

# Human Factors of Advanced Technology ("Glass Cockpit") Transport Aircraft

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## SUMMARY

This is a report of a three-year field study of airline crews at two major U.S. airlines who were flying an advanced technology aircraft, the Boeing 757. The study addresses the opinions and experiences of these pilots as they view the advanced, automated features of this aircraft, and contrast it with previous models they have flown.

The report addresses a large number of aspects of automated flight, but concentrates on the following topics:

1. Training for advanced automation
2. Cockpit errors and error reduction
3. Management of cockpit workload
4. General attitudes toward cockpit automation

The limitations of the air traffic control (ATC) system on the ability to utilize the advanced features of the new aircraft is discussed. In general the pilots are enthusiastic about flying an advanced technology aircraft, but they express mixed feelings about the impact of automation on workload, crew errors, and ability to manage the flight.

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## I. INTRODUCTION

### A. BACKGROUND

The decade of the 1970s saw a rapid introduction into the cockpits of transport aircraft of automatic devices designed to aid the flight crew, and to make flight more efficient. In this context the term "efficiency" usually refers to reduction of fuel consumption, but it may also be extended to include economies in crew and aircraft time, and with increasing importance, conservation of airspace, particularly in the crowded terminal areas. The larger turbine aircraft were equipped with highly sophisticated automatic navigation devices such as inertial navigation systems (INS), omega navigational systems (ONS), flight guidance systems which could steer the aircraft laterally in response to commands from these systems, and autothrottle systems (ATS) which could govern power plants more efficiently than manual control. More sophisticated warning and alerting systems, including the ground proximity warning system (GPWS), stall detection systems, and a variety of crew alerting systems supplemented the crews' ability to sense and detect hazardous conditions.

Generally pilots welcomed these devices on a one-by-one basis: each seemed to do a satisfactory job, or as pilot jargon put it, they worked "as advertised." But as the number and sophistication of these devices increased, pilots, flight managers, and governmental officials developed a growing discomfort that the cockpit may be becoming too automated, and that the steady replacement of human functioning by devices could be a mixed blessing. Terms such as "complacency", "automation atrophy," and "loss of scan" started to appear in the language of pilots, flight managers, and training departments. These terms expressed a concern that the pilots were becoming over-dependent on automation, that manual flying skills may be deteriorating, and that situational awareness might be suffering. In short, the industry seemed to welcome the functional capabilities of the new devices, but feared that flight crews might be falling "out of the loop."

Training departments, especially at overseas carriers flying long segments which offer little chance to keep proficient in departures, approaches and landing, expressed concern over the possibility that manual skills may be deteriorating. This was particularly evident when senior first officers transitioned from wide-body aircraft to captaincy in less electronically sophisticated narrow-body aircraft.

In addition to these concerns, it was clear by the end of the decade that the era of the flight engineer might soon be drawing to an end, even in wide-body aircraft, as the new two-pilot models replaced the old. What would replace his function in the cockpit? Certainly not an increase in workload for the two

pilots, who were already seriously loaded in the terminal environments. The answer the designers proposed was an increase in automation.

In 1981 the Presidential Task Force on Aircraft Crew Complement recommended that transport aircraft could be safely flown by a two-pilot crew; their findings were based largely on the assumption that the flight engineer's duties could be absorbed by increasing the level of cockpit automation (McLucus, Drinkwater, and Leaf, 1981). [1]

The report also stated that the FAA had properly certified the Douglas DC-9-80 (now MD-80) as a two-pilot aircraft. Furthermore, their findings removed the cloud over the soon-to-appear Boeing 767, which the manufacturer had designed as a two-pilot plane, but was prepared to offer with three seats if necessary. In fact, a few 767s and at least one 767 simulator were built with flight engineer stations.

The findings of the Presidential Task Force assured the future of the new aircraft. The MD-80 series, the B767/757, and the A-310 and A-320 models have been an operational and commercial success. At this time, there are EFIS models of the MD-80 and B-737 available, and operators can retrofit older models, and Airbus now offers the EFIS equipped A-300-600.

Despite the success of the new aircraft, there has remained a growing uncertainty about the role of the human in future transports. A number of incidents and accidents, some quite dramatic, were attributed by many to problems of crews operating automated equipment (see Wiener and Curry, 1980; Wiener, 1985a, 1988). The introduction of automation in the older aircraft had been piecemeal. The MD-80 brought to the short and medium haul aircraft the electronic sophistication previously seen only in wide-body and four-engine transports, but it did not represent an advance in cockpit technology, only in application.

