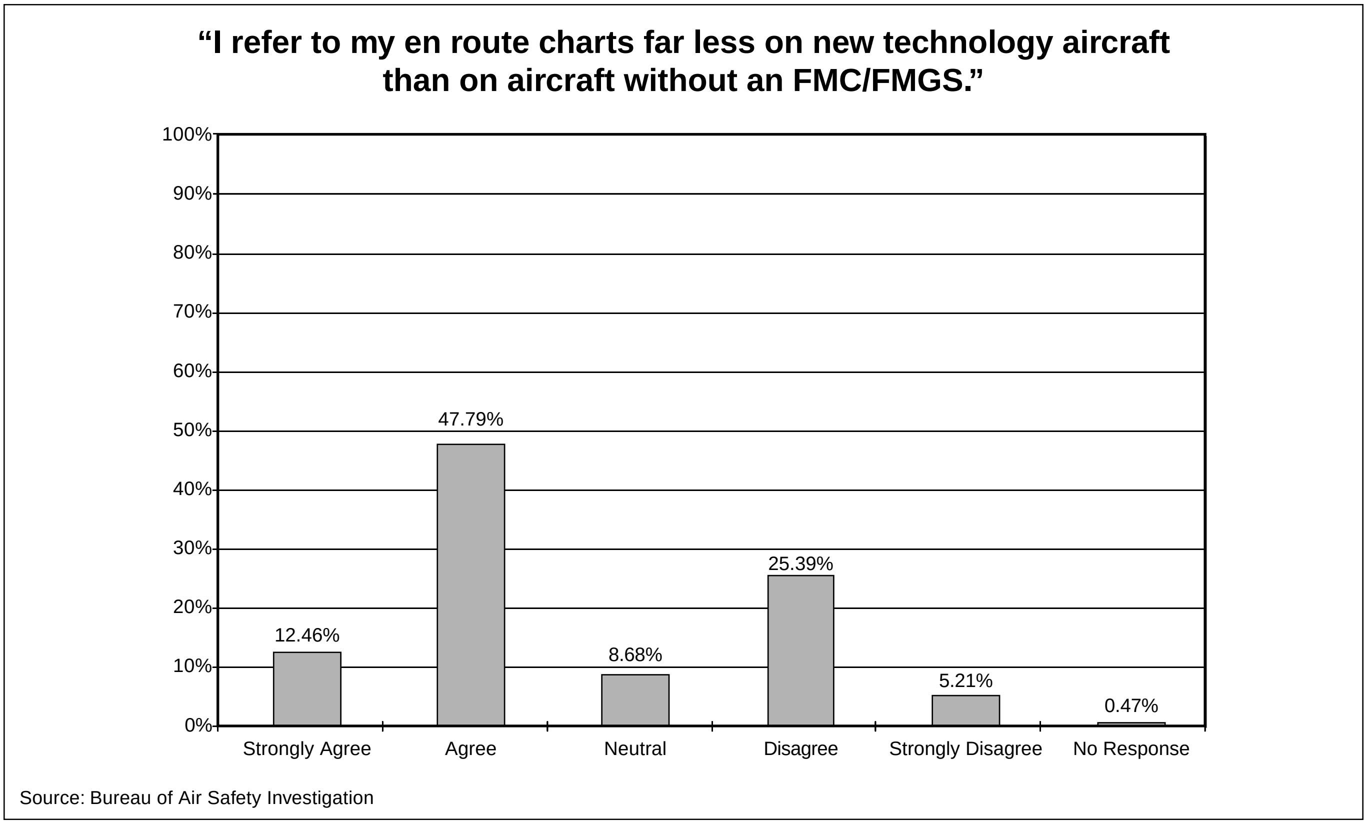
One of the problems facing pilots flying modern automated aircraft is that to gain adequate information, they must consult several sources. In older aircraft, the pilot obtained all necessary information from printed material (maps, charts, aircraft performance manuals and company policy); in an automated aircraft, some of this information is contained within the FMC, some in printed performance manuals and some on charts.

The FMC does not incorporate all the information provided in aircraft documentation. The navigation system does include information about SIDs, en route navigation, STARs, runways and airfield data. However, these systems do not often incorporate data that is essential for well-rounded situational awareness. For example, terrain features, lowest safe altitude (LSALT), minimum safe altitude (MSA) and crossing airways are often excluded, or not highlighted, in computer generated information.

Situational Awareness En Route

Figure B4.1 (page 178) indicates that 60 percent of respondents refer to their en-route charts far less on new-technology aircraft than on aircraft without an FMC/FMGS. Figure B4.5 (page 178) shows that 16 percent of respondents

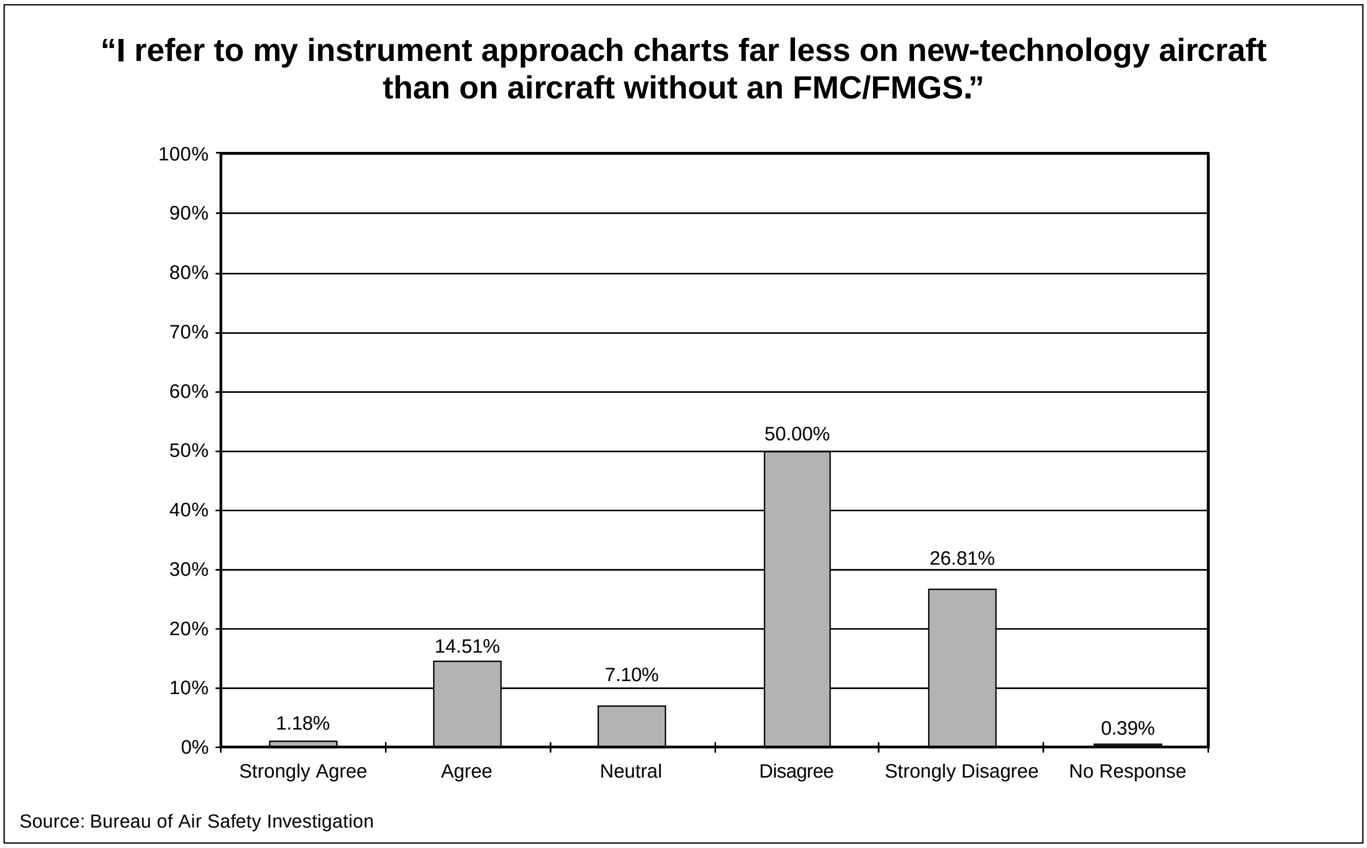
(continued on page 179)



"I refer to my en route charts far less on new technology aircraft than on aircraft without an FMC/FMGS."

Source: Bureau of Air Safety Investigation

Figure B4.1



"I refer to my instrument approach charts far less on new-technology aircraft than on aircraft without an FMC/FMGS."

Source: Bureau of Air Safety Investigation

Figure B4.5

refer to their instrument approach charts far less on new technology aircraft than those on aircraft without an FMC/FMGS. It is unrealistic for pilots of aircraft with FMC/FMGS to believe they can rely on computer data to provide adequate information to build a complete mental model of their environment. It is important for pilots to realise that technology is not yet at the point where it has completely and satisfactorily replaced "paper" information.

Understanding the Limitations of the FMC/FMGS

Thirteen percent of respondents believe that all the information they need for the safe conduct of a flight is contained within the FMC/FMGS (see fig. B4.2). This view cannot be supported at this time. Clearly, aircraft manufacturers are developing the "paperless" cockpit by incorporating electronic checklist and system information in their databases. Often, whether the operator includes this information in its database is an economic decision and is not related to flight operations or safety.

ATC and Situational Awareness

Fourteen percent of respondents reported that they relied on ATC to provide terrain clearance (see fig. B4.3, page 180).

Analysis revealed a statistically significant difference between the opinions of captains and first officers. First officers were more likely to rely on ATC to provide adequate terrain clearance than captains.

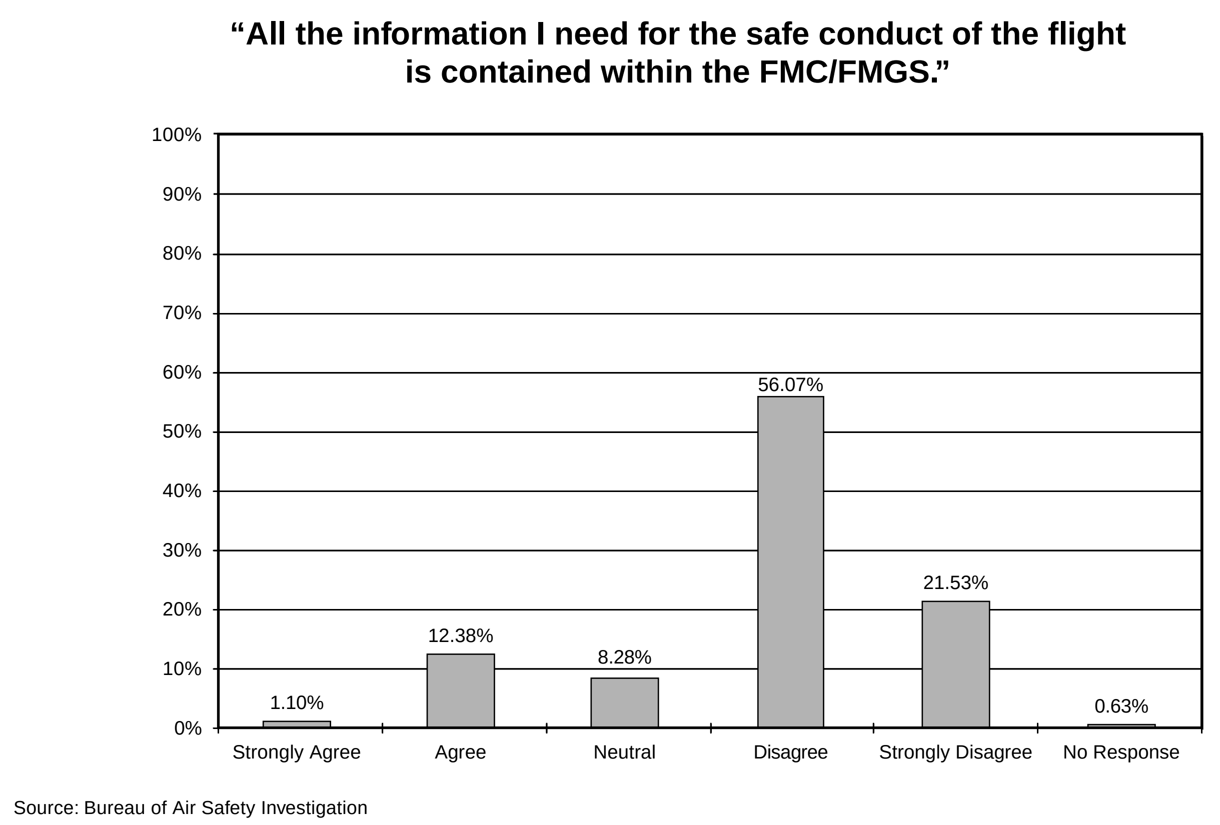
Table B4.3 (page 180) shows the distribution of pilot rank by aircraft manufacturer of those aircrew who rely on ATC for adequate terrain clearance.

Terrain Awareness

Fourteen percent of respondents reported having been surprised to find their aircraft closer to terrain than they had thought (see fig. B4.4, page 181). Such events clearly reflect a lack of situational awareness.

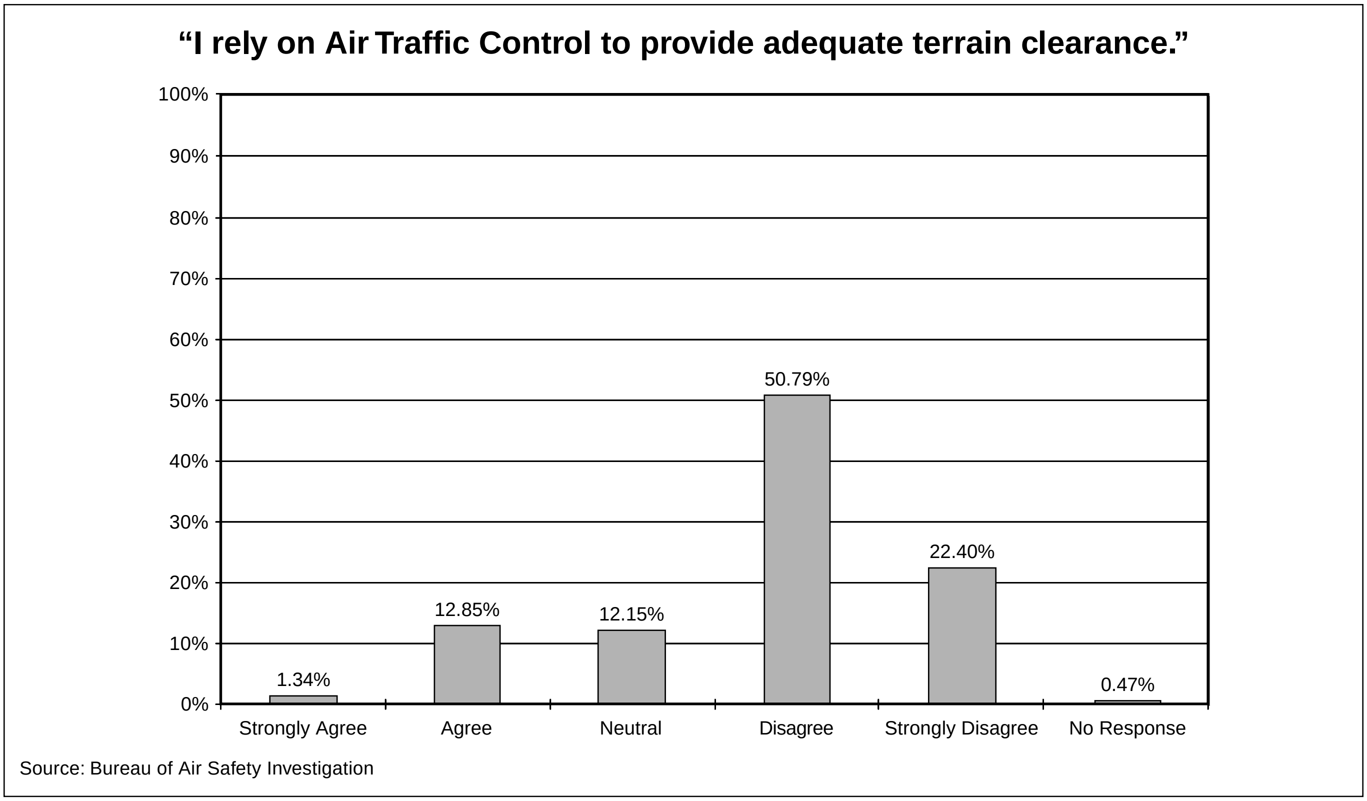
Further analysis revealed 43 respondents who reported relying on ATC to provide terrain clearance and having at times been surprised to find the aircraft closer to terrain than they thought. This does not imply that ATC have failed in their traffic management function, nor does it imply that the aircraft was at risk of collision with terrain.

A significant difference was noted between the responses of captains and first officers. First officers were more likely to find the aircraft closer to terrain than expected, possibly because they were relying on the captain and ATC to ensure the safety of the flight. Hence, first officers may benefit from specific training in situational awareness techniques.



Source: Bureau of Air Safety Investigation

Figure B4.2



Source: Bureau of Air Safety Investigation

Figure B4.3

Table B4.3
"I rely on ATC to provide adequate terrain clearance."

	Captain	First officer
Airbus	15 (11%)	9 (16%)
Boeing	68 (12%)	76 (19%)

Source: Bureau of Air Safety Investigation

Conclusions

Situational awareness relies on the pilot using all the available cues, assessing their significance and taking appropriate action. The pilot must be aware that the source of information, or cues, may differ from aircraft to aircraft, and from flight to flight. Like many CRM concepts, situational awareness may have become a vague concept to many pilots. Therefore, safety would be enhanced by providing pilots with specific situational awareness training during their initial conversion training and during recurrent training exercises.

The responses recorded in this chapter appear to support the concern that some pilots rely solely on computer-generated data as their reference for making decisions. There is no doubt that reliance on a single source of information rarely contributes to safe operations in any environment. Airlines could enhance safety by emphasising to pilots the information that is incorporated in the FMC and the information that must be obtained from other sources.

In other situations, pilots have reported relying on ATC to provide adequate terrain clearance. Controllers are clearly of the opinion that the safety of the aircraft remains the responsibility of the pilot. In this case, ATC is one of the cues or aids that are available to the pilot when making decisions regarding terrain clearance.

Recommendation

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980036):

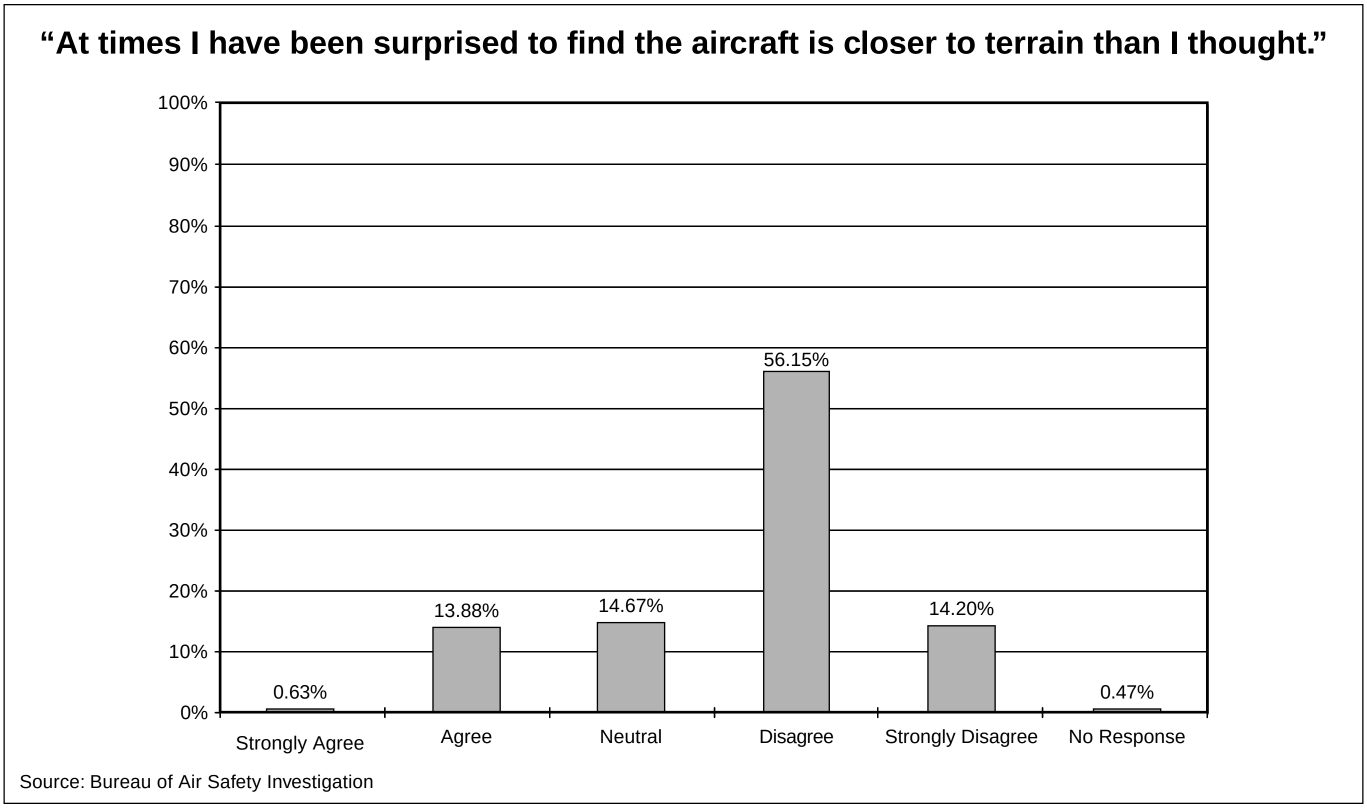
Review their pilot training to consider:

(a) specific training to pilots regarding situational awareness;

(b) differences that may exist between printed and electronic flight information;

(c) responsibilities of ATC regarding the provision of terrain clearance; and,

(d) clear policy regarding the use of en-route charts and instrument approach charts during flight.



Source: Bureau of Air Safety Investigation

Figure B4.4

System Design

Introduction

Research and development in ergonomics, metallurgy, fibre optics, computer hardware and software, and human factors have contributed to the increased safety and efficiency of modern automated aircraft. System design benefits from computer-aided design (CAD) programs which are incorporated in preproduction "debugging." Also, manufacturers continue to receive input from airline personnel and interest groups within the aviation industry. However, even the most extensive preproduction testing has not been able to eliminate errors and potential errors from automated hardware and software.

This chapter discusses the responses of pilots in relation to automated system hardware and software, including the user-friendliness of controls, data entry error detection and correction, crew awareness and communication, and the ability of the FMC/FMGS to cope with last-minute changes.

User-friendly Controls

Contrary to anecdotal evidence, 73 percent of respondents indicated that the FMC/FMGS and associated controls are "user friendly" (see fig. B1.1, page 182). Past design issues, such as the adoption of a non-QWERTY keyboard, touch-sensitive screens, and nonergonomic design do not seem to be reflected in this result.

A statistically significant difference between both pilot rank and aircraft manufacture was noted in the response to this question. First officers were likely to be more satisfied with the user-friendliness of the controls than captains. Airbus pilots were likely to be less satisfied than were Boeing pilots (see table B1.1, page 182).

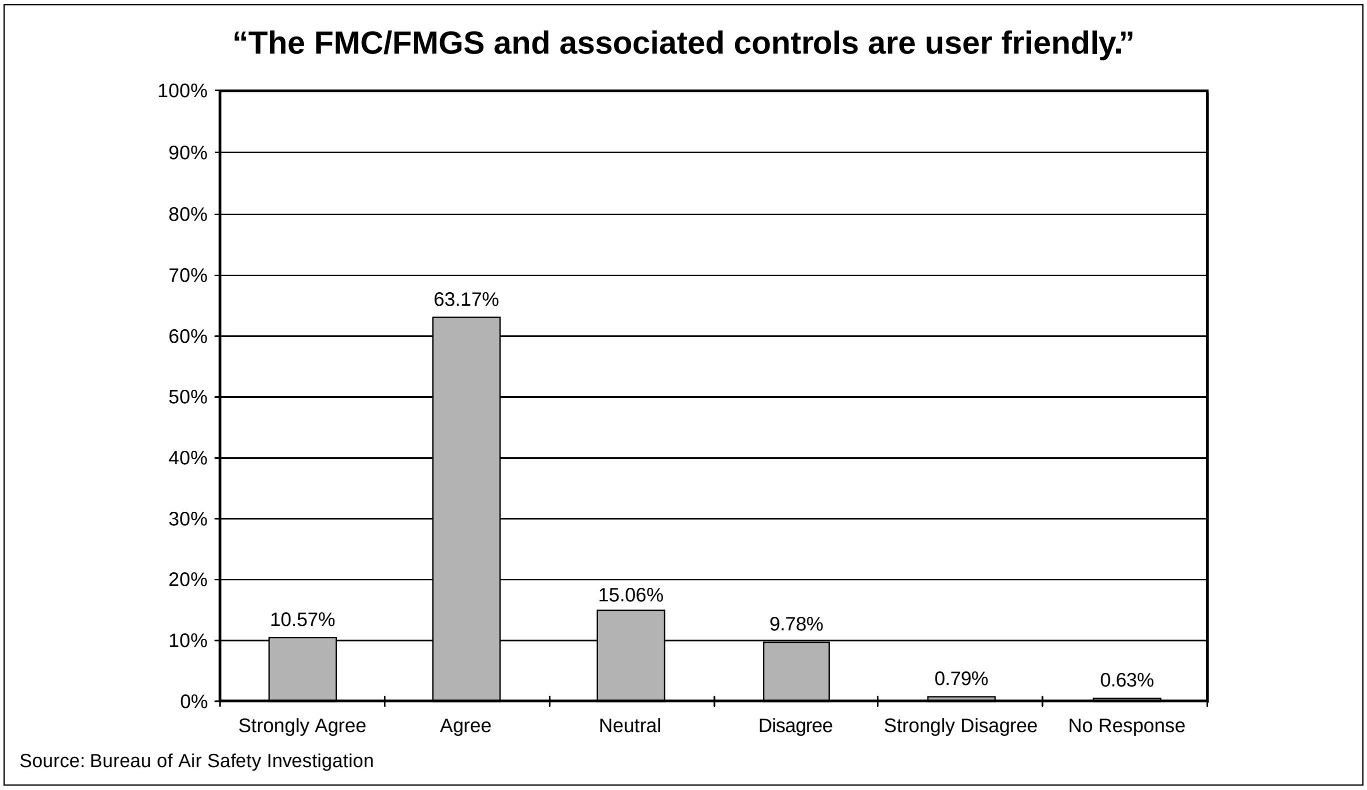
Similarly, statistically significant differences were noted between the responses of pilots from different national groups. As expected, significant differences were also noted between pilots on the basis of their home port.

- **National groups.** Asian groups, Singaporeans and Australians were more positive regarding the user-friendliness of controls compared to New Zealand, British and European pilots.

- **Home port.** Pilots based in Asian ports (excluding Singapore and Hong Kong), Australia and Singapore were more positive regarding the user-friendliness of controls than pilots based in New Zealand, Europe and Hong Kong.

Data-entry-error Detection

Twenty-seven percent of respondents stated that it was difficult to detect when incorrect data had been entered into the FMC/FMGS (see fig. B1.2, page 183).



Source: Bureau of Air Safety Investigation

Figure B1.1

Table B1.1
"The FMC/FMGS and associated controls are not user friendly."

	Captain	First officer
Airbus	27%	21%
Boeing	9%	6%

Source: Bureau of Air Safety Investigation

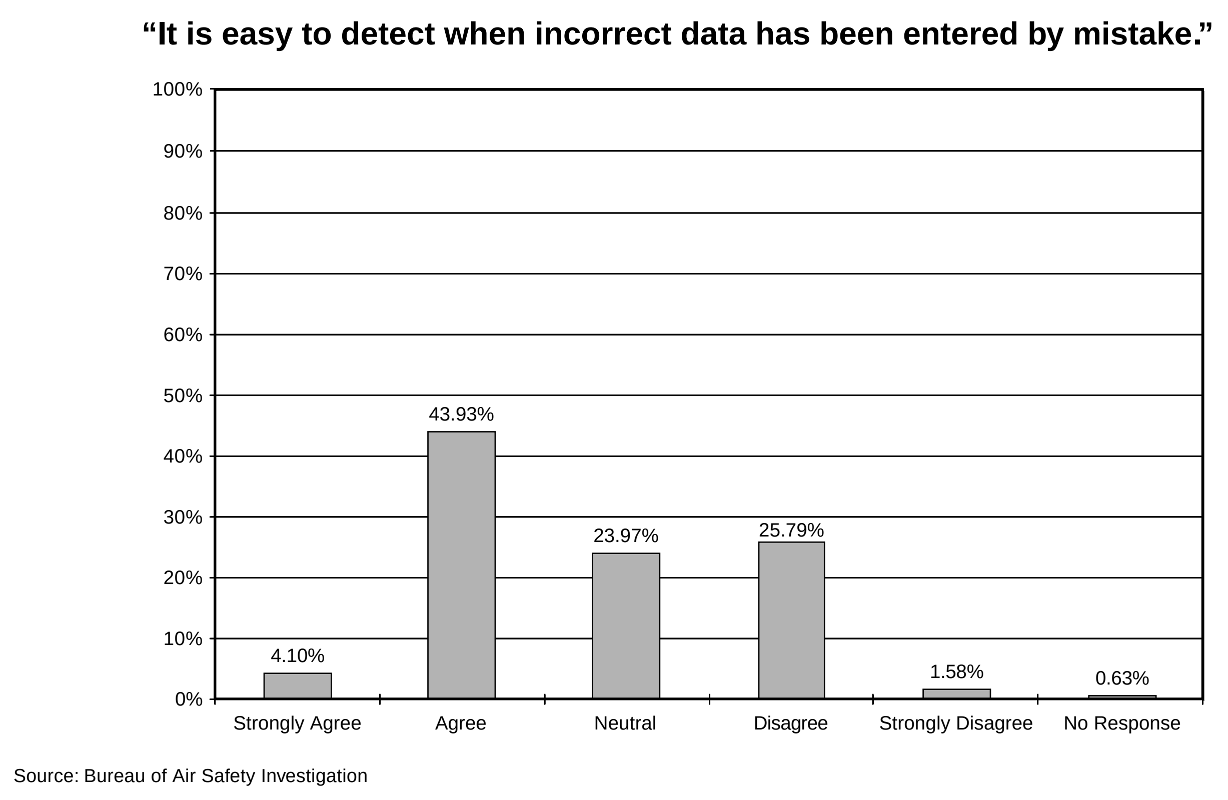
There are two aspects to this question. Firstly, the acceptance of incorrect data by the FMC/FMGS, and secondly, the detection of incorrect data.

Tests completed throughout the course of this study revealed that it is possible to insert incorrect data into the FMC/FMGS. For example, researchers found that it was possible to insert and execute an end-of-descent point below the elevation of an airfield. However, airline standard operating procedures prohibited pilots from flying VNAV approaches below the initial approach altitude.

Data error detection is the other aspect of this question. The pilot is left with only two methods of error detection, namely, human detection (including physical sensation) or electronic detection. Through a process of cross-checking, pilots may realise their mistake, or the FMC/FMGS may generate a warning message or fail to accept some erroneous data.

Either approach highlights a degree of inconsistency. The FMC/FMGS will accept some erroneous data whereas it will not accept others. The pilot may pick up some mistakes while others may not be discovered. For example:

> *Wrong runway inserted for Brisbane [Australia]. Not detected until initial turn off track (due ATIS change).*
>
> *An incorrect OAT was entered into FMC and not picked up in check. This resulted in the auto-throttles not bringing sufficient power for takeoff. Manually overridden and corrected during take-off roll with no further incident.*
>
> *Pacific random track crossing requiring manual entry of waypoints. Waypoint entry error by first crew combination, followed by duty hand-over prior to random track entry. Error was not detected until aircraft had left correct waypoint towards incorrect waypoint — but before substantial navigation anomaly occurred. Procedures for manual entry and cross-check of navigation have deteriorated with increased automation.*
>
> *Putting in a wrong departure in the FMS. Both pilots missed the entry. The wrong departure was flown until ATC spotted it. PON 1D was inadvertently entered instead of PON 3B departure. PON 1D was a new departure included into the database, something which the pilots didn't realise.*



Source: Bureau of Air Safety Investigation

Figure B1.2

Information is presented to pilots on cathod-ray tube (CRT) or liquid-crystal display (LCD) screens. It is possible that pilots experience the same difficulties during the input of information as computer operators do when editing information on-screen. The development and application of advanced system logic would minimise the opportunity for pilots to "execute" unintentional mistakes.

Correcting Mistakes

Fortunately, most data entry errors are detected before they are "executed." Seventy-two percent of respondents reported that incorrect data entered by mistake was easily corrected (see fig. B1.8, page 184).

The following responses contain examples where incorrect data was corrected:

> *Upon receiving a route modification the captain selected the position to the top of the second page and executed without realising the error. Picked up by second officer.*
>
> *Overly "snappy" FMC preflighting led to cost index 1,000 instead of cost index 100 being loaded (key pad bounce perhaps). The higher speed climb was detected airborne.*
>
> *Wrong data entered for runway due to last-minute change. When altering the legs page to track direct to a waypoint, we passed over a waypoint causing the incorrect point being taken to the top of the legs. The error was recognised prior to it being entered.*

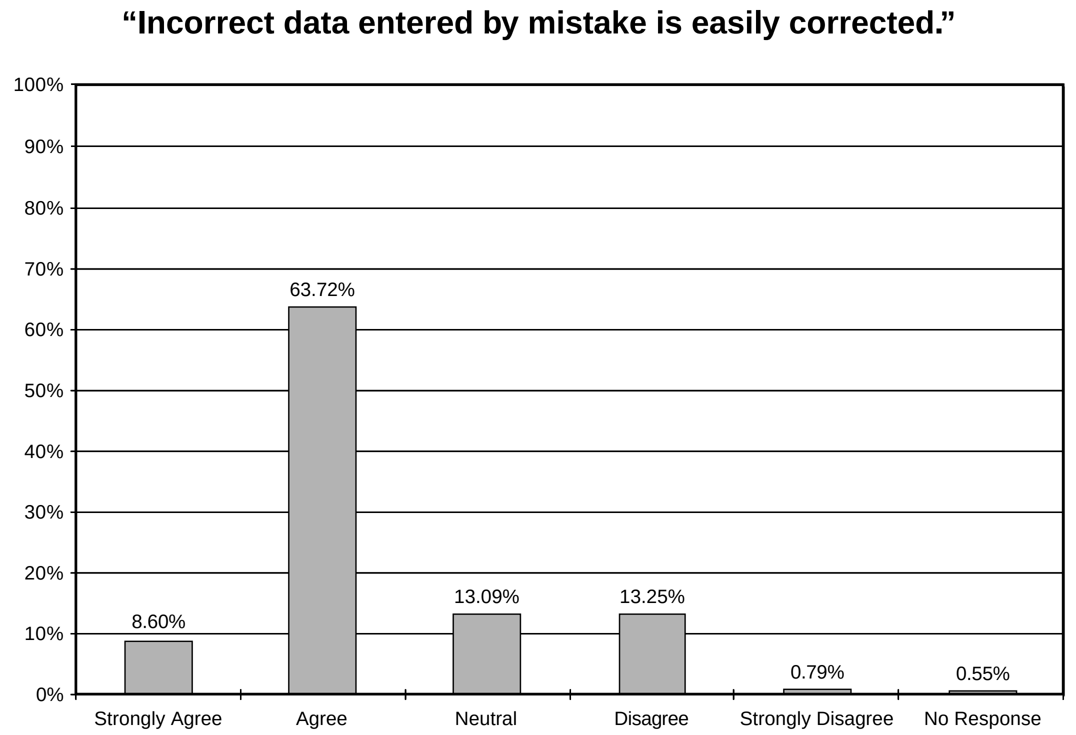
Crew Awareness

System design and cockpit layout should enhance communication and awareness of crew activities. It is important that each crew member is aware of the other crew member's control inputs, including those involving computer/automated controls.

Figure B1.3 (page 184) indicates that 25 percent of respondents reported that they did not always know what the other crew member was doing with the automated systems. Some pilots commented that the other crewmember had "executed" automated functions without informing them. For example:

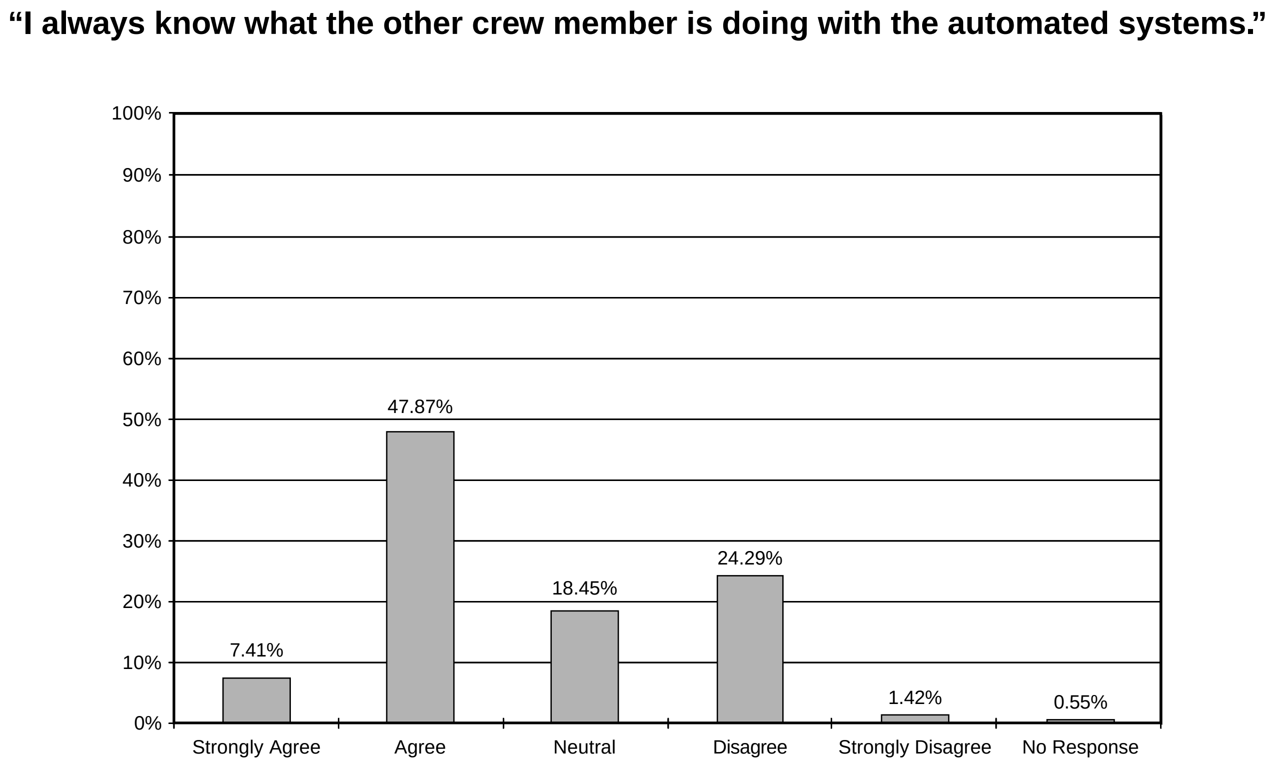
> *On descent into Sydney where VNAV was engaged by the PF without the PNF being informed.*
>
> *The ATC requires a minimum rate of climb shortly after t/off. The PF immediately selected v/s on the MCP without advising the other pilot, resulting in thrust reduction immediately.*

(continued on page 185)



Source: Bureau of Air Safety Investigation

Figure B1.8



Source: Bureau of Air Safety Investigation

Figure B1.3

Pilot Control Inputs

Figure B1.4 shows that 13 percent of pilots had been surprised to find the pilot not flying (PNF) making flight control inputs. Boeing and Airbus pilots were equally likely to report this problem.

Some reported accidents and incidents have occurred in which both operating crew made simultaneous flight control inputs. Aircraft manufacturers are currently addressing the problem of providing feedback to the pilots when dual inputs are being made. In the case where simultaneous inputs are "summed," it is possible that one input will negate the other.

In some cases, pilots may "instinctively" make control inputs, for example, when encountering severe turbulence. A dedicated training program may be warranted to address this undesirable situation.

Understanding the Language of the FMC/FMGS

Thirteen percent of respondents sometimes found it hard to understand the language or technical jargon in messages presented by the FMC/FMGS (see fig. B1.9, page 186).

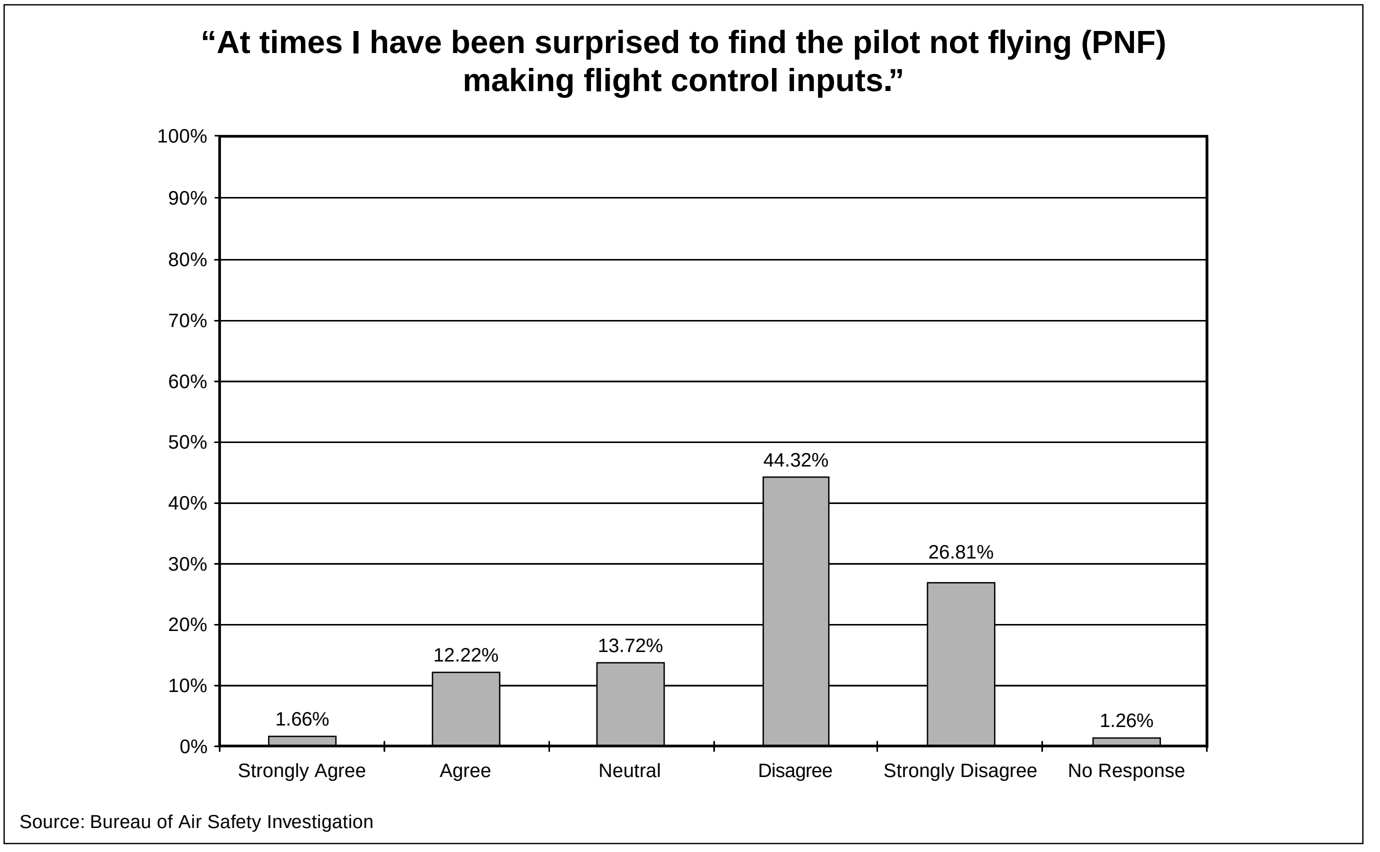
Analysis revealed a statistically significant difference between the responses of Airbus and Boeing pilots. Airbus pilots found it harder to understand the language or technical jargon in messages presented by the FMC/FMGS. Automation terminology is currently being addressed by aircraft manufacturers with the aim of agreeing on standard terms for automated components, modes and messages. These results seem to confirm that a common language of automated hardware and software would be beneficial to all users.

Coping with Last-minute Changes

Approximately 50 percent of respondents agreed that automation did not cope well with the last-minute changes imposed by ATC (see fig. B2.4 on page 150). The ATC aspect of this statement has been addressed in Chapter 1; however, this statement deserves further comment from the aspect of system design.

When asked to outline a specific event where they had difficulty operating an advanced-technology aircraft in accordance with an ATC instruction, pilots reported difficulty with programming runway changes, speed changes and changes to STARs. Particular difficulty was experienced with last-minute changes.

Advances in FMC software have seen the addition of "alternate-route" pages that allow pilots to anticipate and program different routes or approach criteria. While this assists with accelerating the "change process," pilots perceive that further improvements should be made to assist them in coping with ATC requirements.



Source: Bureau of Air Safety Investigation

Figure B1.4

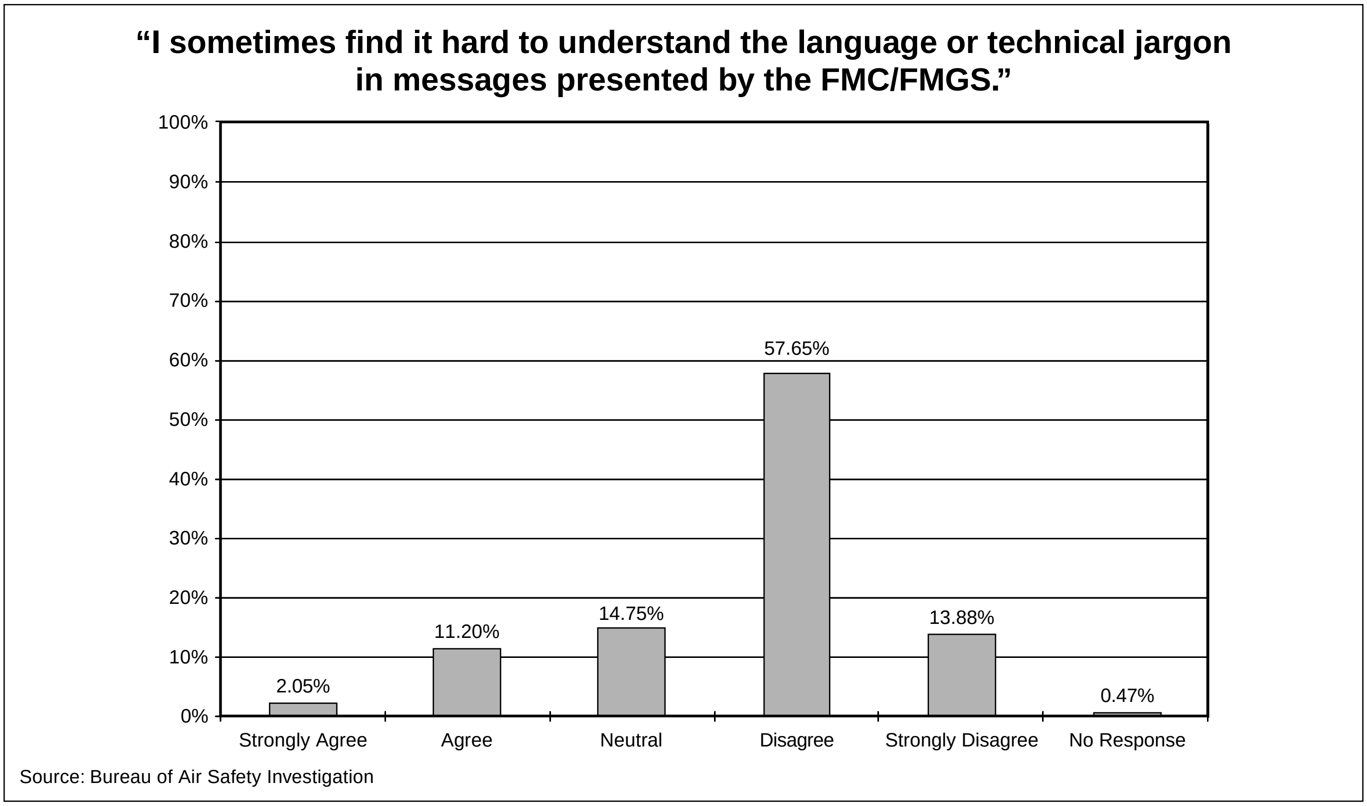


Figure B1.9

System work-arounds

Forty-two percent of respondents confirmed that they sometimes employed system work-arounds to achieve a desired result from the FMC/FMGS (see fig. B5.3, page 187).

An analysis of the information contained in table B5.3 (page 187) reveals that the results are almost evenly distributed across aircraft manufacturer (44 percent Airbus and 42 percent Boeing). However, there is a statistically significant difference between pilot ranks, in that first officers (48 percent) are more likely to be required to "trick" the FMC/FMGS than captains (39 percent). Pilot reports suggest that they are required to enter erroneous data into the FMC/FMGS to overcome deficiencies in aircraft performance, especially during VNAV control. These procedures, which in many cases have evolved into a form of standard operating procedure (SOP) are not addressed by airline operational policies and procedures.

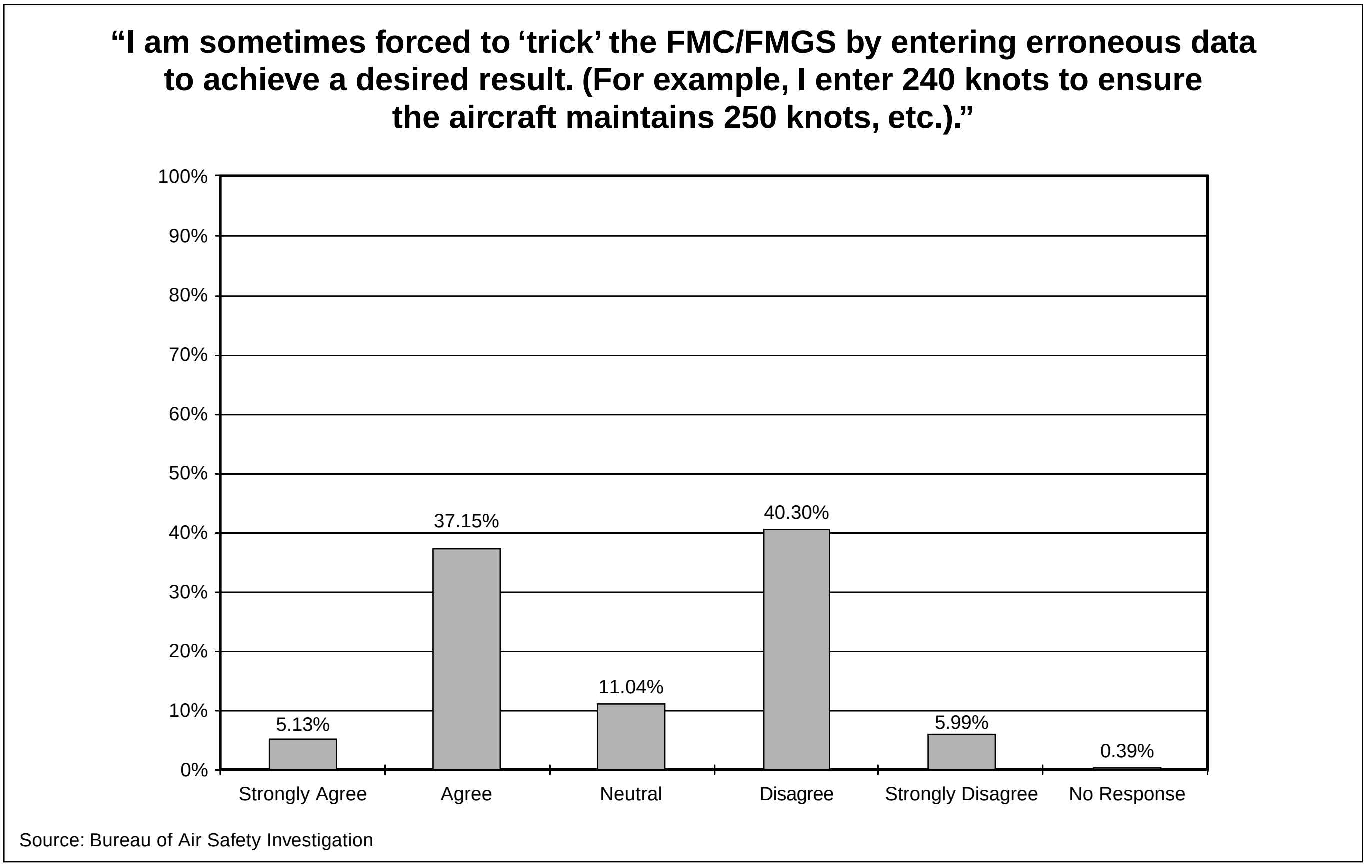
When asked to outline the details of a FMC/FMGS system work-around, pilots revealed that the most common objective of work-arounds was to ensure an accurate descent profile (69 percent), followed by refining speed management during the cruise or holding manoeuvre (8 percent), and providing accurate speed control during descent (7 percent). Their most frequent *strategies* were to manipulate the end of descent point or distance/altitude window (43 percent), insert a different speed or mach number (24 percent), or to insert a different wind component than forecast (9 percent). Approximately 80 percent of these manipulations applied to the descent phase of flight while 15 percent took place in cruise.

These results confirm the responses to question B1.12 where pilots revealed that the feature they liked least of all was the VNAV function.

Conclusions

The results support the current industry concern of ensuring sufficient quality control and pre-flight testing of automated products, especially automation software. The requirement for pilots to engage in FMC/FMGS work-arounds is an indication of the continuing shortfall in some aspects of software/hardware design. Although many of these deficiencies have been rectified in subsequent software releases, "working around" a known problem is a poor solution and represents a significant safety concern. Airline operators passively participate in this process by failing to address the practice of system work-arounds through their policy and procedure documents. It would appear that an undesirable subculture has developed amongst aircrew which needs to be addressed by both aircraft manufacturers and airline management.

System work-arounds are most commonly performed to achieve a desired descent profile which often reflects the incompatibility between advanced-technology aircraft and the current ATC environment.



"I am sometimes forced to 'trick' the FMC/FMGS by entering erroneous data to achieve a desired result. (For example, I enter 240 knots to ensure the aircraft maintains 250 knots, etc.)."

Source: Bureau of Air Safety Investigation

Figure B5.3

Table B5.3
"I am sometimes forced to 'trick' the FMC/FMGS by entering erroneous data to achieve a desired result."

	Captain	First officer
Airbus	38%	51%
Boeing	38%	47%

Source: Bureau of Air Safety Investigation

Similarly, the ability to enter incorrect data, which may or may not by identified, represents a serious safety concern. Aircraft manufacturers should ensure that the ability of systems to accept illogical data is reduced and preferably eliminated.

Further research is needed to determine the circumstances in which non-flying pilots make flight-control inputs. This factor has been a contributing factor in at least one accident and one serious incident within the Asia-Pacific region. Although aircraft manufacturers have taken steps to address a shortfall in hardware design, the human factors aspect of this phenomenon has not yet been fully explored.

Recommendations

The Bureau of Air Safety Investigation recommends that airline operators (R980037):

Review their standard operating procedures (SOP) and airline policy to require only one crewmember to make control inputs at any one time unless stated to the contrary in an emergency/abnormal procedure, and emphasise the consequences of multiple simultaneous flight control inputs.

The Bureau of Air Safety Investigation recommends that aircraft design authorities consider requirements for (R980038):

(a) A means of alerting the pilot when incorrect data has been entered into the FMC/FMGS;

(b) All data entries being able to be corrected easily by flight crew;

(c) Common industry terminology for automation hardware and software;

(d) FMS software and hardware to accommodate the various changes that are imposed by ATC on an advanced-technology aircraft during all phases of operation;

(e) Quality control procedures for FMC software with the aim of eliminating the need for system work-arounds; and,

(f) The position, design and tactile differences of the frequently used mode selectors (such as heading and speed), with the aim of eliminating any confusion regarding the use of these controls.

Training

Introduction

The introduction of automated aircraft systems has been accompanied by significant changes to pilot training methods. Computer-based training (CBT) has largely replaced the traditional classroom. Some ground training courses have been reduced from six weeks to 14 days duration. Much of the “nice-to-know” information, which in the past provided the pilot with a well-rounded understanding of aircraft systems, has been narrowed to a “need-to-know” level. Also, in some cases, aircraft “base training” has been replaced by zero-flight-time (ZFT) simulation.

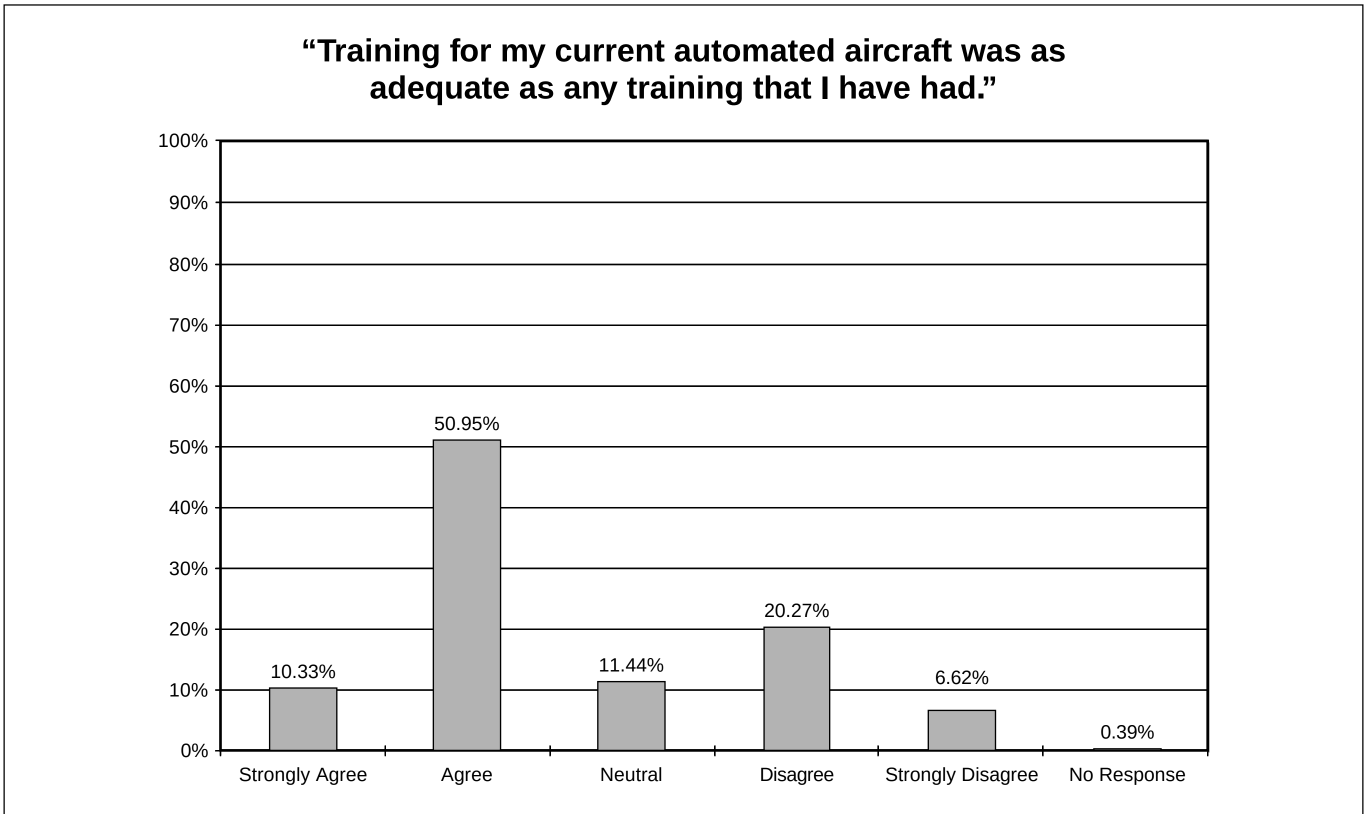
This chapter contains a discussion of respondents” answers to six attitude probes relating to pilot training on advanced-technology aircraft, and a detailed analysis of the written responses to question B8.7 (“What could be done to improve the training you received on this aircraft?”). An analysis of “previous aircraft types” revealed that only 25 percent of respondents had previously flown an advanced-technology aircraft. These responses account for the majority of pilots who were transitioning to an automated aircraft for the first time, possibly without previous biases toward automation or training procedures.

Training Standards

Twenty-six percent of respondents indicated that training for their current aircraft was inadequate when compared with past training (see fig. B8.1).

Significantly more Airbus pilots were dissatisfied with their training than Boeing pilots (see table B8.1, page 189). This possibly reflects the fact that Boeing has a longer history of training pilots than Airbus Industrie.

Table B8.1.1 (page 189) indicates that a degree a dissatisfaction was present across all age groups but that dissatisfaction was directly related to age, so whereas 17 percent of 21–30 year olds were dissatisfied with their training, 39 percent of 51–65 year olds were dissatisfied.



Source: Bureau of Air Safety Investigation

Figure B8.1

Table B8.1
“Training for my current aircraft was inadequate.”

	Captain	First officer
Airbus	41.1%	27.3%
Boeing	28.9%	19.9%

Source: Bureau of Air Safety Investigation

Understanding of Aircraft Systems

The majority of respondents (55 percent) considered that they would have liked a deeper understanding of the aircraft systems (see fig. B8.2). Of this group, only 22 percent indicated that they had previously flown an advanced-technology aircraft (*n* = 717; advanced-technology aircraft types = B-737, B-757, B-767, A310, A320 and A330). This result may reflect a change in training philosophy for advanced-technology aircraft in which information is provided on a “need-to-know” basis. While this training provides a pilot with sufficient information to deal with the more predictable emergency/abnormal situations, it may not adequately prepare pilots to deal with situations requiring deeper systems knowledge, for example, the UA232 accident, Sioux City, Iowa, United States.

Technical Manuals

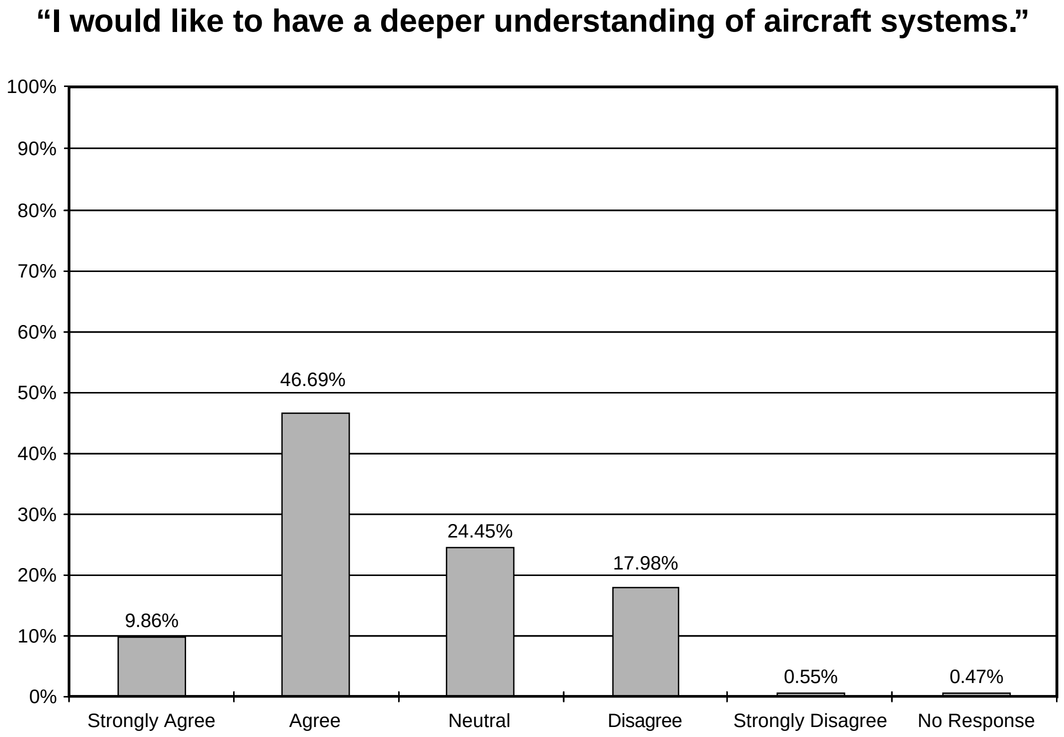
Many of the respondents (40 percent) sometimes had difficulty understanding information in the technical manuals associated with their aircraft (see fig. B8.3, page 190).

Table B8.3 (page 190) indicates that pilots operating Airbus aircraft had more difficulty understanding information in the technical manuals associated with their aircraft than pilots

Table B8.1.1
“Training for my current aircraft was inadequate.”

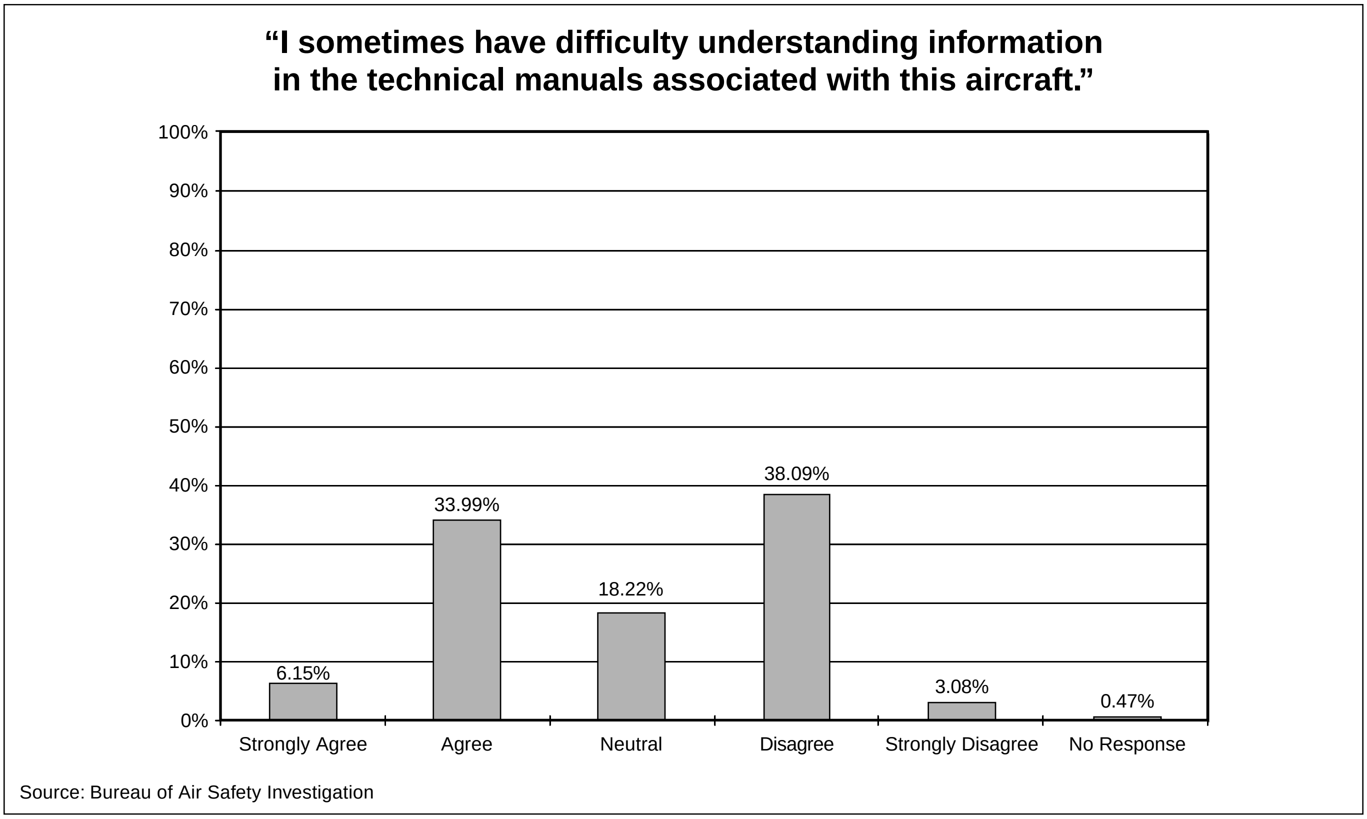
Age of respondent	21–30 years	31–40 years	41–50 years	51–65 years
Percentage	17	22	29	39
Total in age group	134	449	439	497

Source: Bureau of Air Safety Investigation



Source: Bureau of Air Safety Investigation

Figure B8.2



Source: Bureau of Air Safety Investigation

Figure B8.3

Table B8.3
"I sometimes have difficulty understanding information in the technical manuals associated with this aircraft."

	Captain	First officer
Airbus	63%	58%
Boeing	32%	38%

Source: Bureau of Air Safety Investigation

operating Boeing aircraft. Further analysis revealed that this result was highly statistically significant.

Quality of Training Manuals

Similarly, fig. B8.4 (page 191) indicates that 39 percent of respondents were unable to find all the information they needed for their training in the aircraft or company technical manuals. Training manuals should be tailored to the needs of the flight crew. The question arises that if the pilots needed to find some information and it was not contained in the manual or training notes, where did they obtain the information? Relying on opinion or personal experience seriously degrades the quality of information received by the pilot and hence degrades the safety of flight operations.

Effective Training

Most pilots (64 percent) indicated that their training prepared them well to operate their current aircraft (see fig. B8.5, page 191). This result is consistent with overall survey scores that indicate that pilots had responded favourably to automation.

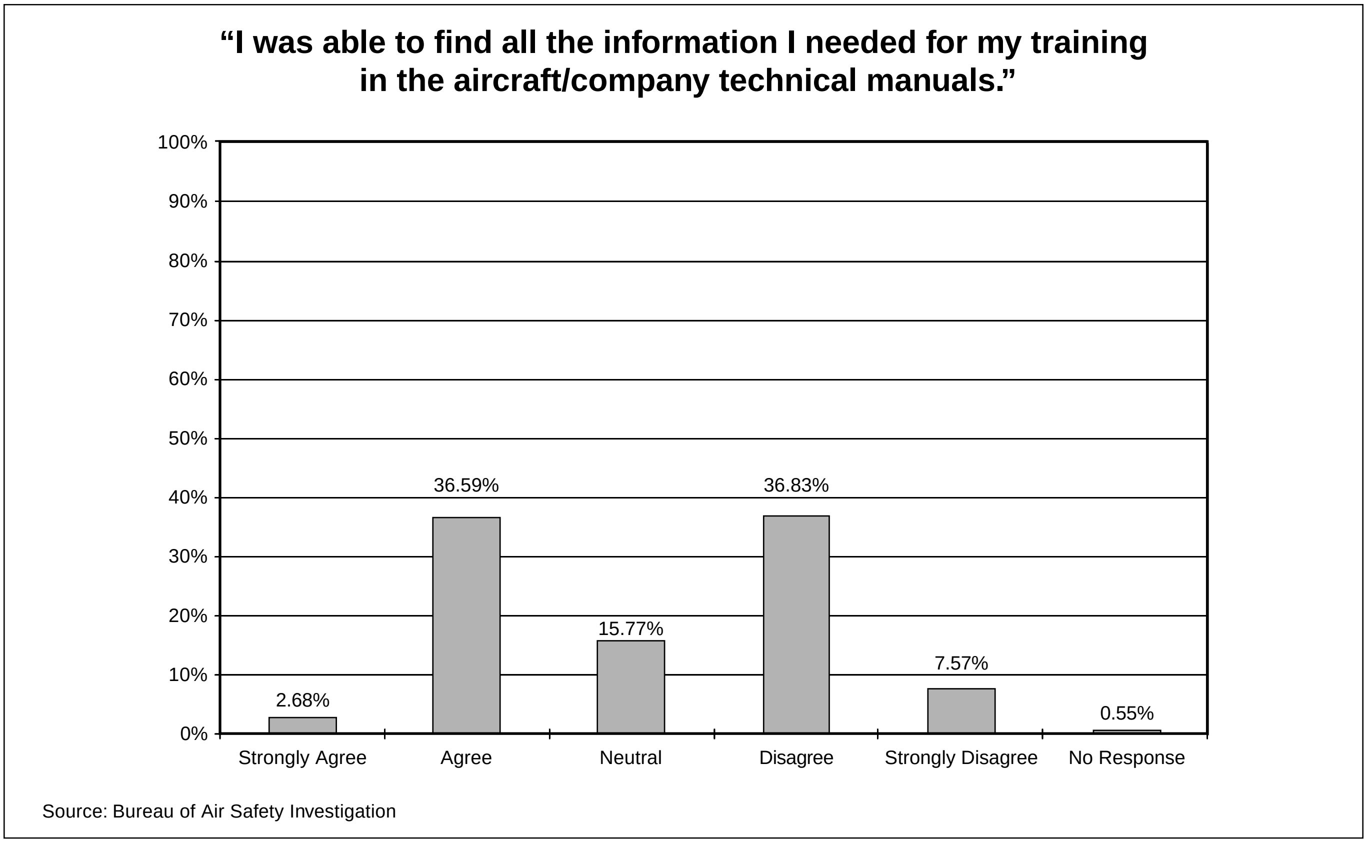
Only 14 percent of respondents felt that their training had not prepared them well to operate their current aircraft (see fig. B8.5). This result is relatively evenly distributed across pilot rank and aircraft manufacturer (see table B8.5, page 192).

Computer-based Training vs. Traditional Teaching Methods

Forty-three percent of pilots preferred computer-based training, while 30 percent preferred traditional teaching methods (see fig. B8.6, page 192).

Further analysis revealed a statistically significant difference between the preference of Boeing pilots when compared with Airbus pilots (see table B8.6, page 193). Boeing pilots had a higher preference for computer-based training than Airbus pilots. However, at the time this survey was conducted, not all Airbus pilots may have experienced computer-based training.

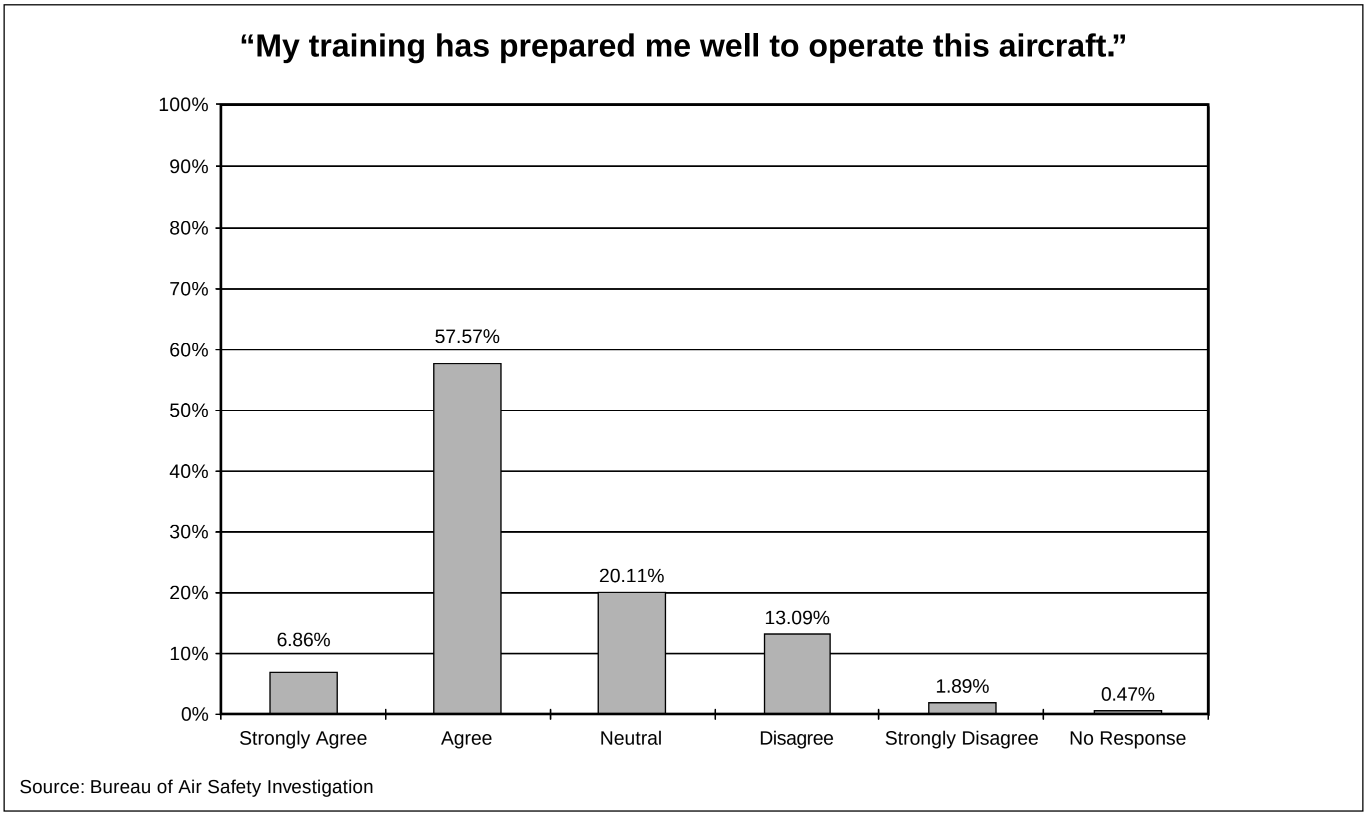
(continued on page 192)



“I was able to find all the information I needed for my training in the aircraft/company technical manuals.”

Source: Bureau of Air Safety Investigation

Figure B8.4



“My training has prepared me well to operate this aircraft.”

Source: Bureau of Air Safety Investigation

Figure B8.5

Table B8.5
“My training did not prepare me well to fly this aircraft.”

	Captain	First officer
Airbus	15.9%	17.9%
Boeing	16.3%	13.7%

Source: Bureau of Air Safety Investigation

Training Improvements

A significant number of pilots (711 or 56 percent) responded to the question B8.7. “What could be done to improve the training you received on this aircraft?” To enable these written responses to be analysed, each question was allocated to one of the following categories, which are listed in order of significance:

1. Automation;
2. Simulator;
3. Teaching methods;
4. Training quality;
5. Training quantity;
6. Manuals;
7. Line operations;
8. Training staff; and,
9. Comments regarding check/training.

Automation

The subject of automation was addressed by 156 respondents in relation to improving their training.

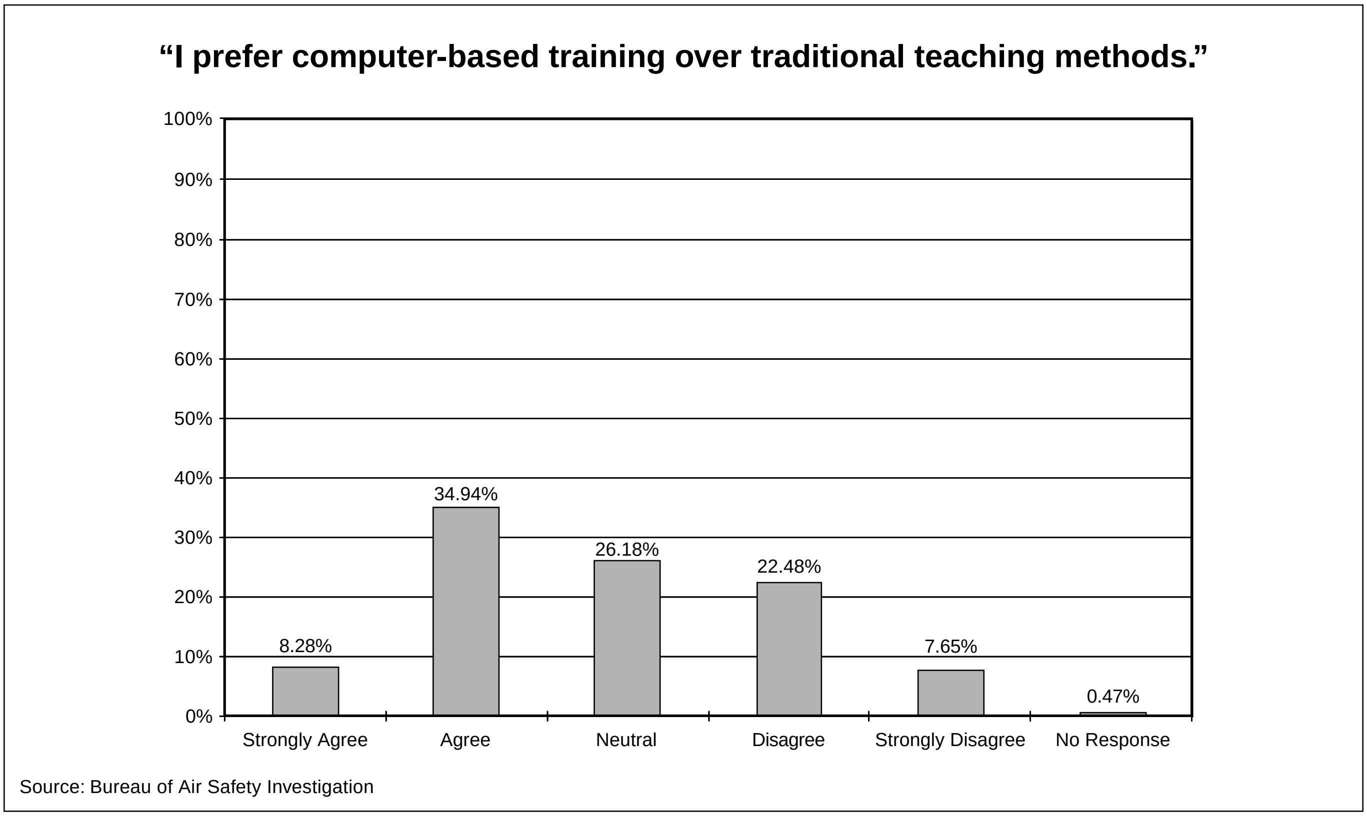
- Approximately 40 percent of this subgroup suggested that more “hands-on” training (FMC/FMGS, MCP), or being allowed more time to use an FMC/FMGS training aid, would have enhanced their training:

  More hands-on practice with the training FMC.

  Much more training is necessary on ground based trainers for managing the FMC and data input.

  Free-play FMC training should be mandatory.

- Other significant comments called for in-depth training on automated systems:



Source: Bureau of Air Safety Investigation

Figure B8.6

Table B8.6
"I prefer computer-based training over traditional teaching methods."

	Captain	First officer
Airbus	34%	23%
Boeing	45%	39%

Source: Bureau of Air Safety Investigation

> *More explanation of modes and their relationship to each other.*
>
> *Mode annunciation and speed protection modes are only explained after completion of ground school. They are not part of the training package.*
>
> *More detail on autopilot / flight director modes and annunciations.*

- Similarly, pilots suggested that the provision of a fixed-base FMC/FMGS trainer, or fixed-base simulator, would have improved their training experience:

> *An FMGC in the classroom, to be able to understand its programming and become familiar with all its features prior to commencing line training. Otherwise your attention during flight is diverted away from flying the aircraft.*
>
> *Improved FMC simulator.*
>
> *Provision of a FMGS for hands-on training.*

- Equally important was the suggestion that "automation philosophy" should be explained during the early stages of conversion training:

> *A course on logic behind the development of the automated systems.*

Simulator

One hundred and ten respondents commented on aspects of their simulator training. Comments were classified according to duration and quality of simulator training.

The majority of comments relating to the duration of training stated that more simulator training should be scheduled. For example:

> *More simulator sessions, with emphasis on teaching rather than assessing the student.*

Similarly, most pilots stated that the quality of simulator exercises needed improvement. Specifically, pilots suggested improving the quality of simulation, providing better simulator training programs (especially regarding rostering), an even flow of information ("too much too quickly"), more comprehensive briefings by the instructor prior to the simulator session and practical demonstrations throughout the session, and the use of a standard syllabus. For example:

> *Better use of simulator. There is a tendency to try and cover too much in too short a time. We are expected to be proficient without sufficient training time being allocated to really feel comfortable with abnormal operations.*

Pilots offered three significant suggestions as to how their simulator training could be improved:

1. More time should be spent concentrating on normal operations including takeoff, descent, circuits and manual flying. For example:

   More emphasis during ground school and SIM endorsement on a normal line flight, with some ATC constraints, in order to become more familiar with the FMGC.

   More normal operations training in simulator during initial endorsement.

2. There should be more emphasis on automation, especially the use of various "modes." For example:

   Much more simulator time concentrating on mode changes and mode awareness.

   More SIM time at first on mode use of MCP in upper air work.

   More time could be spent practising in the simulator with the automatic modes. Too often we seem to be asking, "What's it doing now?"

   Training was well structured and prepared pilots well. However, a little more simulator experience in basic flying using all the FMA modes would have been helpful without additional pressure of non-normal situations to manage.

   Hands-on training in the simulator on profiles requiring FMC selection/manipulation and mode control panel selection/operation.

3. Free time, or free-play simulator sessions, would have improved their training. Some (8 percent) commented that post-training simulator practice or self-help sessions would have been beneficial:

   Free-time simulation sessions during which individual pilots could practice the aspect of flight they feel needs improving.

> *Having time in simulators to experiment without being graded or rated in training records.*
>
> *Simulator available for self-help programs is very good improvement.*

Teaching Methods

One hundred and four pilots made specific comments regarding the method of teaching during their training.

Most of those who made comments would have preferred face-to-face lectures, presentations, and discussion groups during their ground training. Conversely, 21 pilots preferred computer-based training (CBT). Interestingly, 13 pilots suggested that CBT and "chalk and talk" should be integrated:

> *Face-to-face teaching with technical specialists of the aircraft's systems will help in the safe operation of the aircraft.*
>
> *Greater use of multimedia PC-tech for systems and procedures training.*
>
> *Computer based training requires back-up lectures by a well trained, experienced lecturer.*

Quality of Training

Sixty-one respondents commented on the quality of their training. Most of these pilots reported that their training was superficial, lacking in-depth system/software information. This comment corresponds to those made regarding "manuals":

> *Better systems knowledge. It is amazing how little I know about the B-767 but am still required to operate it to a high standard.*

Pilots also commented that the information presented throughout their course was often out of date or inadequate:

> *More accurate up-to-date information.*
>
> *The training handouts are nearly all out of date, some by 5 or 6 years.*

Quantity of Training (General)

Sixty pilots made specific comments regarding the quantity and duration of their training with regard to specific topics or areas.

Most respondents suggested they should have received more training, while only five pilots would have been satisfied with less training.

Most pilots suggested that more training should be available to those pilots transitioning from older technology aircraft, while 13 specified more time during the engineering-course and ground-school phase. Pilots specifically suggested that they would have benefited from more time spent discussing automation, particularly the FMC/FMGS functions. Also more time could have been spent in the simulator. These comments are consistent with previous comments.

Manuals

This subgroup comprised 52 respondents. Comments related to the reference manuals available to pilots in the course of their training and during their subsequent operational duties. Three significant issues arose from these comments:

1. Pilots considered that manuals should provide more detailed information. For example:

> *Information provided (manuals, checklist etc.) are on a need-to-know basis. Information which is "good to know" should also be included. Information provided should be concise and easy to interpret.*

2. Manuals are not "user friendly," and the overall presentation requires improvement (index, colour coding, layout, cross reference system):

> *Improved tech manuals, explanations, documentation. The technical manuals do not always present information in a user-friendly way, especially as there can be a number of manifestations of the same problem. Automated features each require different treatment.*
>
> *Manuals provided for my fleet type are below standard, new procedures are passed by inter-office memos or more often than not, by hearsay. Most inappropriate.*

Line Training

Forty-four pilots commented on the quantity, content/syllabus and organisation of their line training.

Of those who commented on the duration of line training, all stated that more line training (more sectors) would have been beneficial. For example:

> *More line training. There was not enough time available during line training to learn about the systems in more detail.*
>
> *More sectors as pilot flying.*
>
> *More sectors for those who have not done FMC work before.*

Comments on the content or syllabus of line training were almost equally distributed across the following issues:

- Greater emphasis on automation/systems;
- More dynamic training;
- More informative training;
- Greater emphasis on crew roles (PF/PNF); and,
- More information on company procedures.

Comments concerning the organisation of line training suggested allowing more observer/supernumerary flights, and providing better training blocks/schedules.

Training Staff

This subgroup comprised 37 responses. These comments addressed the selection of ground-training staff, the quality of instruction and aspects of the training program relating to both ground, simulator and line-training personnel.

Five respondents believed that the selection process for instructors was inadequate. All indicated that instructors were not necessarily selected or appointed according to their instructional abilities:

> *Six years in an airline and 100 years as a captain does not qualify a pilot to train.*

Most of these respondents were dissatisfied with the ability of their instructors (knowledge, language, experience), while some suggested that instructors should undergo specific training in instructional techniques or that the company should provide better instructor training. The following comments illustrate this view:

> *Better instructors. On this aircraft conversion I was given no training which I could discern as training. Basically I completed the course finding out as I went along by myself. This airline's concept of training is "It's in the book." Read the book and you'll find out.*
>
> *Educate the trainer in teaching methods.*
>
> *Train the training pilots. A line captain is made a training captain and is not even given a brief on what is required.*

Approximately half of the respondents suggested that training personnel should be specialist, full-time and qualified instructors. Other answers centred around three suggestions: that programs should also use line personnel to bring a sense of practicality to the training course; that the company should provide for continuity of instructors; and that all instructors should use a set syllabus and standard procedures, and should agree on what is to be expected of flight crew throughout the course. The following comments illustrate this view:

> *Use specialist instructors who can answer questions instead of Audio Visual training.*
>
> *Require a formal syllabus of training and qualified flying instructors.*
>
> *Better continuity of instructors.*
>
> *Having all the flight instructors and simulator instructors agree on what is expected of line crew. If one or two instructors try to impose their methods as requirements, it merely confuses trainees and line crew. Even our chief pilot is party to this, so I guess there is no hope.*

Comments Regarding Check-and-training

The following 10 comments were received regarding the check-and-training process on advanced-technology aircraft:

> *Serious cultural problem, the current culture is a become-orientated rather than a learning culture. CRM training is a token sham, the result being that local pilots prefer flying with expatriates.*
>
> *More training and demonstration, less "checking." It is easy for training to simply become a verification process.*
>
> *Receive better and more continuation training than currently receiving, instead of only a checking element. A better training component prepares you better for a check.*
>
> *Be exposed to more than one training captain. There are so many ways to operate this aircraft, you need to see other people operating it to decide what does and does not work for you.*
>
> *Less emphasis in the simulator on "tests" and more on training.*
>
> *A more constructive check pilot attitude to simulator checking.*
>
> *More training and reviewing and less checking would be highly desirable after qualifying.*
>
> *A more consistent overall training effort by all crew – a culture which encourages more crew to be formally involved in training.*
>
> *Less checking and more training.*
>
> *We were over-checked.*
>
> *More training as against an emphasis on checking instead – e.g., too much of the training captain waiting for and criticising mistakes rather than advising what may be expected.*

Conclusion

In the past, each new generation of jet aircraft was an evolutionary development of the previous type. A pilot transitioning from one aircraft type to another could transfer many of the skills learnt on the previous type and tailor them to the new aircraft type or model. This is not the case with many of the pilots transitioning to advanced-technology aircraft. Approximately 75 percent of respondents had not previously operated an automated aircraft and hence were faced with learning many new skills during their transition period.

Most pilots stated that their training had adequately prepared them to operate their aircraft. The majority also indicated that they preferred computer-based training over traditional teaching methods. These responses are consistent with the overall tone of the survey, which indicates that pilots have generally adapted well to automation.

Other responses, however, pointed toward improvements that could be made in training procedures.

Pilots clearly expressed their desire to obtain a deeper understanding of aircraft systems.

The depth of training, the provision and availability of training aids, and the quality of training manuals should equip flight crew to adequately deal with skill-based, rule-based and knowledge-based operational errors. Respondents perceived that one effect of new training regimes had been to reduce their knowledge of aircraft systems. It appears that the modern concept of requiring pilots to possess less systems knowledge than would have been the case with less automated aircraft types, may become problematic if instruction manuals are of poor quality, and frustrate further personal study.

Pilots suggested several ways of improving the training they received on their current aircraft and the implementation or improvement of the following areas could be beneficial:

1. Ensure that pilots are familiar with the aircraft manufacturer's automation design philosophy and the airline automation policy. Examples of two airline automation policies are provided in chapter 12.

2. Ensure that all ground, simulator and flight instructors are suitably qualified and comprehensively trained in modern instructional/teaching techniques.

3. Provide automation training aids.

4. Ensure that training manuals provide up-to-date, in-depth information in a user-friendly presentation.

Several airlines have recognised the benefits of "free-play" simulator sessions where pilots are free to nominate the scenarios they wish to explore. Several respondents suggested that their training could have been improved by "free-play" simulator sessions or by the provision of desktop and fixed-base automation simulators. Currently, NASA is researching the effectiveness of personal-computer (PC) based training programs, particularly those related to FMC/FMGS training. Early results suggest that this method of training, which is portable and conducted in the pilot's own time and at the pilot's own pace, may significantly contribute to automated training programs.

It is important that pilots receive reliable technical data/ information. Although modern teaching methods generally provide information on a need-to-know basis, it is clear that pilots continue to "fill in the gaps" by procuring information from various sources. The traditional, and sometimes dubious, sources of information have been expanded through various avenues, including the Internet. Information gained through this method is often only opinion, or oriented to experience, which is very difficult to verify. While many valuable discussion groups have been promoted over the Internet, it is also clear that a significant level of in-flight experimentation is occurring worldwide. Airline training departments can offer a high degree of quality assurance by providing adequate information through trained staff using quality manuals or electronic means.

Anecdotal evidence suggests that regulatory authorities may be hindering the advancement of training programs, especially simulator training programs, by insisting on rigid programs that are required to meet license issue and renewal criteria. There is a concern that regulators are not able to keep pace with technological changes taking place within the aviation industry. The analysis of written responses highlights the need for training programs to be much more flexible, allowing some ability to adapt to the needs of the student. Those airlines and authorities that exercise some degree of flexibility have made significant advancements in their approach to training regimes.

Recommendations

The Bureau of Air Safety Investigation recommends that Civil Aviation Safety Authority (R980039):

1. Consider the need for:

    (a) Simulator and flight instructors to be trained in instructional/teaching techniques at a recognised educational facility;

    (b) Ground, simulator and flight instructors to undergo regular refresher training in instructional/teaching techniques at a recognised educational facility; and,

    (c) Ground, simulator and flight instructors to demonstrate their ability as an instructor/teacher on a regular basis.

2. Assess the quality of printed and electronic training/reference material with respect to advanced-technology aircraft.

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980040):

Review the qualifications of all ground, simulator and flight instructors and where necessary provide training in instructional/teaching techniques with the aim of accrediting instructional/teaching staff.

Workload

Introduction

The term "mental workload" refers to the difference between the amount of information processing resources required by a situation and the amount of such resources available to the person at the time (Wickens, 1992). The more that the demand approaches capacity, the greater the workload. When the demand reaches a level such that the person's performance is significantly affected, then a person can be said to be "overloaded."

A high workload level can have a variety of influences on human performance. The majority of these effects can be considered as attempts by the person to reduce demands by simplifying them. For example, a high workload can lead to a narrowing of the perceptual information a person attends to and a narrowing of the number of tasks a person attempts to perform. A person generally focuses on those information sources and tasks that he or she thinks to be the highest priority. However, this prioritisation process is subjective and may not necessarily be optimal. Working memory and decision making processes are also limited by high workload. These limitations can exacerbate a variety of decision-making biases and lead to a focus on certain aspects of tasks (e.g., speed) in opposition to others (e.g., accuracy).

If multiple tasks are being performed simultaneously, the performance of each of the tasks often deteriorates to some extent. The amount of interference between tasks increases if the same stages of information processing, input modalities, processing codes and types of response are involved. Another commonly discussed means of reducing task demands involves reverting to stereotyped patterns of behaviour. In addition, there is a tendency to focus on simpler tasks and responses, which generally but not always are the more established patterns of behaviour.

High workload can have negative influences on all aspects of human information processing. It can also be associated with the physiological responses associated with an increased perception of threat or stress. The maintenance of a high workload over a sustained period of time can therefore be associated with a variety of other negative influences.

This chapter discusses the responses of pilots regarding their perception of the effect of automation on workload. The questions in this section address periods of low workload, emergency situations and total workload. Pilots were also asked to assess the effect of automation on fatigue.

Workload and Boredom

Thirty-six percent of respondents considered that times of low workload in an automated aircraft were boring (see fig. B6.1, page 198). This supports anecdotal evidence that suggests that automation accentuates times of low workload. It also relates to question B9.4 where 32 percent of respondents indicated that they had inadvertently fallen asleep on the flight deck of an advanced-technology aircraft.

Analysis revealed a significant difference between the responses to this question when considering both pilot rank and aircraft manufacturer. First officers considered times of low workload to be more boring than did captains, while Boeing pilots considered times of low workload more boring than did Airbus pilots (see table B6.1, pge 198).

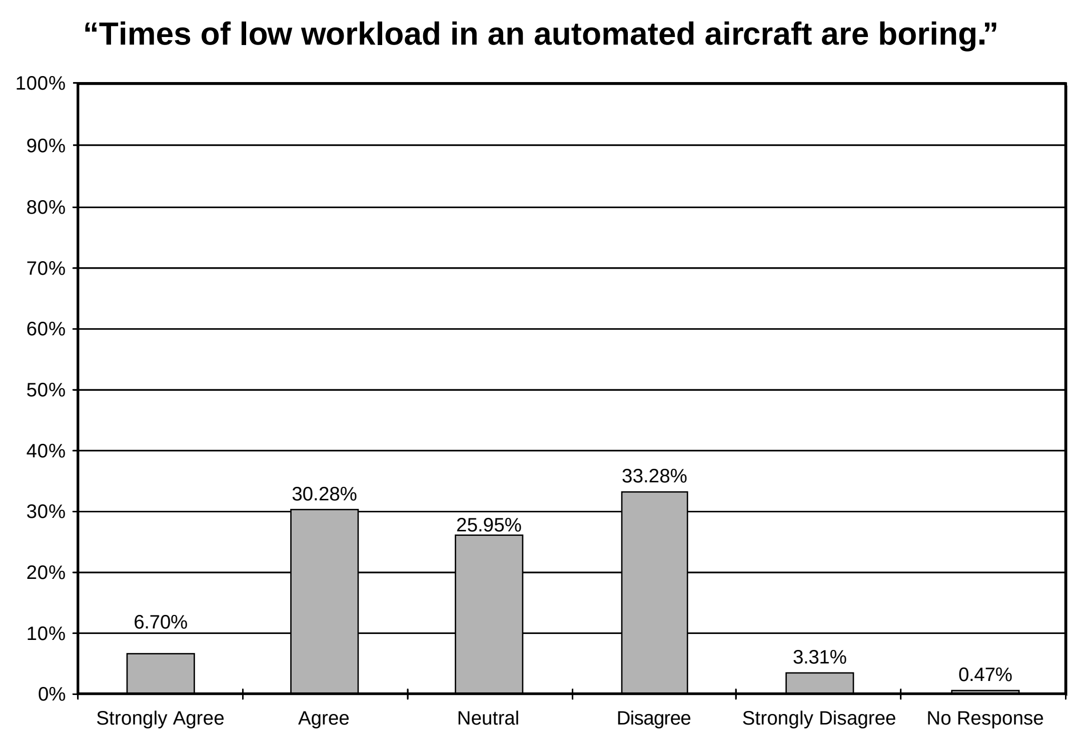
Workload and Emergencies

The majority of respondents (77 percent) considered that in an emergency, automated systems reduced their workload (see fig. B6.2, page 199). This result is contrary to anecdotal evidence that points to automation escalating periods of high workload. Further analysis revealed statistically significant differences in the responses to this question by pilot rank and aircraft manufacturer. More Boeing pilots than Airbus pilots considered that automation had reduced their workload in an emergency situation, and first officers responded more positively than captains. An analysis of the previous types flown by current Boeing and Airbus pilots revealed that approximately the same proportion of each group had previously flown jet transport aircraft such as BAe 146, and larger aircraft (Boeing pilots = 79 percent, Airbus pilots = 78 percent). The mean hours in type for Boeing pilots (2,379 hours) was approximately 30 percent greater than for Airbus pilots (1,789 hours). It may be that the more familiar a pilot becomes with automated functions, the greater he/she perceives their contribution to a reduction in workload. Further research is needed to determine if any specific differences between aircraft types might contribute to aviation safety.

Automation's Effect on In-flight Fatigue

Forty-eight percent of respondents considered that the introduction of automation had reduced the effect of fatigue during flight (see fig. B6.3, page 199).

Hawkins (1993) outlines the difficulty in defining fatigue. It may reflect inadequate rest, disturbed or displaced biological rhythms (often described as jet lag), excessive muscular or physical activity, or may result from a sustained period of



Source: Bureau of Air Safety Investigation

Figure B6.1

Table B6.1
"Times of low workload are boring."

	Captain	First officer
Airbus	25%	25%
Boeing	36%	42%

Source: Bureau of Air Safety Investigation

demanding cognitive activity. Like workload, fatigue affects human performance and therefore must be managed to ensure satisfactory performance levels are maintained throughout a duty period.

Pilots responding to question B6.5 nominated several phenomena that directly reduce the effect of fatigue during flight. Compared with pilots who operate aircraft without FMC/FMGS, pilots operating automated aircraft perceived that they were required to engage in less mental activity, make fewer mental calculations and make fewer references to aircraft manuals (9.38 percent, n = 224). Approximately 12 percent indicated that less physical activity was required to fly automated aircraft and 8 percent that pilots assumed more of a monitoring role.

Automation and Total Workload

The majority of respondents consider that automation reduced total workload (see fig. B6.4, page 200).

Written Responses

Question B6.5 asked pilots to explain how automation had affected their workload. Seven hundred and fifty-eight pilots (59 percent) responded to this question.

Four hundred and forty-seven pilots indicated that their workload was less when compared with aircraft without FMC/FMGS. For example:

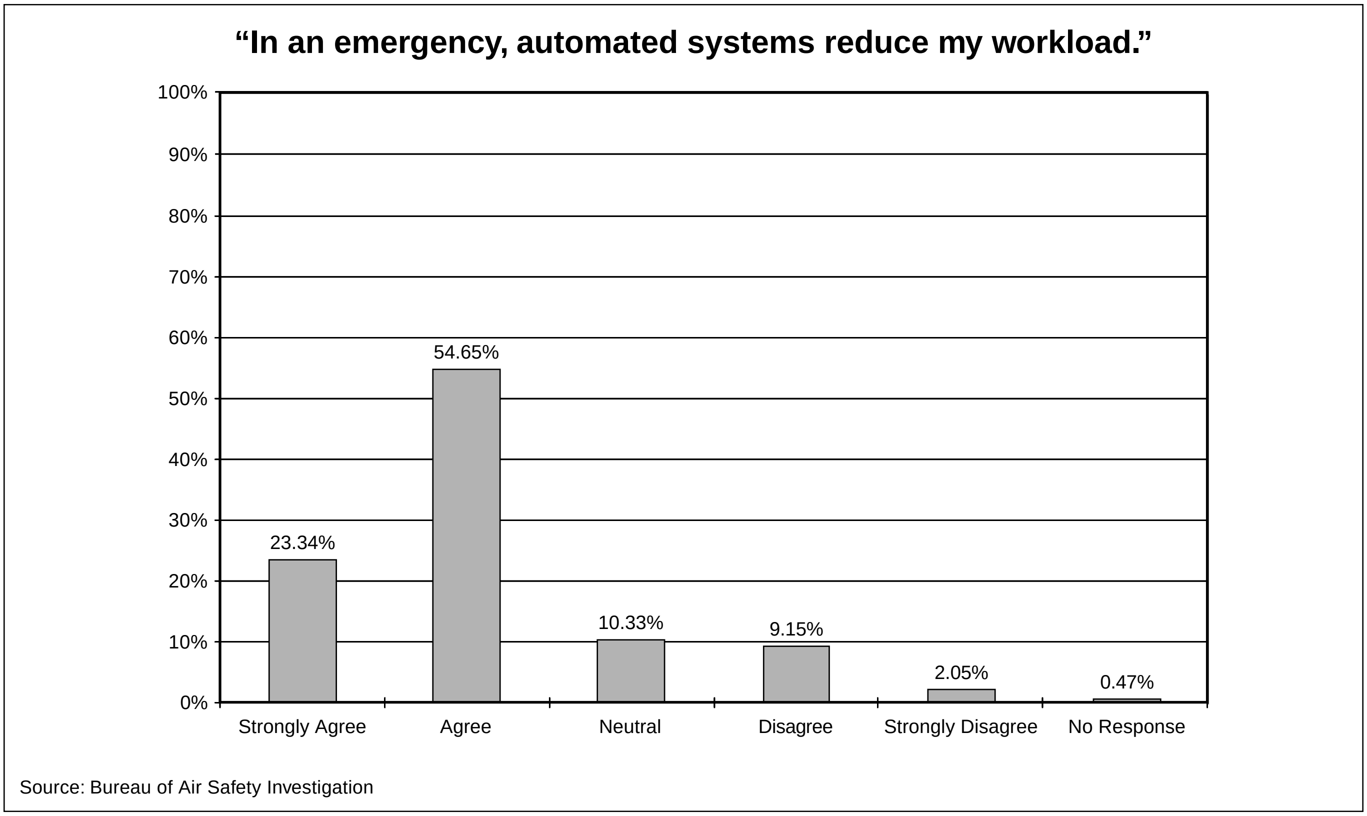
> *Reduced due better planning of track miles to touchdown, better autopilot gives more precise speed and navigation control, better confidence in autoland, better confidence in nonprecision approach, clearer raw data.*

One hundred and forty-eight pilots concluded that their workload was mixed (some aspects increased, some decreased) or their workload priorities had been rearranged or altered. For example:

> *Normal ops automation is very beneficial, non-normal ops workload is extremely high due to two crew ops brought about by automation*

Some respondents indicated that their workload had increased while others considered that their workload was the same as when flying nonautomated aircraft.

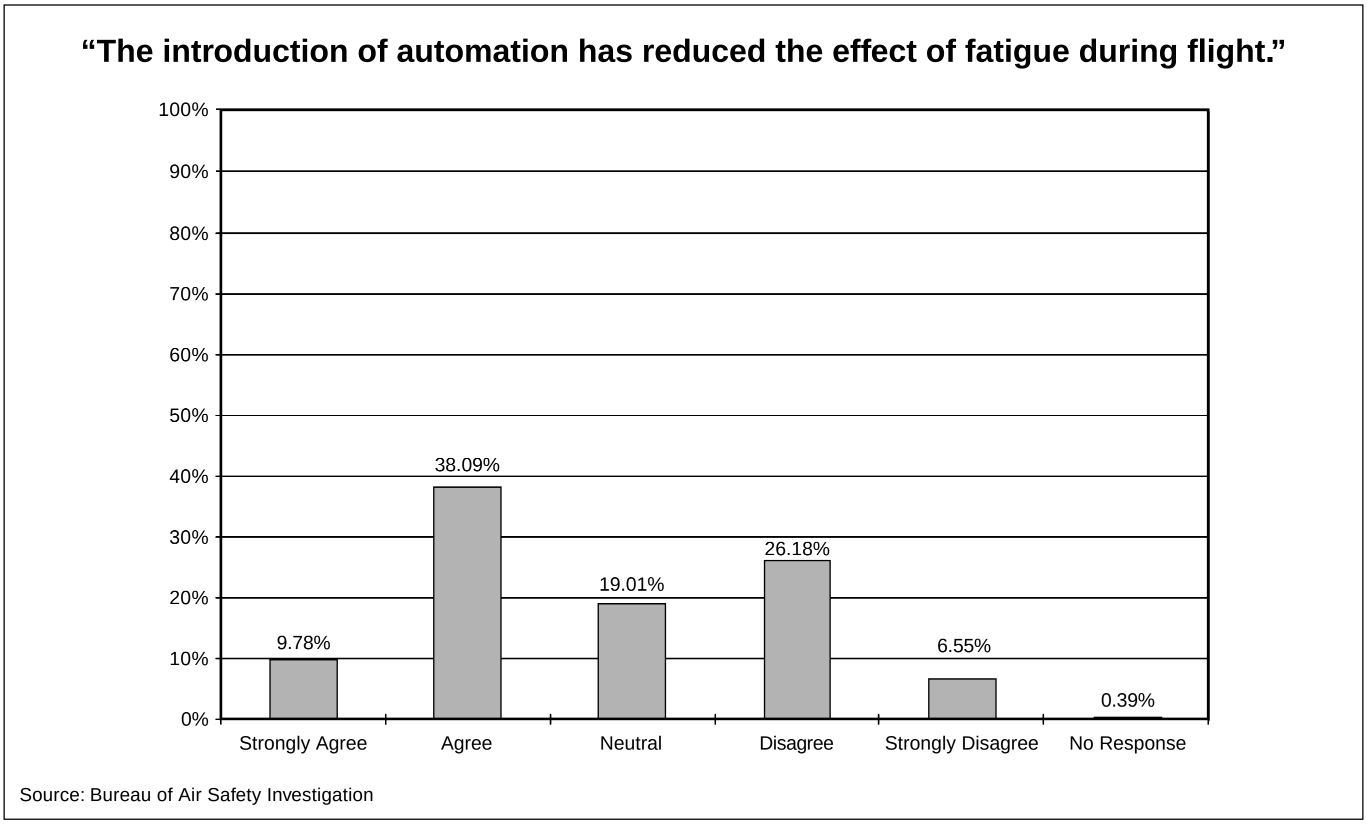
(continued on page 200)



"In an emergency, automated systems reduce my workload."

Source: Bureau of Air Safety Investigation

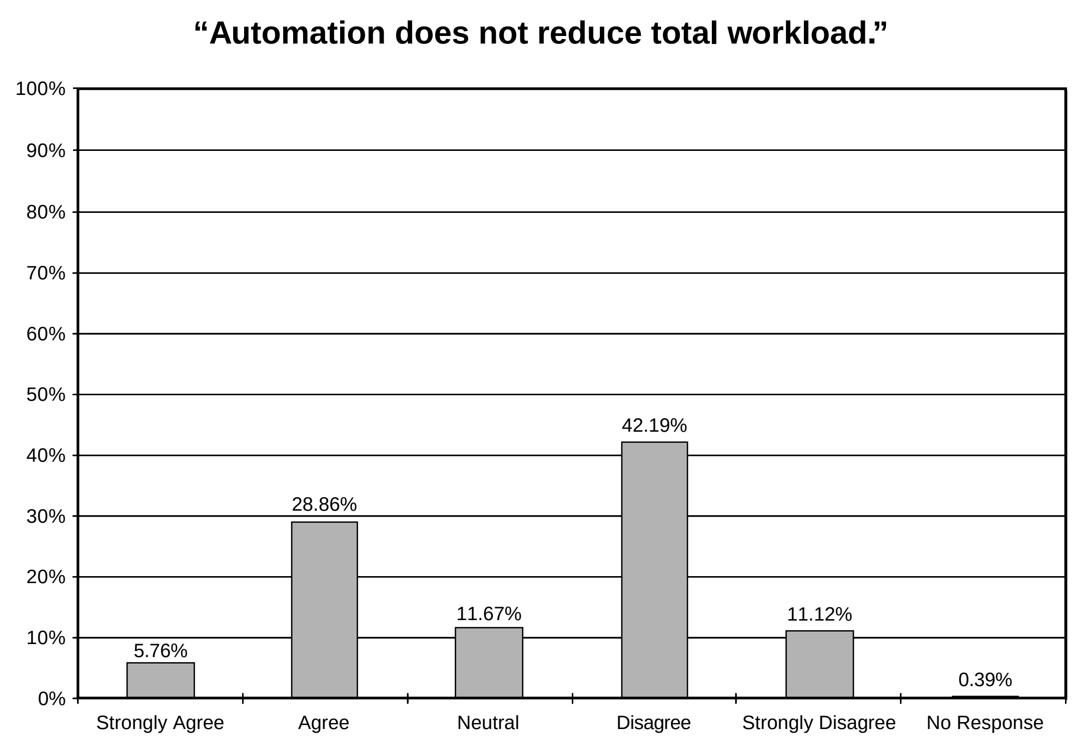
Figure B6.2



"The introduction of automation has reduced the effect of fatigue during flight."

Source: Bureau of Air Safety Investigation

Figure B6.3



Source: Bureau of Air Safety Investigation

Figure B6.4

Reduced Workload

Of the 447 pilots who indicated that their workload had reduced, 75 made comments regarding a specific phase of flight. Of these, 22 percent experienced reduced workload during descent, approach, terminal area operations or during holding manoeuvres. Seventeen percent of this subgroup (*n* = 75) indicated that although their overall workload had decreased, they had detected an increased workload with regard to emergency situations / late ATC changes / holding / navigation and diversion. Significantly, 16 percent of the subgroup recorded the opposite opinion, namely that they had detected a decreased workload with regard to emergency situations / late ATC changes / changes general and diversion.

Two hundred and twenty-four pilots nominated why they thought their workload had decreased. Of these, 62 percent attributed the decrease in workload to automation hardware (for example, FMC, autopilot, navigation systems) or the way in which information from these systems was displayed. The next two categories related to the consequences of automation with 9 percent attributing the decrease in workload to “less mental activity/mental calculations/looking up manuals,” and 8 percent highlighting that “pilots now take on a monitoring role.”

One hundred and fifty-seven pilots commented on the consequences of a reduced workload, with 75 percent indicating that they had more time to manage/monitor/concentrate on the flight.

Workload Mixed/Rearranged/Altered

Approximately 20 percent (*n* = 148) of the respondents who provided written comment on workload indicated that some aspects of their workload had increased while other aspects of their workload had decreased.

Of this group, 105 nominated a specific phase of flight in which their workload had been affected. Forty-five percent perceived that workload in relation to emergency situations/late ATC changes/changes general and diversion had increased. Thirteen percent indicated that their workload during preflight/ground/takeoff and SID had increased, while 12 percent commented that their workload during preflight/ground/takeoff and SID had increased but had decreased during cruise / in flight or en route.

Forty pilots from this subgroup nominated why they thought their workload had altered. Twenty-five percent commented that pilots currently assumed a monitoring role, while 25 percent commented that the cockpit crew had been reduced to two pilots.

Only five pilots from this subgroup commented on the consequences of an altered workload with three pilots indicating that they had more time to manage/monitor/concentrate on the flight.

Conclusion

Pilots can suffer from performance degradation at both ends of the workload spectrum. The pilot's ability to perform tasks necessary for flight is degraded with too little stimulation just as it is through excessive stimulation or workload.

Pilots appeared satisfied that automation had reduced the excessive physical and mental workload normally encountered during emergency situations. However, the majority of flight operations are conducted under normal conditions during the cruise phase of flight (especially in long-haul operations). The results of this survey indicate that an optimum workload during normal operations had not been achieved. This phenomenon is recognised by airlines that have installed crew alertness monitoring equipment on automated flight decks. Developments such as the future air navigation systems (FANS) have the possibility of further reducing pilot stimuli within the cockpit.

Similarly, while pilots generally agreed that automation had reduced fatigue during flight, it appears that further advancement needs to be made in this area. It is essential that any safety enhancements produced through automation are not negated by a failure to address the issue of fatigue. The combination of automation, ergonomic design and aircraft environmental control (including noise control) should be considered together with in-flight duty patterns to control levels of fatigue.

Further research might establish whether the automation of other aspects of the aviation industry (e.g., maintenance procedures) would reduce workload and fatigue and hence reduce overall error rates.

A Comparison with Previous Studies

Introduction

Ten of the questions included in this survey were based on attitude probes developed by Wiener for his study of human factors in advanced-technology aircraft during the late 1980s (Wiener, 1989, used with permission). The purpose of this was to compare the responses of pilots within the Asia-Pacific region to those of their North American counterparts.

Wiener asked a volunteer sample of B-757 pilots from two companies to answer two separate questionnaires that were mailed to each pilot one year apart (1986 and 1987). Thirty-six identical attitude questions were included in both questionnaires. The following charts (see figs. 11.1 to 11.10, pages 202–206) represent the results of Phase 1 and Phase 2 of Wiener's study (labelled Wiener 1 and Wiener 2), followed by the BASI results of 10 similar attitude questions. The BASI results are then reported for Boeing pilots and Airbus pilots.

Table 11.1 reports the characteristics of the samples quoted in this chapter.

It is reasonable to expect that time, culture, technological advancement, training and experience would have had an effect on the attitudes of pilots and that the responses from the two surveys would be significantly different.

Contrary to this expectation, the results from the BASI study were not significantly different from the findings of Wiener.

Conclusion

Although this comparison is limited to only 10 attitude probes, figs 11.1–11.10 indicate that pilot attitudes towards automation are remarkably similar, despite differences in culture, technological advancement, training and experience.

It would appear that after approximately 10 years, the efforts of the aircraft manufacturers and airline training departments have not adequately addressed the issue of automation surprise, the lack of mode awareness and deficiencies in systems knowledge.

To summarise the results of the 10 attitude probes:

1. Automation surprise was common across all groups.

(continued on page 207)

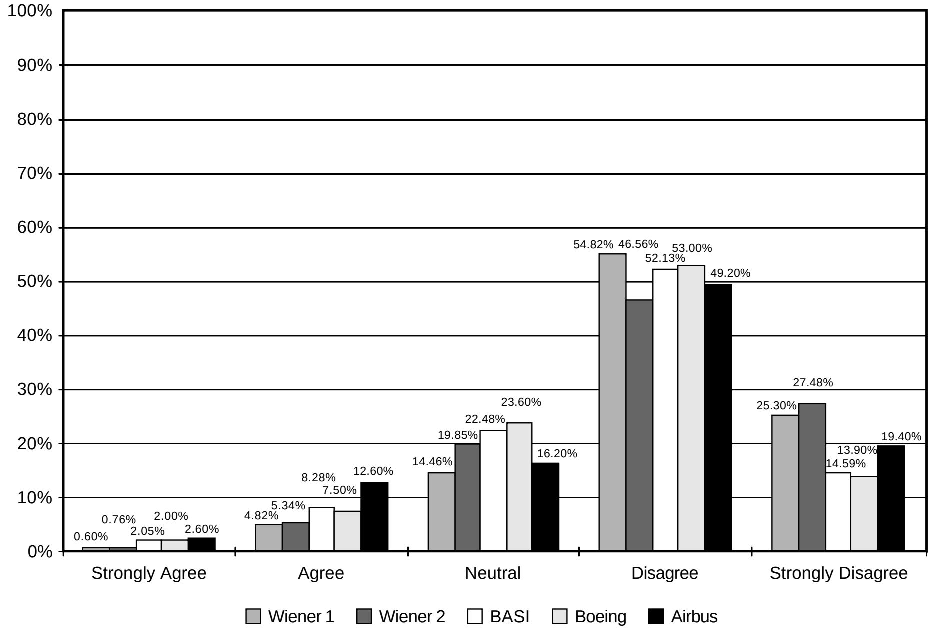
Table 11.1
Summary Data

	Wiener 1 & 2	BASI
Captains	58.7%	56.1%
First officers	41.3%	36.7%
Second officers	0%	7.2%
Total aeronautical experience (average)	11,000 hours	9,667 hours
Hours in type (average)	Wiener 1 = 500 hours (B757) Wiener 2 = 1,100 hours (B757)	BASI = 2,264 hours (all types) Airbus = 1,789 hours Boeing = 2,379 hours

Source: Bureau of Air Safety Investigation

System Design and Automation

Wiener - “I think they’ve gone too far with automation.”
BASI - “They’ve gone too far with automation.”

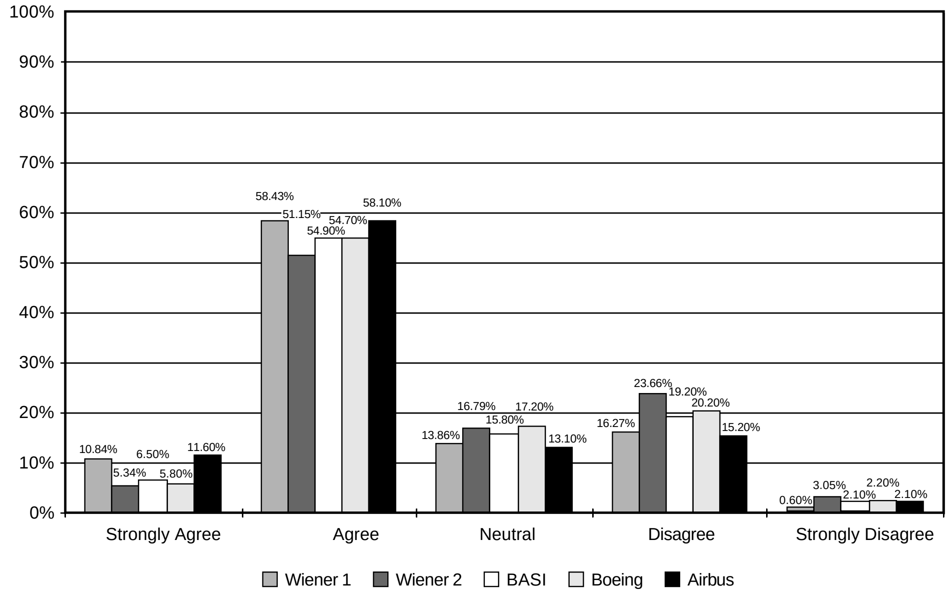


Source: Bureau of Air Safety Investigation

Figure 11.1

System Design and Automation

Wiener - “In B-757 automation, there are still things that happen that surprise me.”
BASI - “With automation, there are still some things that take me by surprise.”

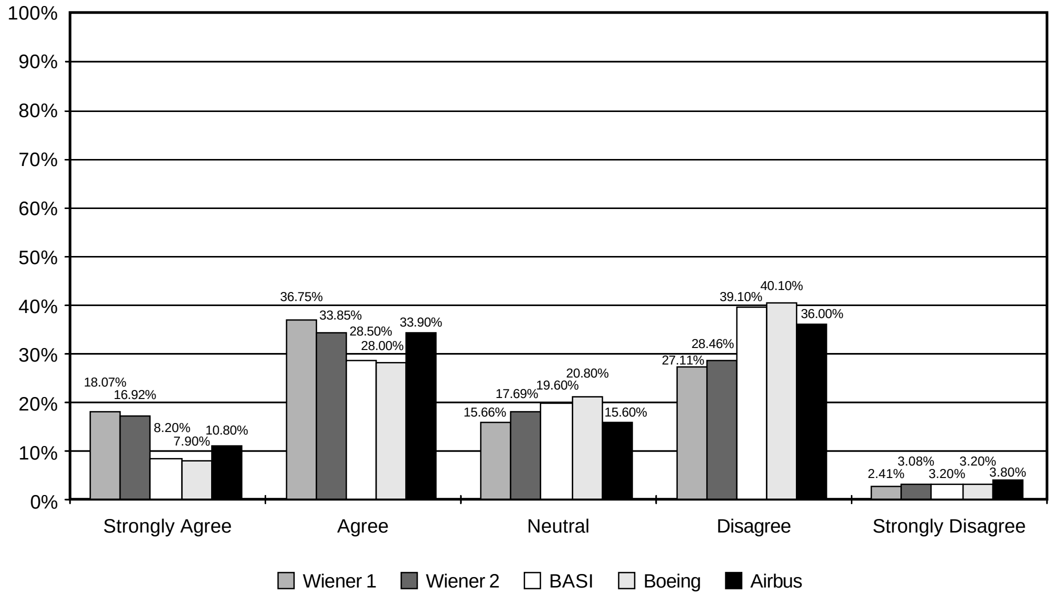


Source: Bureau of Air Safety Investigation

Figure 11.2

Air Traffic Control

Wiener - “In the B-757 there is too much programming going on below 10,000 feet and in the terminal area.”
BASI - “There is too much programming going on below 10,000 feet.”

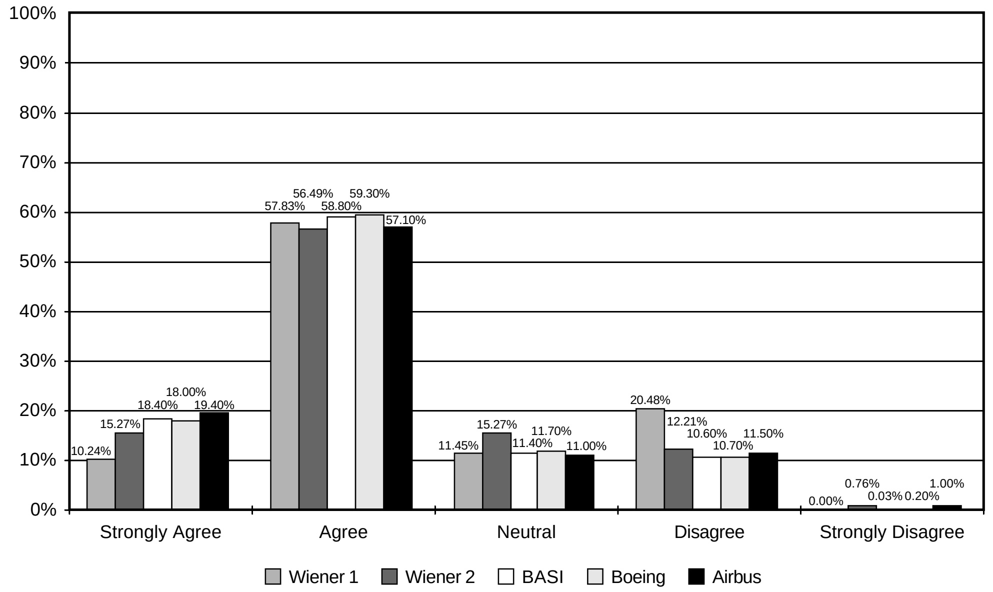


Source: Bureau of Air Safety Investigation

Figure 11.3

Modes

Wiener - “I always know what mode the autopilot/flight director is in.”
BASI - “I always know what mode the autopilot/autothrottle/flight director is in.”

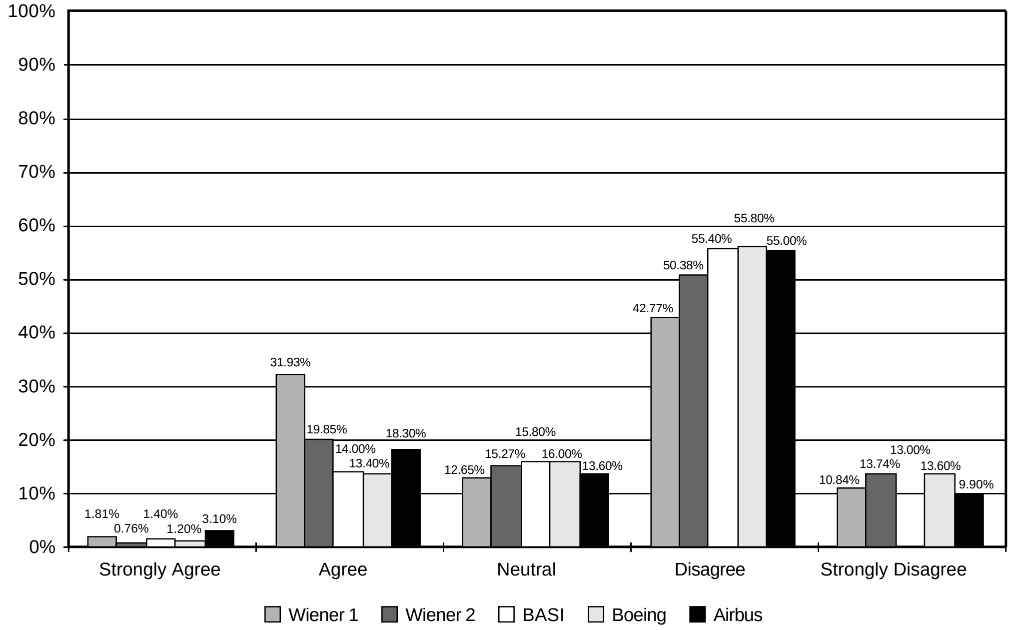


Source: Bureau of Air Safety Investigation

Figure 11.4

Modes

Wiener - “There are still modes and features of the B-757 FMS that I don’t understand.”
BASI - “There are some modes that I don’t understand.”

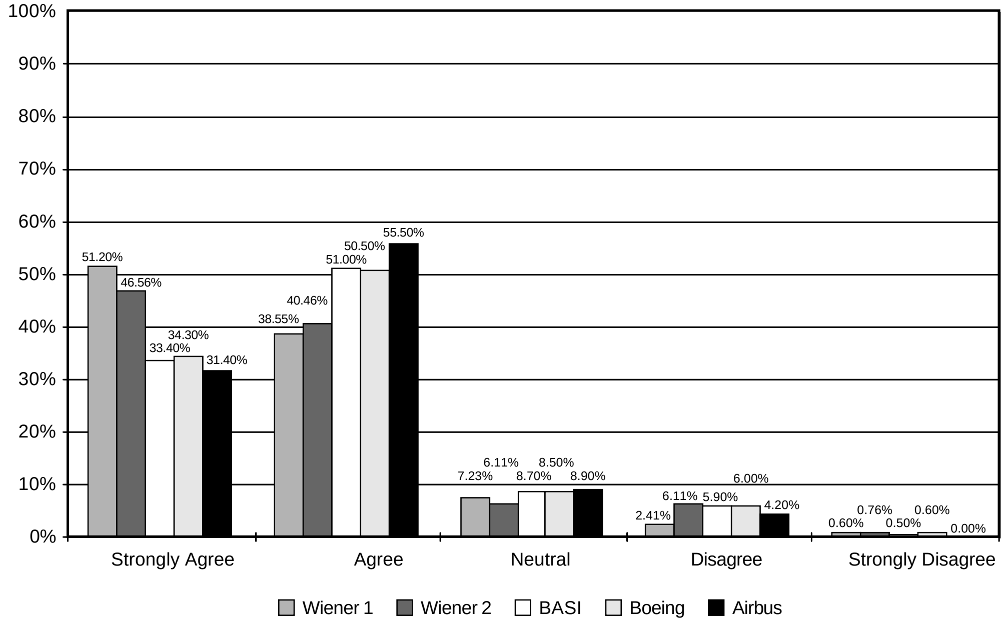


Source: Bureau of Air Safety Investigation

Figure 11.5

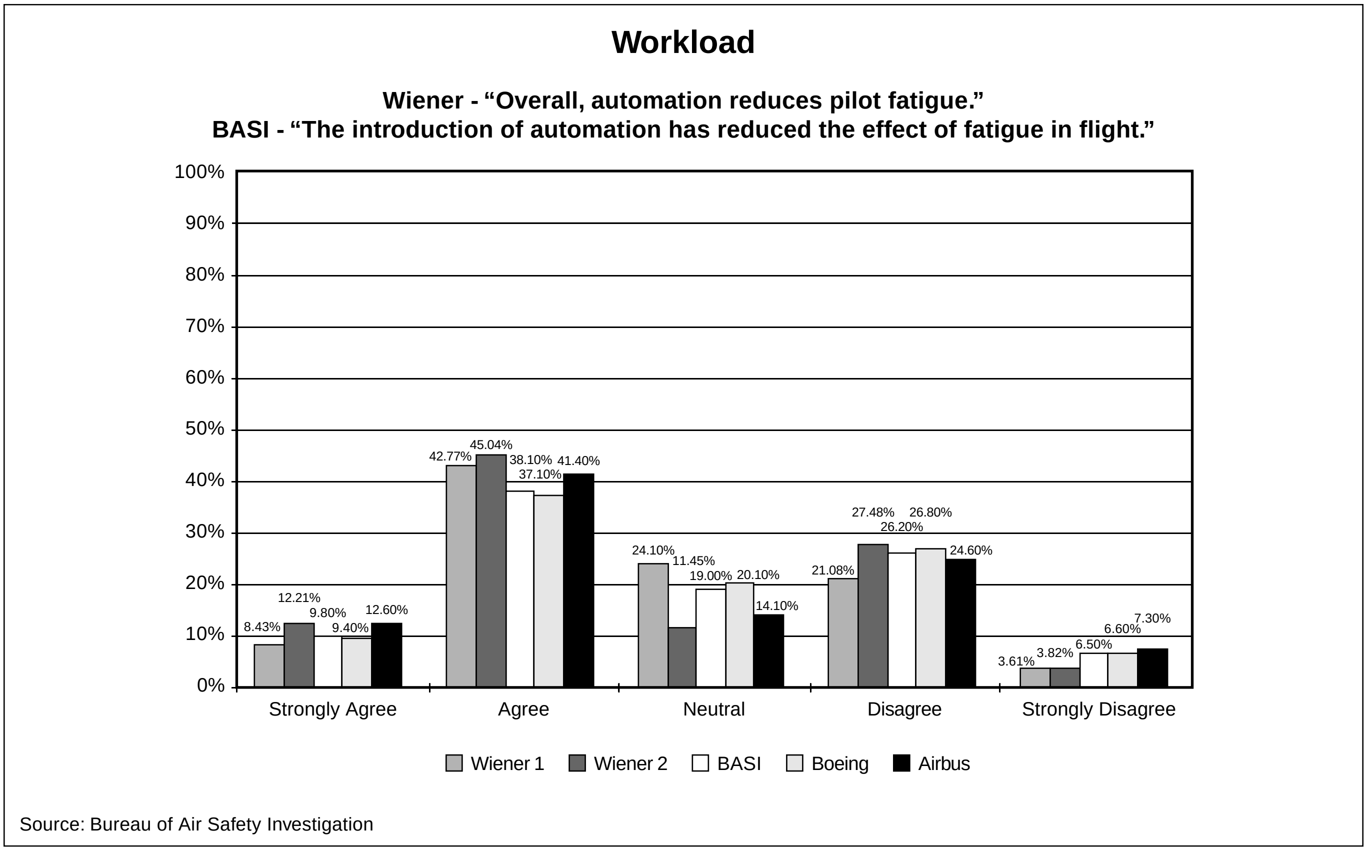
Flying Skills

Wiener/BASI - “I prefer to hand fly part of every trip to keep my skills up.”



Source: Bureau of Air Safety Investigation

Figure 11.6

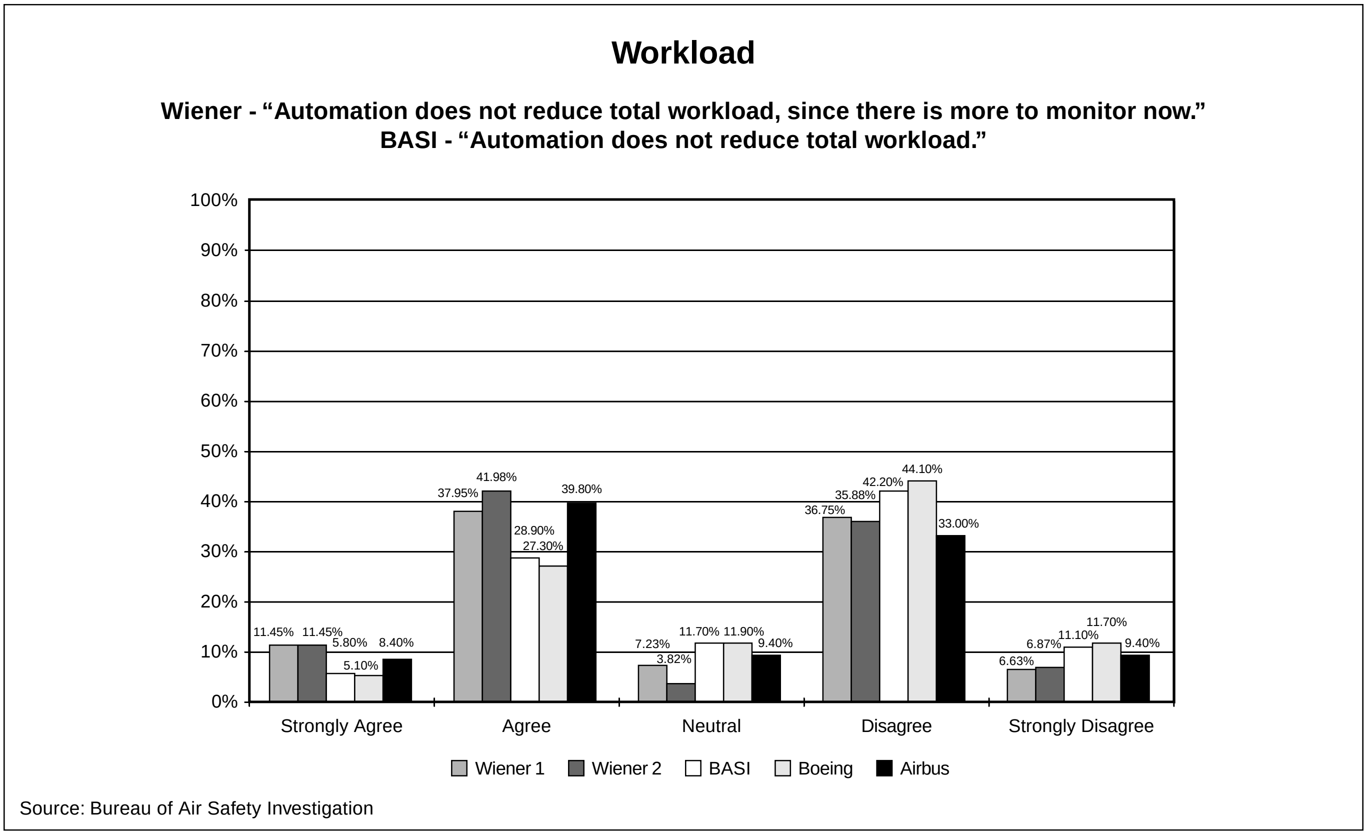


Workload

Wiener - “Overall, automation reduces pilot fatigue.”
BASI - “The introduction of automation has reduced the effect of fatigue in flight.”

Source: Bureau of Air Safety Investigation

Figure 11.7

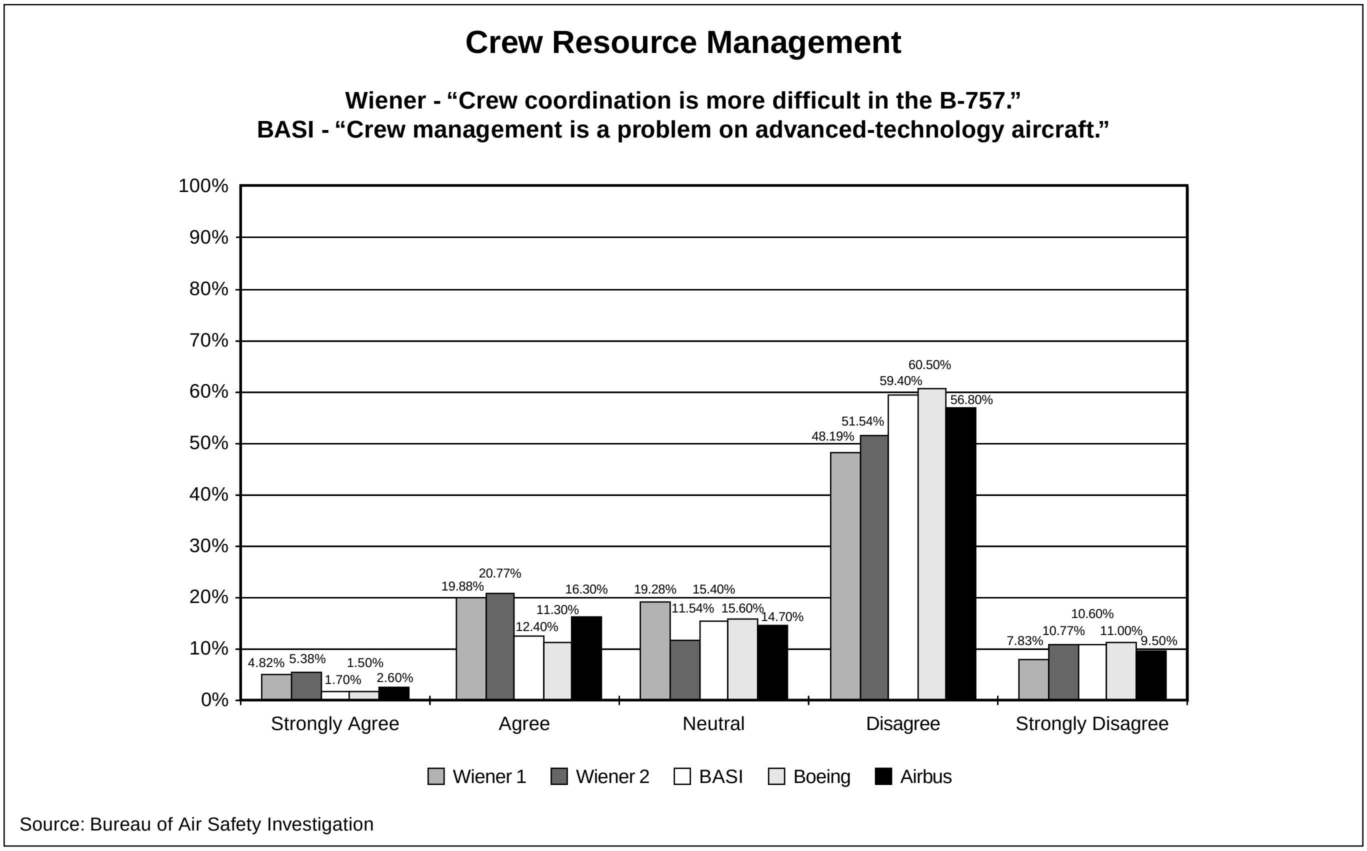


Workload

Wiener - “Automation does not reduce total workload, since there is more to monitor now.”
BASI - “Automation does not reduce total workload.”

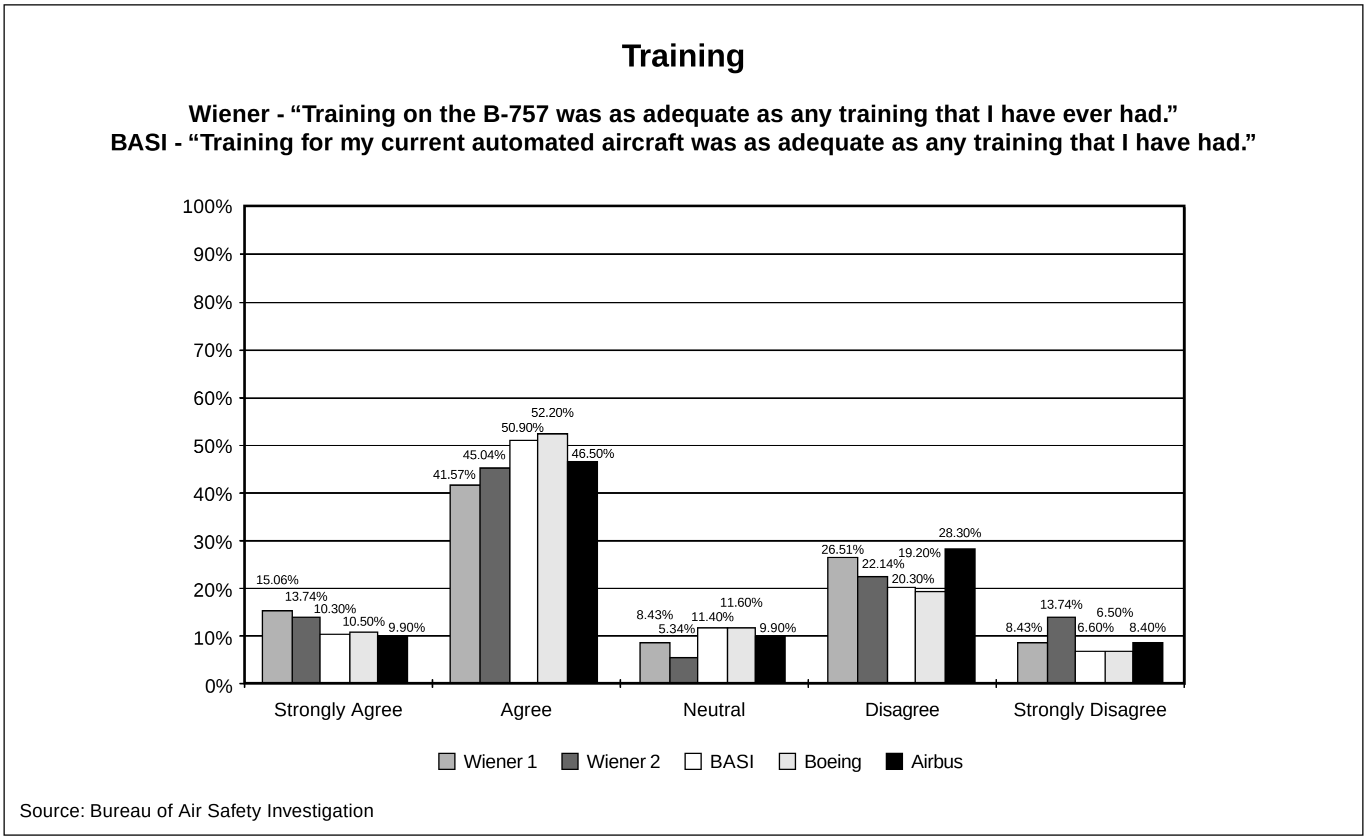
Source: Bureau of Air Safety Investigation

Figure 11.8



Source: Bureau of Air Safety Investigation

Figure 11.9



Source: Bureau of Air Safety Investigation

Figure 11.10

2. An average of 11 percent of pilots did not always know what mode the autopilot / autothrottle / flight director was in.

3. An average of 9 percent of pilots agreed that there were some modes that they did not understand.

4. The majority of all pilots preferred to hand-fly part of every trip to keep their skills up.

5. Most pilots agreed that automation had reduced the effect of fatigue in flight.

6. Pilots were polarised on the issue of the effect of automation on workload reduction.

7. The majority of pilots did not agree that crew management was a problem on advanced-technology aircraft.

8. Most agreed that their training had been adequate.

General Conclusion

The purpose of this survey was to evaluate the human-system interface of advanced-technology aircraft in service within the Asia-Pacific region, to collect information on flight deck errors, to assess the severity of those errors, to identify design-induced errors and to identify areas where pilots inappropriately manipulate automated systems. The success of the study was attributed to the cooperation of many of the airlines that form the Orient Airlines Association (recently renamed Association of Asia-Pacific Airlines) and the overwhelming amount of information supplied by pilots who were flying advanced-technology aircraft. The study has also been enthusiastically supported by the manufacturers of advanced-technology aircraft.

General Findings

In general, the pilots who participated in this study possessed positive attitudes toward automation. However, several problem areas were identified. These are summarised below.

Human-system Interface Problems

"System interface" is used here to relate to specific automated components (e.g., the MCP) and in a larger context to relate to the relationship between automated aircraft and the ATC system.

This study highlighted the following safety issues:

1. Database errors, data-entry errors, error detection and correction continue to limit the safety benefits of automation software.

2. Some pilots reported having difficulty understanding the language or technical jargon in messages presented by the FMC/FMGS. Aviation safety would benefit from a common language base for all software applications. FMC messages should lead the operator intuitively to the source of a problem.

3. Systems interface is partly dependent upon the quality of training. Some pilots perceived that the quantity and quality of training they received for their current aircraft was inadequate. Pilots also commented on the experience and qualification of instructional staff. Training, and hence safety, could be enhanced by airline operators ensuring staff (ground, simulator and flight instructors) are trained in appropriate educational techniques.

4. It would appear that aircraft automated systems and the ATC environment have largely developed independently. The results of this survey indicate that ATC does not make use of the capabilities of automated aircraft, that ATC is not always familiar with the aerodynamic characteristics of modern automated aircraft, and that last-minute changes imposed by ATC increase pilot workload. Both pilots and ATC personnel need to be aware of the limitations of each other's environment. Future development should improve the macro interface between aircraft and ATC with the aim of improving ATC procedures. Government and environment groups need to appreciate that their actions may jeopardise the quality of aviation safety.

Flight Deck Errors

The results of this study raised the following concerns relating to flight deck errors:

1. The results highlighted occasions of simultaneous control inputs by both pilots. This phenomenon has been cited as a contributing factor in a number of accidents or incidents within the Asia-Pacific region. These results are not limited to aircraft equipped with side-stick controls. Aircraft manufacturers should evaluate the design philosophy of modern automated control systems, as recent system modifications do not adequately address the case of unannounced simultaneous control inputs by both pilots. Standard operating procedures and airline policy should clearly address this issue.

2. The majority of respondents reported that they had on occasion inadvertently selected the wrong mode. Further research is required to determine the cause of this phenomenon and its impact on aviation safety. Incorrect mode selection may indicate a lack of mode awareness, poor training, vague SOPs, inadequate airline policy or in-flight briefings that do not address which modes are to be selected in a particular manoeuvre.

3. A significant proportion of respondents indicated that there had been times when the other pilot had not told

them something they needed to know for the safe conduct of the flight. Pilots need to be aware of the safety implications of not effectively communicating during flight, especially considering future ATC procedures that will further reduce the amount of verbal communication on the flight deck.

Design-induced Errors

The FMC, FMA and MCP are all major components of the human-system interface. Any limitation or design fault in any of this automated hardware could potentially cause errors.

Respondents to this study reported that they often transpose the heading select knob and the command airspeed bug knob on the MCP. Aircraft manufacturers should evaluate the position, size, shape and tactile cues of these controls.

Mode awareness is necessary for the safe operation of advanced-technology aircraft. Some pilots reported that mode changes can occur without adequate indication.

System Work-arounds

Respondents confirmed the widespread practice of entering erroneous information into the FMC/FMGS to manipulate the performance parameters of the aircraft. The majority of cases were recorded during the descent and approach phase of flight for the purpose of achieving a desired descent profile. This may reflect partly on poor ATC procedure design, and partly on the inability of current software programs to accurately control aircraft performance. Of greater importance were the cases in which pilots entered erroneous data to override warning messages such as “INSUFFICIENT FUEL.” Such actions are not addressed in airline policy documents or SOPs and seem to be encouraged by flight training staff and aircraft manufacturers. Although there is no evidence to suggest that safety is being compromised by these actions, there is a strong argument to the effect that this action promotes bad habits and negates the professionalism of pilots generally. If this attitude were to be incorporated in other areas of flight operation, it could constitute a serious safety concern.

Final Conclusion

The results of this study have established a baseline of information regarding the operation of advanced-technology aircraft within the Asia-Pacific region. Automation appears to have contributed to the overall safety health of airline operations and is generally accepted by pilots; however, these results also point to the existence of specific automation-induced errors that could result in safety hazards. Some of these errors are more easily corrected than others. Some may be addressed through airline policy and SOPs, while others are insidious, latent and extremely costly and time-consuming to address.

Summary of Recommendations

Introduction

The following recommendations are organised according to their corresponding chapter. Where applicable, recommendations have been addressed to:

- Airservices Australia;
- The Civil Aviation Safety Authority (Australia);
- Aircraft design authorities;
- Airlines within the Asia-Pacific region; and,
- Airlines around the world.

However, this does not restrict the applicability of the recommendations to the above-mentioned agencies. BASI encourages foreign agencies, both government and civil, to adopt all, or any, of the following recommendations in the interests of improving aviation safety throughout the international aviation industry.

Traditionally, recommendations flowed from “reactive” investigations where active or latent failures were found to have directly contributed to an accident or incident. In response, government authorities, aircraft manufacturers and airline operators made changes to various aspects of their operation with the aim of limiting further occurrences. Unlike reactive investigations, much of modern research is framed in a proactive sense. Researchers are given the difficult task of finding potential problems before they arise. Fortunately, safety professionals within the aviation industry are embracing proactive remedies, although ever so slowly. The traffic-alert and collision avoidance system (TCAS) is a good example of a proactive safety tool that some airline operators were reluctant to implement. Safety professionals now often quote the accidents that have been avoided by responding to a TCAS message.

The objectives of this project are largely proactive. Our task has been to determine specific errors and assess the severity of those errors. Consequently, some of the following recommendations are phrased in a proactive sense. Regulatory authorities, aircraft manufacturers and airline operators are now required to do the same, basing their response on the evidence provided by 1,268 pilots, many of whom are line pilots with considerable experience. Our concern is that appropriate mechanisms and an appropriate mindset are not yet in place to assess proactive recommendations. This is the greatest challenge currently before the aviation industry.

1. ATC

The Bureau of Air Safety Investigation recommends that Airservices Australia (R980024) and the Civil Aviation Safety Authority (R980025):

Review their airways and procedures design philosophies to:

(a) Ensure that STAR, SID and airways design is compatible with aircraft FMS programs;

(b) Allow a ±10-knots range with respect to descent speed below 10,000 feet to allow for the tolerances of FMS-equipped aircraft, with the aim of reducing the requirement for system work-arounds;

(c) Provide ATC personnel with information on the aerodynamic characteristics of advanced-technology aircraft; and

(d) Seek the cooperation of airline operators for a program of advanced technology flight deck observation for all ATC personnel during both their initial and recurrent training.

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980026):

Consider a program of flight crew observation of ATC operations during both initial and recurrent training. Such a program should be incorporated into the syllabus of training and include subjective elements requiring observation and assessment.

2. Automation

The Bureau of Air Safety Investigation recommends that airline operators (R980027):

1. Ensure that flight crew of advanced-technology aircraft are educated in the concept, and safety implications, of passive command syndrome.

2. Include a comprehensive statement of automation policy in their general operations manual and/or airline policy documents.

3. Crew Resource Management

The Bureau of Air Safety Investigation recommends that airline operators (R980028):

Employ appropriate methods and examples during initial and refresher CRM training to enhance the transmission of safety information between flight crew members during flight. Such training should stress the consequences of not communicating essential flight safety information.

4. Flying Skills

The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (R980029):

Ensure that all recurrent and rating renewal simulator exercises are appropriate considering the level of automation fitted to the aircraft type. Such exercises should reflect the level of serviceability that the pilot may be expected to encounter during line operations.

5. General

The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (R980030):

Review the minimum standards for the quality of information provided in FMC databases with the aim of eliminating FMC database errors.

The Bureau of Air Safety Investigation recommends that airline operators (R980031):

1. Include in the ground-training phases of pilot endorsement courses:

   (a) sufficient technical knowledge of aircraft systems; and,

   (b) knowledge of the design philosophies employed by aircraft system manufacturers;

   to give pilots sufficient systems understanding to permit analysis of system abnormalities and to determine appropriate responses in situations for which checklists are not available.

2. Consider the safety lessons from discussions of incident and accident scenarios during all initial, recurrent and CRM training programs.

The Bureau of Air Safety Investigation recommends that aircraft design authorities and airline operators (R980032):

Consider effective systems and procedures to ensure that flight crew of automated aircraft do not inadvertently fall asleep during flight.

6. Modes

The Bureau of Air Safety Investigation recommends that aircraft design authorities (R980033):

Consider a requirement to ensure that all FMGS mode changes are visually and aurally annunciated.

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980034):

Review their procedures with regard to mode selection and consider:

(a) if flight crews should state intended mode selection during all flight crew briefings;

(b) if flight crews should announce and acknowledge all mode changes during flight;

(c) refresher training regarding mode mechanics and mode usage on a regular basis; and,

(d) clear and consistent guidelines regarding mode usage.

The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority (R980035):

Review the achievement requirements for aircraft technical examinations with the aim of improving the knowledge pilots possess regarding mode characteristics and application.

7. Situational Awareness

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980036):

Review their pilot training to consider:

(a) specific training to pilots regarding situational awareness;

(b) differences that may exist between printed and electronic flight information;

(c) responsibilities of ATC regarding the provision of terrain clearance; and,

(d) clear policy regarding the use of en route charts and instrument approach charts during flight.

8. System Design

The Bureau of Air Safety Investigation recommends that airline operators (R980037):

Review their standard operating procedures (SOP) and airline policy to require only one crew member to make control inputs at any one time unless stated to the contrary in an emergency/abnormal procedure, and to emphasise the consequences of multiple simultaneous flight control inputs.

The Bureau of Air Safety Investigation recommends that aircraft design authorities consider requirements for (R980038):

(a) a means of alerting the pilot when incorrect data has been entered into the FMC/FMGS;

(b) all data entries being able to be corrected easily by flight crew;

(c) common industry terminology for automation hardware and software;

(d) FMS software and hardware to accommodate the various changes that are imposed by ATC on an advanced-technology aircraft during all phases of operation;

(e) quality control procedures for FMC software with the aim of eliminating the need for system work-arounds; and,

(f) the position, design and tactile differences of the frequently used mode selectors (such as heading and speed), with the aim of eliminating any confusion regarding the use of these controls.

9. Training

The Bureau of Air Safety Investigation recommends that Civil Aviation Safety Authority (R980039):

1. Consider the need for:

   (a) simulator and flight instructors to be trained in instructional/teaching techniques at a recognised educational facility;

   (b) ground, simulator and flight instructors to undergo regular refresher training in instructional/teaching techniques at a recognised educational facility; and,

   (c) ground, simulator and flight instructors to demonstrate their ability as an instructor/teacher on a regular basis.

2. Assess the quality of printed and electronic training/reference material with respect to advanced-technology aircraft.

The Bureau of Air Safety Investigation recommends that airline operators within the Asia-Pacific region (R980040):

Review the qualifications of all ground, simulator and flight instructors, and where necessary, provide training in instructional/teaching techniques with the aim of accrediting instructional/teaching staff.♦

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Survey Questionnaire Details

Note:

The following is not a reproduction of the survey form but contains all the questions that were included, plus a description of the responses requested.

Part A

Part A sought information about the respondent, his/her employment and experience.

1. TICK the boxes which describe your position in the company

   Captain
   First Officer
   Second Officer
   Cadet Pilot

   Management Position
   Check Pilot
   Training Pilot
   Supervisory Pilot
   Company Test Pilot
   Line Pilot

   Qualified
   Under Training

2. I fly *domestic routes* (flights which do not cross international borders e.g., Sydney to Melbourne)

   international short haul routes (flights to adjoining airspace e.g., Australia to New Zealand, Singapore to Jakarta, Hong Kong to Taipei)

   international long haul routes (flights crossing more than one international boundary e.g., Manila to London, Tokyo to Los Angeles, Jakarta to Jeddah)

3. I am Male / Female
4. My age is
5. My nationality is
6. My first language is
7. My second language is
8. My home port (base) is
9. What type of aircraft do you currently fly?
10. When did you complete your engineering course/ground school course for this aircraft?
11. Approximately how many hours have you logged on your current aircraft type?
12. What was your previous aircraft type?
13. In what capacity did you fly that aircraft? Captain/First Officer/Second Officer/Cadet Pilot
14. Approximately how many flight hours have you logged (Total Aeronautical Experience)?
15. Approximately how many sectors have you flown as "pilot flying" in the last 90 days? (A sector is a flight between any two points where you have conducted the takeoff and/or landing).

Part B

Part B sought the respondent's views on matters concerning advanced-technology aircraft. The questions were of three types:

(a) phrased as statements to which the respondent indicated agreement or disagreement and the intensity of feeling (Likert Scale responses);

(b) requests for narrative responses; and

(c) requests for YES/NO answers and amplification of YES responses.

System Design and Automation

Questions 1.1 to 1.10 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

1.1 The FMC/FMGS and associated controls are "user friendly."

1.2 It is easy to detect when incorrect data has been entered by mistake.

1.3 I always know what the other crew member is doing with the automated systems.

1.4 At times I have been surprised to find the pilot not flying (PNF) making flight control inputs.

1.5 They've gone too far with automation.

1.6 With automation there are still some things that take me by surprise.

1.7 The FMC/FMGS sometimes fails to capture an altitude as I expect.

1.8 Incorrect data entered by mistake is easily corrected.

1.9 I sometimes find it hard to understand the language or technical jargon in messages presented by the FMC/FMGS.

1.10 I look at the FMA when I want to know what the aircraft is doing.

Please complete the following sentences in your own words:

1.11 On this aircraft, the automated feature I like most is;

1.12 On this aircraft, the automated feature I like least is;

1.12.1 Please describe in detail a mistake which you made, or saw someone make, which you think could be attributed to automation. Describe specifically what happened and why it happened.

Air Traffic Control

Questions 2.1 to 2.5 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

2.1 Air Traffic Control makes use of the capabilities of this aircraft to its fullest.

2.2 Air Traffic Control appears to be familiar with the descent profile of my aircraft.

2.3 Air traffic controllers sometimes ask for information which is difficult to extract from the FMC/FMGS in a reasonable amount of time.

2.4 The current level of automation does not cope well with the last minute changes imposed by Air Traffic Control.

2.5 There is too much programming going on below 10,000 feet.

2.6 I am concerned about the Air Traffic Control procedures within the following geographical area:

2.7 Please outline a specific event where you had difficulty operating an advanced-technology aircraft in accordance with an ATC instruction.

Modes

Questions 3.1 to 3.8 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

3.1 I always know what mode the autopilot / autothrottle / flight director is in.

3.2 It worries me that the automated systems may be doing something that I don't know about.

3.3 On occasions I have inadvertently selected the wrong mode.

3.4 Mode changes can occur without adequate indication.

3.5 There are too many modes available on the FMC/FMGS.

3.6 There are some modes that I still don't understand.

3.7 When it comes to mode selection, the company sets out clear guidelines and

3.8 Good crew briefing will always include what modes will be used.

3.9 Please outline the details of a specific event where you had difficulty with Mode Selection, Mode Awareness or Mode Transitions.

Situational Awareness

Questions 4.1 to 4.5 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

4.1 I refer to my enroute charts far less on new technology aircraft than on aircraft without an FMC/FMGS.

4.2 All the information I need for the safe conduct of the flight is contained within the FMC/FMGS.

4.3 I rely on Air Traffic Control to provide adequate terrain clearance.

4.4 At times I have been surprised to find the aircraft closer to terrain than I thought.

4.5 I refer to my instrument approach charts far less on new technology aircraft than on aircraft without an FMC/FMGS.

4.6 Please outline any specific event which caused you to question your position in relation to terrain, or other aircraft.

Flying Skills and System Software

Questions 5.1 to 5.3 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

5.1 I prefer to hand fly part of every trip to keep my skills up.

5.2 My manual flying skills have declined since I started flying advanced-technology aircraft.

5.3 I am sometimes forced to "trick" the FMC/FMGS by entering erroneous data to achieve a desired result. (For example, I enter 240 knots to ensure the aircraft maintains 250 knots etc).

5.4 Please outline the details of a specific event where you were required to "trick" the FMC/FMGS by the input of false data.

Workload

Questions 6.1 to 6.4 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

6.1 Times of low workload in an automated aircraft are boring.

6.2 In an emergency, automated systems reduce my workload.

6.3 The introduction of automation has reduced the effect of fatigue during flight.

6.4 Automation does not reduce total workload.

6.5 Please explain how automation has affected your workload.

Crew Resource Management and Safety

Questions 7.1 to 7.5 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

7.1 On this aircraft, the role of the pilot flying (PF) and the pilot not flying (PNF) is always clear.

7.2 There have been times when the other pilot has not told me something I needed to know for the safe conduct of the flight.

7.3 Crew management is a problem on advanced-technology aircraft.

7.4 I sometimes find the automated systems taking over command of the aircraft.

7.5 At this airline, fleet management has a good awareness of the day-to-day issues faced by pilots operating advanced-technology aircraft.

Training

Questions 8.1 to 8.6 sought Likert Scale responses.

Strongly Agree Agree Neutral Disagree Strongly Disagree

8.1 Training for my current automated aircraft was as adequate as any training that I have had.

8.2 I would like to have a deeper understanding of the aircraft systems.

8.3 I sometimes have difficulty understanding information in the technical manuals associated with this aircraft.

8.4 I was able to find all the information I needed for my training in the aircraft/company technical manuals.

8.5 My training has prepared me well to operate this aircraft.

8.6 I prefer computer based training over traditional teaching methods.

8.7 What could be done to improve the training you received on this aircraft?

General

Questions 9.1 to 9.4 sought YES / NO answers and, if YES, requested amplifying information.

9.1 Have you ever encountered an abnormal/emergency situation while flying your current aircraft (excluding simulator base training)

If YES please describe the situation.

9.2 Have you detected any FMC/FMGS database errors (waypoint, Lat/Long, SID, or STAR route/restriction errors etc)

If YES please describe these errors.

9.3 Did you discuss any advanced-technology aircraft accidents or incidents during your conversion training?

If YES please list the accidents or incidents which were discussed.

9.4 Have you ever inadvertently fallen asleep on the flight deck of an advanced-technology aircraft?

9.5 What was the most difficult part of your conversion to advanced-technology aircraft?

9.6 Further comments or suggestions. You may care to comment on the aspects of automation which have not been specifically covered in this survey.

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Appendix A

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- Dr. Ashleigh Merritt (University of Texas)
- Dr. Earl Wiener (University of Miami)

Appendix B

Abbreviations

AAPA	Association of Asia-Pacific Airlines
ACAS	Airborne collision avoidance system
AFDS	Autopilot and flight director system
A/T	Auto throttle
ATC	Air traffic control
BASI	Bureau of Air Safety Investigation
CRM	Crew resource management
CRT	Cathode ray tube
DME	Distance measuring equipment
ECAM	Electronic centralised aircraft monitoring
EOD	End of descent
FAA	Federal Aviation Administration (USA)
FLCH	Flight level change
FMA	Flight mode annunciator
FMC	Flight management computer
FMGS	Flight management guidance system
FO, F/O	First officer
HDG SEL	Heading select function
IATA	International Air Transport Association
ILS	Instrument landing system
IMC	Instrument meteorological conditions
kts	Knots
LCD	Liquid crystal display
LNAV	Lateral navigation
LSALT	Lowest safe altitude
LVL CHG	Level change
MCP	Mode control panel
MSA	Minimum safe altitude
NM	Nautical miles
NASA	National Aeronautics and Space Administration
SID	Standard instrument departure
SOP	Standard operating procedures
STAR	Standard terminal arrival route
TCAS	Traffic-alert and collision avoidance system
V/S	Vertical speed
VNAV	Vertical navigation
VOR	VHF Omni-directional radio

U.S. Aviation Incident Rates Decline For Large Carriers in 1998

FAA data also show a small increase in incident rates for commuter air carriers and a decrease in the incident rate for air taxi aircraft.

FSF Editorial Staff

Incident rates for large U.S. air carriers[1] declined slightly in 1998, continuing a trend that has persisted throughout much of the decade (Table 1 and Figure 1, page 218). This trend is shown by U.S. Federal Aviation Administration (FAA) data published in *FAA Aviation System Indicators: 1998 Annual Report* for the 1992–1998 period and in supplemental data available on the World Wide Web at the Office of Safety System home page: http://nasdac.faa.gov.

For U.S. commuter air carriers,[2] the 1998 data show a slight increase in incident rates over the previous year, but the numbers were lower than those recorded in 1996 (Table 2 and Figure 2, page 219).

The incident rate for U.S. air taxi aircraft[3] declined in 1998, as it has each year since 1995 (Table 3 and Figure 3, page 220).

FAA calculates incident rates for large air carriers and commuter air carriers using both flight hours and departures; for air taxi aircraft, departure data are not available, and the incident rate is calculated using flight hours.

FAA defines an aircraft incident as “an occurrence, other than an accident, that affects or could affect the safety of operations and that is investigated and reported on FAA Form 8020-5.” Aircraft incidents do not include near midair collisions, operational errors or deviations, pilot deviations, vehicle and pedestrian deviations, or runway incursions.

The data show that U.S. large air carriers operating under U.S. Federal Aviation Regulations (FARs) Part 121 were involved in 3.98 incidents per 100,000 departures in 1998, down from 4.21 incidents per 100,000 departures in 1997 and the lowest rate for any of the seven years covered by the report. The highest rate was 6.38 incidents per 100,000 departures in 1992.

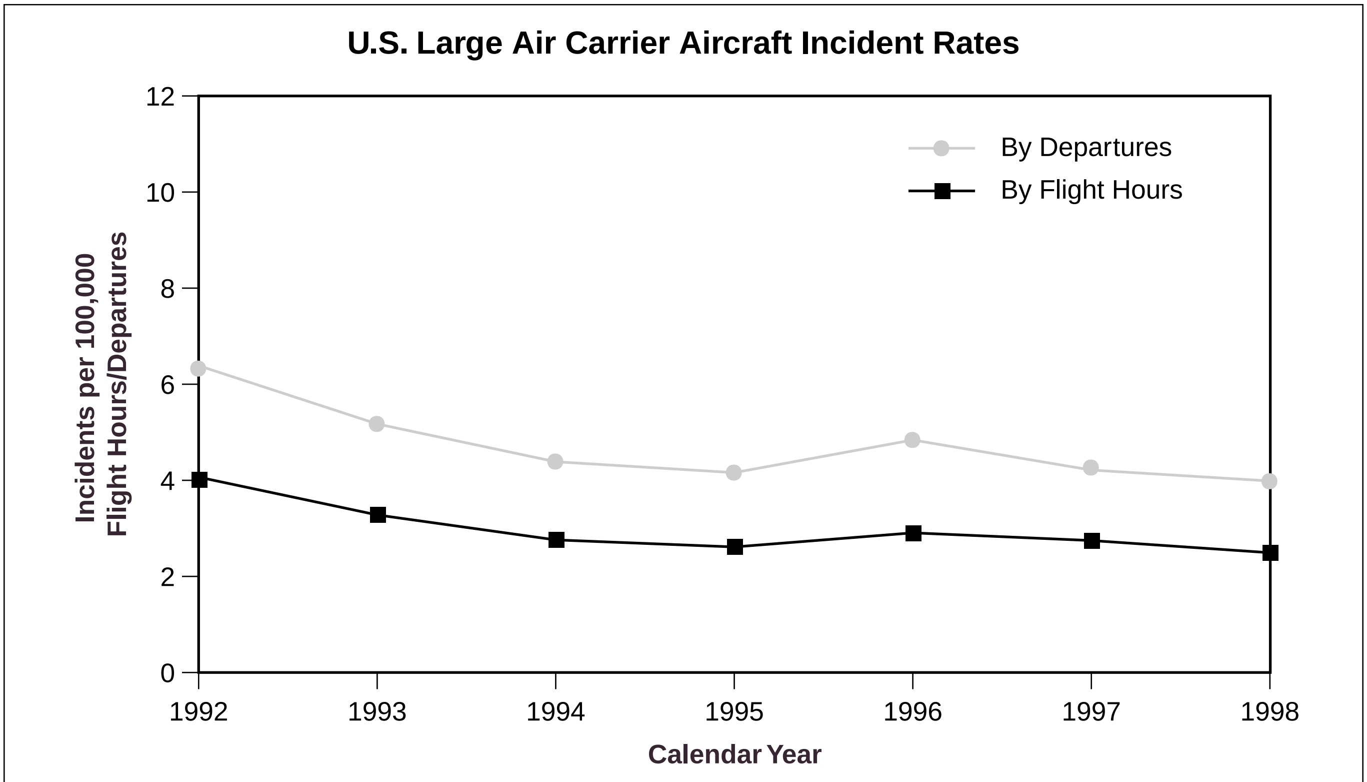
The rate for U.S. commuter air carriers operating under Part 135 was 1.77 incidents per 100,000 departures in 1998, up from 1.51 incidents per 100,000 departures in 1997, the lowest rate recorded in the seven-year period. The highest was the 1992 rate of 6.87 incidents per 100,000 departures.

FAA regulatory changes that took effect in April 1997 transferred many operations formerly conducted under

Table 1
U.S. Large Air Carrier Aircraft Incident Data

Calendar Year	Number of Incidents	Number of Flight Hours	Incident Rate (Per 100,000 Flight Hours)	Number of Departures	Incident Rate (Per 100,000 Departures)
1992	503	12,359,715	4.07	7,880,707	6.38
1993	417	12,706,206	3.28	8,073,173	5.17
1994	362	13,124,315	2.76	8,238,306	4.39
1995	353	13,505,257	2.61	8,457,465	4.17
1996	398	13,746,112	2.90	8,228,810	4.84
1997	434	15,829,408	2.74	10,300,040	4.21
1998	411	16,508,000	2.49	10,318,000	3.98

Source: U.S. Federal Aviation Administration



Source: U.S. Federal Aviation Administration

Figure 1

commuter air carrier rules (Part 135) to large air carrier rules (Part 121). The 1998 data represent different groups of carriers compared with data for earlier years.

For air taxi aircraft operating under Part 135, the 1998 incident rate was 5.64 per 100,000 fight hours, down from 6.76 per 100,000 flight hours the previous year. The 1998 rate was the lowest for the seven-year period; the highest was 11.78 incidents per 100,000 flight hours in 1995.

Notes

1. Large air carrier is defined as a scheduled or nonscheduled aircraft operation conducted under FARs Part 121. Effective March 20, 1997, Part 121 includes scheduled and nonscheduled operations of all turbojet-powered airplanes, airplanes having more than 30 passenger seats and airplanes having a payload capacity of more than 7,500 pounds (3,400 kilograms). Also included are scheduled operations of aircraft with more than nine and fewer than 31 passenger seats and with a payload capacity of 7,500 pounds or less.

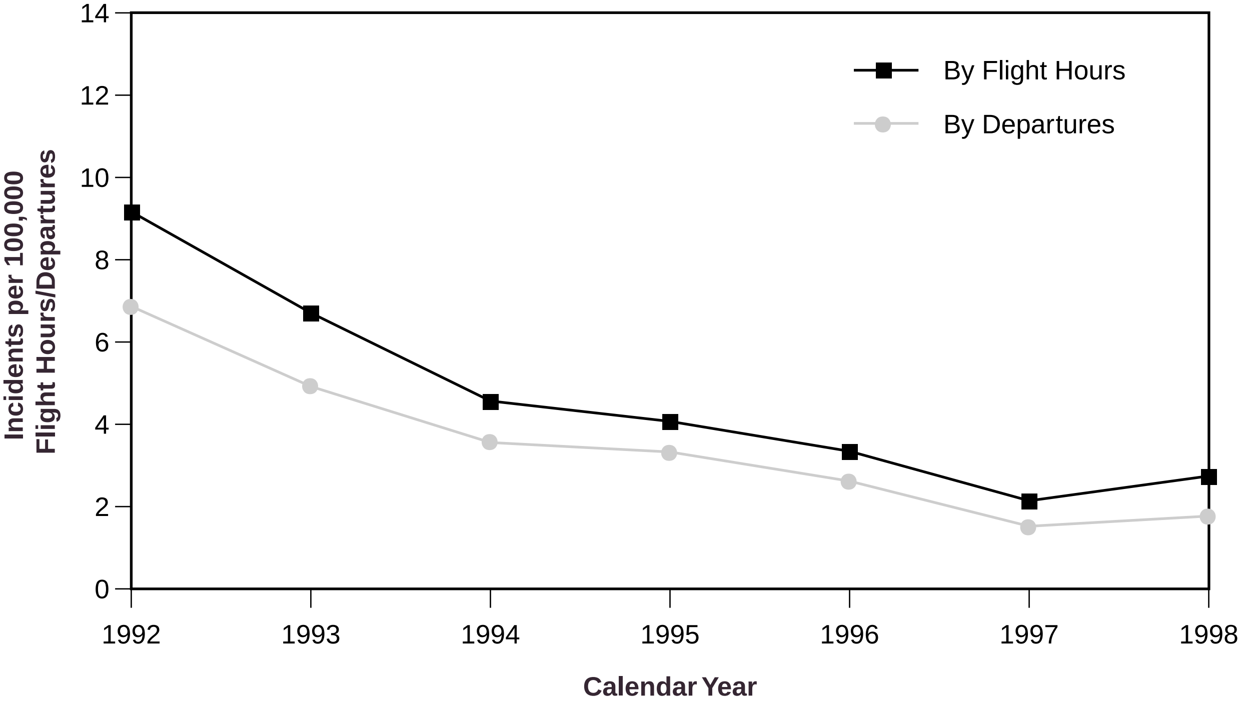
2. Commuter air carrier is defined as a scheduled passenger operation conducted under Part 135 with a frequency of operations of at least five round trips per week on at least one route between two or more points according to the published flight schedules. Commuter operations use airplanes, other than turbojet-powered

Table 2
U.S. Commuter Air Carrier Aircraft Incident Data

Calendar Year	Number of Incidents	Number of Flight Hours	Incident Rate (Per 100,000 Flight Hours)	Number of Departures	Incident Rate (Per 100,000 Departures)
1992	214	2,335.349	9.16	3,114,932	6.87
1993	177	2,638,347	6.71	3,601,902	4.91
1994	127	2,784,129	4.56	3,581,189	3.55
1995	107	2,627,866	4.07	3,220,262	3.32
1996	92	2,756,755	3.34	3,515,040	2.62
1997	21	982,764	2.14	1,394,528	1.51
1998	14	513,000	2.73	791,206	1.77

Source: U.S. Federal Aviation Administration

U.S. Commuter Air Carrier Aircraft Incident Rates



Source: U.S. Federal Aviation Administration

Figure 2

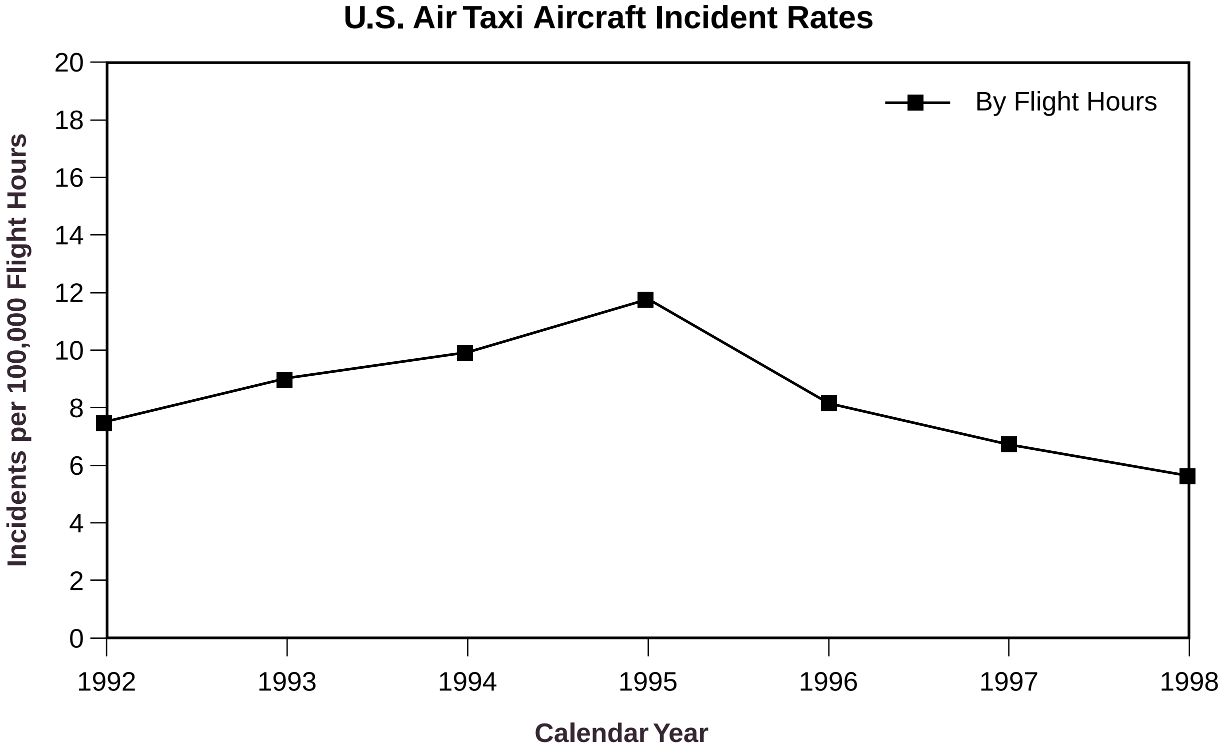
airplanes, with nine passenger seats or fewer and a maximum payload capacity of 7,500 pounds or less, or rotorcraft.

3. Air taxi is defined as an on-demand air carrier operation conducted under Part 135 for compensation or hire, including nonscheduled passenger-carrying operations conducted with either rotorcraft or airplanes, including turbojet-powered airplanes, having 30 passenger seats or fewer and a payload capacity of 7,500 pounds or less. Also included are scheduled passenger-carrying operations that make fewer than five round trips per week on at least one route between two or more points according to the published flight schedules and that use rotorcraft or airplanes, other than turbojet-powered airplanes, with fewer than nine passenger seats and a maximum payload capacity of 7,500 pounds or less. The category also includes cargo operations conducted with airplanes having a payload capacity of 7,500 pounds or less, or rotorcraft.♦

Table 3
U.S. Air Taxi Aircraft Incident Data

Calendar Year	Number of Incidents	Number of Flight Hours	Incident Rate (Per 100,000 Flight Hours)
1992	148	1,967,000	7.52
1993	150	1,659,000	9.04
1994	184	1,854,000	9.92
1995	201	1,707,000	11.78
1996	165	2,029,000	8.13
1997	152	2,250,000	6.76
1998	143	2,537,000	5.64

Source: U.S. Federal Aviation Administration



Source: U.S. Federal Aviation Administration

Figure 3

FAA Publishes Information for Airports Regarding Disabled Individuals

Advisory circular identifies relevant U.S. statutes and regulations.

FSF Library Staff

Advisory Circulars

Access to Airports by Individuals with Disabilities. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5360-14. June 30, 1999. 34 pp. Available through GPO.*

This AC is intended to help airports operated by public entities and those receiving federal financial assistance to comply with current laws and regulations concerning individuals with disabilities. The AC identifies relevant statutes and regulations relevant to airports, presents in a single document the main features of each statute and regulation, provides legal citations to facilitate research, lists sources of assistance or additional information, and identifies the final rules.

The AC also presents and reconciles the federal accessibility regulations that implement the Americans with Disabilities Act of 1990, the Air Carrier Access Act of 1986, the Rehabilitation Act of 1973 as amended and the Architectural Barriers Act of 1968 as amended, which affects architectural aspects of airport accessibility and employment opportunities for individuals with disabilities. [Adapted from AC.]

Announcement of Availability: FAA-S-8081-8A, Flight Instructor Practical Test Standards for Glider. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 61-130. April 26, 1999. 1 p. Available through GPO.*

FAA has published FAA-S-8081-8A to establish the standards for flight instructor practical tests for glider. Practical tests conducted by FAA inspectors, designated pilot examiners and check airmen (examiners) must comply with these standards. This document also will be helpful to flight instructors and applicants preparing for the tests.

This AC announces the availability of FAA-S-8081-8A, *Flight Instructor Practical Test Standards for Glide*r, and provides information on obtaining electronic and printed copies. [Adapted from AC.]

Specification for L-884, Power and Control Unit for Land and Hold Short Lighting Systems. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5345-54. April 29, 1999. 11 pp. Available through GPO.*

This advisory circular (AC) contains FAA standards for power units and control units for land-and-hold-short lighting systems.

Operational requirements for lighting systems and other visual navigation aids required to conduct land-and-hold-short operations (LAHSO) can be found in FAA Order 7110.114, Land and Hold Short Operations (LAHSO). [Adapted from AC.]

Reports

Follow-up Assessment of the Federal Aviation Administration's Logistics Center Safety Climate. Behn, Lydia D; Thompson, Richard C.; Hilton, Thomas F. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-99/19. June 1999 25 pp. Available through NTIS.**

Keywords:
1. Organizational Safety Climate
2. Employee Perceptions
3. Logistics Center

This report details the safety perceptions of employees at the FAA Logistics Center in Oklahoma City, Oklahoma, following the implementation of a safety-awareness program. A baseline assessment was conducted in 1992, and a follow-up took place in 1995. The 1995 follow-up survey was intended to assess differences in perceptions of safety due to changes in the safety program since 1992, and also to identify the management factors and organizational factors that may have had an impact on those safety perceptions. The 1995 follow-up survey was voluntarily completed by 329 (49 percent) of the 662 FAA Logistics Center employees during a mandatory monthly safety meeting.

Results suggest that when an organization's managers and supervisors take actions to improve the safety climate of the organization, there are positive results. Personal support for safety is largely independent of management, supervisor and coworker support for safety. [Adapted from Introduction and Discussion.]

Cognitive Style and Learning: Performance of Adaptors and Innovators in a Novel Dynamic Task. Pounds, Julia; Bailey, Larry L. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-99/12. April 1999. 12 pp. Available through NTIS.**

Keywords:
1. Cognitive Style
2. Performance
3. Learning
4. Innovation
5. Reasoning
6. Practice
7. Air Traffic Control

FAA is responsible for maintaining the increasingly complex U.S. airspace. The safety and efficiency of the system depend on highly trained air traffic control specialists (ATCSs). Ongoing development includes new automation to assist ATCSs, and human interaction with technology is a vital component of this system.

This study examines predictions about the influence of cognitive style on general performance when learning complex, dynamic tasks such as those required for air traffic control. The study is based on Kirton's (1976) theory of Adaptors and Innovators, which suggests that cognitive style influences performance and that Adaptors outperform Innovators on procedure-bound tasks.

Participants were presented with problems using computer-based scenarios in screening, practice and experimental trials. Cognitive style had a significant effect on performance only during experimental trials. Results suggested that Innovators might have had an initial advantage but were eventually surpassed by Adaptors, either because Adaptors benefited more from practice or because Innovators were unable to maintain their level of performance. [Adapted from Introduction and Conclusion.]

GPS User-interface Design Problems. Williams, Kevin W. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-99/13. April 1999. 11 pp. Available through NTIS.**

Keywords:
1. Global Positioning System
2. Human-computer Interface
3. Aircraft Displays
4. Applied Psychology

This report reviews the human factors problems associated with the user-interface design of a set of global positioning system (GPS) receivers that are certified for use in aircraft for instrument nonprecision approaches. The report focuses on specific inconsistencies across the set of interfaces that could cause confusion or errors. These inconsistencies involve the layout and design of knobs and buttons, labeling of controls, the placement and use of warnings, feedback or the lack thereof, and the integration of specific flying tasks while using the receivers.

The report provides recommendations for solving some of the problems and makes suggestions to FAA, GPS manufacturers and pilots for the development and future use of these receivers. [Adapted from Introduction.]

Passenger Facility Charges: Program Implementation and the Potential Effects of Proposed Changes. Report to Congressional Committees, May 1999. Report GAO/RCED-99-138. 73 pp. Figures, tables, appendixes. Available through GAO.***

Since the early 1990s, most passenger-service airports in the United States have been able to charge boarding fees (passenger-facility charges) of US$1 to $3 per passenger to fund capital-development projects. This FAA-managed program raises $1.4 billion per year.

Views differ within the industry about the future of the passenger-facility-charge program. Airport associations favor higher charges to help finance airport development that they consider necessary. Airlines, on the other hand, question the need for some of the proposed projects and want a more stringent screening process for approval.

This report describes how the passenger-facility-charge program is helping airports fund capital development, and also discusses the potential impact of proposals to change the program, including the option of making no changes. [Adapted from Introduction and Executive Summary.]

Air Traffic Control: FAA's Modernization Investment Management Approach Could Be Strengthened. Report to U.S. Congressional Requesters, April 1999. Report GAO/RCED-99-88. 53 pp. Figure, tables. Available through GAO.***

Under a costly and ambitious program to modernize the air traffic control system, FAA is acquiring new surveillance, data-processing, navigation and communication equipment as well as new facilities and support equipment. The modernization effort's 126 projects are expected to cost US$26.5 billion from fiscal year 1982 through fiscal year 2004. Of this total, FAA estimates that $12.9 billion will be needed for 59 information-technology projects that support the air traffic control system.

This report examines the extent to which the FAA Acquisition Management System provides a comprehensive approach for managing the agency's investments in air traffic control information technology. Historically, FAA has a poor record of delivering systems on time and within budget parameters and performance parameters. [Adapted from Introduction and Executive Summary.]

Books

Survival for Aircrew. Prew, Sarah-Jane. Brookfield, Vermont, United States: Ashgate Publishing Co., 1999. 130 pp.

This book is an instructional tool for all crewmembers who fly over wilderness areas or water. The book outlines survival techniques for passengers and crewmembers who suddenly find themselves in a survival situation, with special emphasis on the crew's role. The book also instructs crewmembers in survival techniques that do not require special knowledge or equipment, and covers only what crewmembers need to know.

The book is organized into two sections: sea survival and land survival. Land survival is further divided into chapters covering desert survival, jungle survival and Arctic survival. Each type of situation is addressed from preparation through finding shelter, lighting fires and seeking rescue. Contains a Bibliography and Index. [Adapted from Introduction and Preface.]

Air Disaster Volume 3. Job, Macarthur. Fyshwick, Australia: Aerospace Publications, 1998. 155 pp.

This volume covers the years 1988 to 1994 and continues the theme of volumes one and two, examining how unsuspected hazards have come to light through aircraft mishaps. Even with high levels of technical success and organizational success, human failings, engineering errors and forces of nature periodically combine to produce circumstances that lead to a disaster. The accidents in this volume are intended to shed light on the operational obstacles and human obstacles they reveal.

Volume three examines 13 complex accidents, draws material primarily from official investigation reports and adds research from other sources. The text is supplemented with diagrams and photographs. [Adapted from Introduction.]♦

Sources

* Superintendent of Documents
U.S. Government Printing Office (GPO)
Washington, DC 20402 U.S.

** National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
+1(703) 487-4600

*** U.S. General Accounting Office (GAO)
P.O. Box 6015
Gaithersburg, MD 20884-6015 U.S.
Telephone: +1(202) 512-6000; Fax +1(301) 258-4066

Updated U.S. Federal Aviation Administration (FAA) Regulations and Reference Materials

Advisory Circulars (ACs)

AC No.	Date	Title
21-15L	April 12, 1999	*Announcement of Availability: Aircraft, Aircraft Engines, and Propeller Type Certificate Data Sheets and Specifications*. (Cancels AC 21-15K, *Announcement of Availability: Aircraft, Aircraft Engines, and Propeller Type Certificate Data Sheets and Specifications*, dated March 13, 1997).
60-11C	April 26, 1999	T*est Aids and Materials That May Be Used by Airman Knowledge Testing Applicants*. (Cancels AC 60-11B, *Aids Authorized for Use by Airmen Written Test Applicants*, dated Oct. 10, 1990).
65-9A	June 16, 1999	Announcement of Availability: Change 1 of AC 65-9A, Airframe & Powerplant Mechanics — General Handbook.

International Reference Updates

Joint Aviation Authorities (JAA)

Date	
March 15, 1999	Revision to JAA Administrative and Guidance Material, Section One: General Guidance and Reference Material.
June 1, 1999	Revision to JAA Administrative and Guidance Material, Section One: General Guidance and Reference Material.
June 1, 1999	Revision to JAA Administrative and Guidance Material, Section Two: Maintenance.
June 1, 1999	Revision to JAA Administrative and Guidance Material, Section Three: Certification.
June 1, 1999	Revision to JAA Administrative and Guidance Material, Section Four: Operations.

Aeronautical Information Publication (A.I.P.) Canada

Amendment No.	Date	
3/99	July 15, 1999	Updates the General, Aerodromes, Communications, Meteorology, Rules of the Air and Air Traffic Services, Search and Rescue, Licensing, Registration and Airworthiness, and Airmanship sections of the A.I.P.

Airclaims

Supplement No.	Date	
114	June 1, 1999	Updates “Major Loss Record.”
115	June 1999	Updates “World Aircraft Accident Summary.”

Accident/Incident Briefs

Hydraulic System Failure Cited In Airplane's Collision with Jetway

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Some accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. The information may not be entirely accurate.

FSF Editorial Staff

Air Carrier

Braking Problem Traced to Failed 'O' Ring Seal

Airbus A310-300. Minor Damage. No injuries.

About one hour after the airplane left the Caribbean bound for an airport in England, one of its three hydraulic systems failed because of a loss of fluid. The crew followed procedures displayed on the electronic centralized aircraft monitoring system and the flight-crew operations manual (FCOM), and proceeded with the flight.

Meteorological conditions upon the airplane's afternoon arrival in England included clear skies and a light westerly wind. The runway was dry, and a manual landing was conducted. The aircraft was slowed with reverse thrust and gentle braking. The flight crew taxied to the gate at a normal taxi speed with occasional gentle braking.

"The brakes worked correctly, and all indications were normal," the report said.

But after the aircraft was brought to a halt in the correct position at the gate, the report said, "the commander then became aware of some movement on the left side of the aircraft which he thought may have been movement of the jetway, but on looking to his right, he saw that the aircraft was slowly moving forward.

"He therefore applied maximum pressure to the brake pedals, but to no avail," the report said. "The ground crewman … repeatedly instructed the crew to stop, but the aircraft continued moving until the no. 1 engine struck the jetway."

The report said that, after the aircraft initially came to a halt, there was no time to put chocks in position before the aircraft began moving forward again.

No one was hurt in the incident, and passengers left the aircraft using steps that were positioned at the rear doors.

Inspections found that the no. 1 engine was not damaged. Fresh hydraulic fluid was found around a sampling valve during an examination of hydraulic components in the right main gear bay. The valve, which was attached to a manifold, was part of the "yellow" hydraulic system — the same system that had failed an hour into the flight. When an electric pump was used to pressurize the system to open cargo doors after the incident, fluid sprayed from the valve.

"It was later found that an 'O' ring seal in the valve had failed," the report said. After the seal was replaced, the system was charged, purged and found to function normally.

The report said that the failure of the "yellow" hydraulic system during flight "presented no problems other than an extended landing distance due to the loss of some of the spoilers." The report also said that the accumulators might have lost "a significant amount of pressure" in the six hours that the system was unpressurized.

"The checklist contained no warning of this possibility or advice on taking the precaution of charging the accumulators before parking the aircraft at a stand," the report said.

In response to a draft of the report, the manufacturer said that standard operating procedures in the FCOM required checking accumulator pressure when applying the parking brake. A modified procedure was being developed to avoid a recurrence of the incident, the report said.

Landing Gear Breaks After Touchdown on Wet Runway

Boeing 737. Minor damage. Four minor injuries.

Lightning, heavy rain and strong winds were reported at an airport in China as the airplane began its landing roll. The airplane veered off the runway, and a section of the landing gear separated from the airplane.

The report quoted an airport official as saying that the pilot attributed the accident to poor visibility, and an official said that the runway was wet because of rain from the aftermath of a typhoon.

The pilot and three passengers received minor injuries. Seventy-eight other passengers and eight crewmembers were uninjured.

Damaged Tire Prompts Emergency Landing

Boeing 737-400. Minor damage. One serious injury.

The captain reported damage to one of the aircraft's tires during the takeoff roll at a Caribbean airport. He continued the takeoff and flew about three hours to burn off fuel before executing an uneventful emergency landing. After landing, the crew began an emergency evacuation of the aircraft through exits on the aircraft's right side — the side opposite the damaged tire. The right front slide did not deploy properly, and some passengers instead used the left front exit. One passenger received serious injuries; the other 148 passengers and eight crewmembers were not injured.

Air Taxi Commuter

Landing Gear Damaged in Takeoff Ordered by Hijackers

Beech King Air 200. Minor damage. No injuries.

Visual meteorological conditions prevailed, and an instrument flight plan had been filed for the domestic passenger-cargo flight that departed from an airport in Peru. After the flight began, four of the seven passengers hijacked the airplane and forced the pilots to land in a field, the report said. The hijackers then demanded that the pilots take off. During the takeoff roll, the left main landing gear dipped into a hole and collapsed. The takeoff was aborted, and the airplane came to a stop upright. There were no injuries.

Wet Pavement Blamed for Airplane's Roll off Runway

Piper Chieftain. Substantial damage. One minor injury.

Visual meteorological conditions prevailed at the time of the unscheduled flight from the United States to a private airport in the Bahamas. The report quoted an attorney for the aircraft operator as saying that the runway was wet when the aircraft touched down about 1715 local time, and that the aircraft hydroplaned and went off the end of the runway and over rough terrain before coming to a stop with the nose section in water. Substantial damage was reported to the aircraft. One passenger received minor injuries; five passengers and the pilot were not hurt.

Four Tires Blow Out During Aborted Takeoff

Learjet 36A. Substantial damage. No injuries.

An on-demand air medical transport flight was rolling for takeoff at an airport in the Middle East when the pilot lost control about 0100 local time. The airplane then struck terrain. Visual meteorological conditions prevailed.

The pilot told company officials that the aircraft had reached 120 knots when both left main landing gear tires blew out. The airplane swerved to the left, and when the pilot applied right rudder and brake to align the airplane with the runway, both right main landing gear tires blew out. The pilot said that he then deployed the drag chute and the airplane went off the right side of the runway. The right main landing gear separated, and parts of the right wing hit the ground. No injuries were reported among the pilot, the first officer, the doctor, the flight nurse, a mechanic, the patient and one passenger.

Corporate
Business

Airplane Strikes Terrain on Night Instrument Approach

Learjet 24. Destroyed. Three fatalities; one serious injury.

Night instrument meteorological conditions prevailed, and the pilots were flying on an instrument flight plan from the United States to an airport in Mexico. Mexican officials said that the pilots had been cleared for an instrument landing system approach, and the copilot said that the airplane was on a distance-measuring equipment arc to intercept the localizer when the aircraft struck terrain. The airport's elevation is 79 feet above sea level, the report said.

The pilot and two passengers were killed; the copilot was seriously injured in the accident, which destroyed the aircraft.

Confusion over Airport Information Lands Pilots On Closed Runway Segment

Gulfstream G-IV. No damage. No injuries.

The aircraft was completing the final segment of a three-part flight from France to an airport in England just before midnight in visual meteorological conditions. The flight crew listened to automatic terminal information service (ATIS), which included special instructions for landing because of work on Runway 23, the active runway. ATIS advised that "reduced distances only are available until time 0630 hours. Pilots please note the green threshold bar is not, repeat not, the touchdown point. Approach to touchdown must be made using a 3.5-degree approach angle to the temporary Alpha PAPIs [precision approach path indicators]."

The crewmembers were concerned about the meaning of the special instructions and discussed them, concluding that the intent was for aircraft "to avoid landing at the green lighted end of the runway," the report said. The pilots initially were given radar vectors, then flew a visual approach, aiming to align the touchdown with red "wing bars" on both sides of the runway. But just before touchdown, they saw runway end cones and flew over them to land, brake and come to a stop 100 meters (328 feet) before the threshold of Runway 5. The pilots did not know that they were on the closed section of the runway until controllers told them so several minutes later.

The three crewmembers and their passenger were not injured, and the airplane was not damaged. After the incident, the ATIS message was changed to notify pilots, "Caution, due to work in progress, reduced landing distances are in operation. Only the first 1,500 meters of Runway 23 is available. Pilots must fly the 3.5-degree APAPI approach."

Cracked Navigation Light Blamed on Unaided Taxiing In Parking Area

Britten-Norman Trislander. Minor damage. No injuries.

The pilot arrived about midnight at his aircraft, which was parked on the spur taxiway of a maneuvering area at an airport in England. Major work was under way in the area, which was crowded with parked aircraft, and the pilot was accompanied by a worker who was to have helped him taxi out of the area.

The worker was called away, and the pilot said that, since he had successfully maneuvered out of the area without assistance in the past, he decided to do so again. After he was out of the congested area, he noticed that he could not see the glow of his right navigation light, so he stopped the aircraft and discovered that the right navigation-light lens and bulb were broken. He had felt no impact, but he examined a British Aerospace Jetstream 41 that was parked on the spur taxiway and discovered that its left-aileron-hinge fairing was damaged. His operating company subsequently began requiring pilots to use the guidance of an airport worker when the maneuvering area is restricted.

Other General Aviation

Jammed Aileron Cited in Airplane's Collision with Terrain

Cirrus SR20. Airplane destroyed. One fatality.

The pilot made several right turns while climbing to an altitude of about 6,500 feet MSL after a mid-day takeoff from an airport in the United States. The airplane began descending and turning to the left about the same time the pilot declared an emergency. Radar data and statements from eyewitnesses on the ground indicated that, as it approached the airport, the airplane made only turns to the left.

About two miles north of the airport, the pilot reported a flight-control problem. After two passes along the runway, the airplane hit the ground south of the airport in a nose-low, left-wing-low attitude. The accident killed the pilot, who was the airplane's only occupant.

Examination of the wreckage revealed no evidence of fire or in-flight structural failure, and no sign of any in-flight malfunction, except for scratches and rub marks on the leading edge of the right aileron and the upper surface of the right-wing skin near the area where it meets the aileron.

Static tests on other Cirrus SR20 prototypes "revealed that it is possible for the leading edge of the right aileron to become jammed against the wing when the aileron is deflected downward and the wing is flexed upward to its maximum design limit. The gap tolerances between the aileron and wing are critical factors in determining the potential for jamming."

Plane Strikes Terrain in Swamp after Unsuccessful Search for Fuel

Cessna 421B. Unknown damage. One serious injury, two minor injuries.

The pilot took off from a Caribbean airport on an afternoon flight in visual meteorological conditions to an airport on a nearby island, intending to refuel the aircraft there. The pilot filed no flight plan for the flight, which began 26 minutes before the accident. After landing, he was told that fuel was not available, and he flew to another island for refueling.

While on a straight-in approach, the pilot radioed that he was "low on fuel." The aircraft struck terrain in a swamp about 400 yards short of the runway. The pilot was seriously injured; two passengers suffered minor injuries.

'Engine-out' Discussion Precedes Accident in Cornfield

Cessna 310N. Unknown damage. Two fatalities.

The flight instructor and his student, a private pilot, were overheard discussing "engine-out" procedures and unusual-attitude maneuvers before taking off in visual meteorological conditions on a mid-day training flight from an airport in the United States.

Witnesses said that they saw the airplane shortly after takeoff "a couple of hundred feet off the ground" in a steep left bank and heard its engines "laboring real hard." The airplane struck terrain in a cornfield two miles from the airport. Both pilots were killed.

After the accident, the left fuel selector was found in the "left aux" position; the right fuel selector was in the "left main" position. About one ounce (30 milliliters) of fuel was recovered from the right fuel filter and half an ounce (15 milliliters) was recovered from the left. Documents also said the throttles were full forward, the mixtures were full rich, and the propellers were full forward.

Notes found at the accident site listed procedures for engine failure and for flight at minimum control speed with the critical engine out.

A witness said that the two pilots had flown together earlier in the day and had landed to eat lunch and top off the fuel tanks.

Rotorcraft

Helicopter Strikes Desert Terrain During Winter Storm

Eurocopter BO 105. Destroyed. Three fatalities.

The pilot of the emergency-medical-service helicopter, which was equipped with instruments but not certified for instrument flight, delivered a patient to a hospital and then departed in night-time instrument meteorological conditions for a return trip to the home base about 40 miles away.

The pilot — who had logged more than 10,000 hours, including nearly 3,600 hours of instrument time — was operating under a company flight plan and was scheduled to make position reports every 15 minutes on a company radio frequency; contact was never made.

Two motorists in the area said that the sky was overcast with freezing rain that turned into wet snow and then freezing sleet. They estimated visibility at 50 feet (15 meters), and both reported seeing a helicopter, which appeared to be using its searchlight to follow the highway.

A resident of the area said he heard the sounds of an aircraft flying back and forth for about 10 minutes, followed by a "big thump." As he drove toward the origin of the sound to investigate, he estimated visibility at less than 50 yards (53 meters). He found the flaming wreckage on upward-sloping desert terrain. The pilot and two crewmembers died in the accident.

Both engines showed evidence of damage by foreign objects, and their blades were bent opposite the direction of rotation.

Helicopter Strikes Terrain as Pilot Tries to Land to Aid Airsick Passenger

Bell 206B. Destroyed. No injuries.

The pilot said that his passenger had become airsick and that he was attempting to land with a strong quartering tailwind. He said that the helicopter "was practically in a hover [with] full power applied … when a gust of wind from behind hit me just as I was turning into the wind using left pedal. The helicopter weather-vaned."

A subsequent gust prompted a right yaw that caused a loss of tail-rotor effectiveness, the pilot said. The helicopter struck terrain and rolled over, and its left skid and main-rotor blades were severed. The pilot and his passenger were not injured.

Weather was reported clear, with 10 miles (16 kilometers) visibility and 10 knots of wind.

Helicopter Strikes Ground after Maneuvering into Power Line

Robinson R22. Substantial damage. One minor injury.

The pilot was spraying a cornfield when he maneuvered into a hover next to a power line. He backed up and inadvertently placed the tail rotor between two wires. When he began to move the helicopter forward, the tail struck the higher wire. That resulted in the loss of the tail rotor and "caused a resultant uncontrollable starboard rotation." The helicopter struck the ground and rolled onto its right side. The helicopter was substantially damaged, and the pilot received minor injuries.♦

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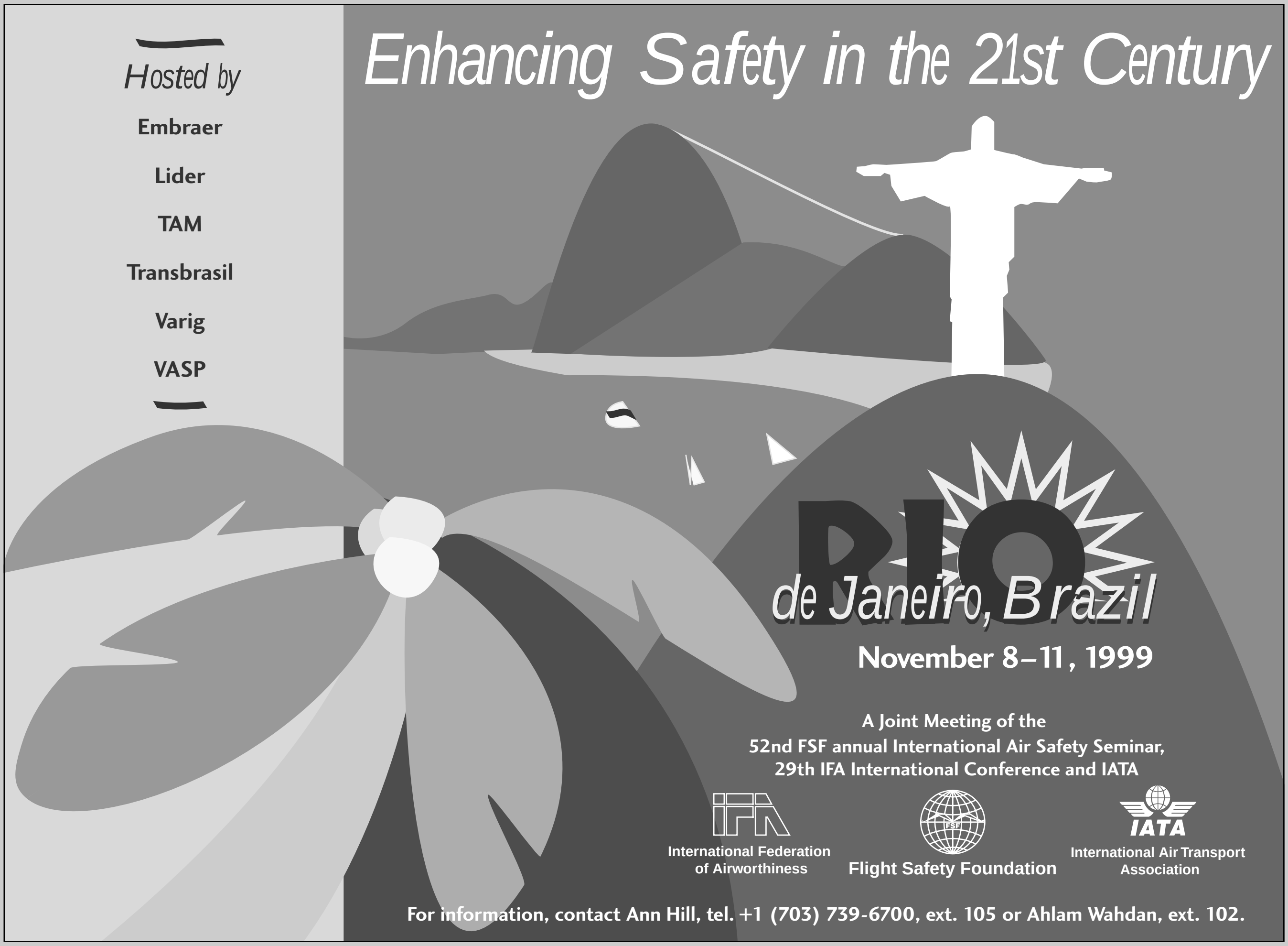

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