The 767/757 avionics represented a generation of change in cockpit sophistication: an integrated system, built around the inertial unit for guidance and advanced displays, a sophisticated autopilot/autothrottle and electronic engine control system, and a systems monitoring system, Engine Indicating and Crew Alerting System (EICAS), of previously unknown sophistication. Many referred to EICAS as the "electronic flight engineer."

Other events impacted on the concern for safety. In August 1981 the Professional Air Traffic Controllers Organization (PATCO)

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[1] Dates in parentheses point to the references cited in Chapter XII. No attempt has been made in this report to provide a comprehensive review of the literature of human factors and automation. Comprehensive reviews can be found in Wiener and Curry, 1980; Wiener, 1985a, 1988; and Chambers and Nagel, 1985.

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strike and subsequent firing of the striking controllers by President Reagan left the system stripped of most of its experienced controllers, a problem still reflected today in the relatively low experience level of the existing controller force. The Airline Deregulation Act of 1978 brought not only increased traffic, but a concentration of that traffic in the newly emerging hub-and-spoke terminals. Serious questions were raised about not only the ability of two-pilot crews to handle the workload of the modern aircraft, but also about the loss of the "third pair of eyes" to maintain extra-cockpit scan in the terminal areas.

Equipment reliability was not the issue. The dispatch reliability of the new aircraft proved to be higher than those with traditional cockpits. The problems appeared at the human-device interface.

### NASA Studies

In 1979, the Aerospace Human Factors Division of NASA-Ames Research Center undertook a broadly defined study of human factors in cockpit automation. The project was begun under the direction of Dr. Renwick Curry, assisted by the author, on leave from the University of Miami.

In the summer of 1980 NASA-Ames held a joint NASA/Industry workshop to discuss the problems of defining automation and determining directions for future research. This workshop was summarized in a paper by Boehm-Davis, Curry, Wiener, and Harrison (1983). Another NASA/Industry workshop was conducted in August 1988 (Norman and Orlady, 1989).

Early in the project we recognized the need for guidelines and principles for the design, operation, and training for cockpit automation. These guidelines might aid designers, aircraft operators, and training departments to recognize and deal with the various human factors in automated aircraft, especially those with advanced digital flight guidance systems. The first guidelines appeared in a 1980 paper by Wiener and Curry. These are reprinted in Appendix 1. Other authors (Hoagland, 1984; Braune and Fadden, 1987; Speyer, 1987) have discussed the status of present automation guidelines, their inadequacies, and the need for future guideline development.

At that time the McDonnell-Douglas MD-80 (DC-9-80) was about to come onto the line, and the B767/757 was not far behind. The appearance of these new aircraft offered a very attractive opportunity for a field study of the initial transition of crews. Two field studies were undertaken: by Wiener on the MD-80, in cooperation with Republic Airlines (now Northwest) and by Curry on the 767. These studies documented the problems encountered during initial transition and early line experience, as well as aspects of automation that had been thought to be problems that turned out not to be (see Curry, 1985; Wiener, 1985b).

## Design philosophy

Much has been said of design philosophies of the "glass cockpit" aircraft. This is a complex matter and it cannot be covered adequately here. For a review of cockpit integration philosophy, see Sexton, 1988. Suffice it say that Boeing's philosophy centered around a low-workload environment, in which systems would be simplified, checklists minimized, and to the degree possible routine systems operations would be automated. Boeing's cockpit philosophy emphasized as a first step system simplification, rather than automation. Systems displays would remain silent or blank when in normal configuration, and would display information only when abnormal conditions existed. The EICAS would relieve the crew of most systems monitoring, which had been the primary duty of the flight engineers. The new design philosophy was referred to as the "quiet, dark cockpit."

Furthermore, the CRT displays offered a capability not attainable with traditional electromechanical displays, or even most digital displays: for the first time the displays were reconfigurable. Crews could select or deselect information to be displayed on the primary flight display (PFD), consisting of the ADI and HSI, both displayed on color CRTs, and could select, from a list of alternatives, the display configuration. For example location of adequate emergency airports could be displayed on the map mode of the HSI at pilots' discretion, and the pilot may select from six modes of display on the HSI. The map scale was pilot-selectable. A planning mode allowed the crew to review their lateral course on the map display. Thus the "Boeing philosophy" included maximum discretionary ability of the crew to configure the displays as they deemed appropriate at various phases of flight (see Wiener-Curry guidelines, Appendix 1).

### B. PURPOSE OF THIS STUDY

The emphasis of the first two field studies (Curry, 1985; Wiener, 1985b) was on initial transition of flight crews, and their early operating experience. The present study sought to extend the scope of the investigation, to include the full range of crews operating a state-of-the-art transport aircraft. Primary focus would be on management of the flight, the impact of automation on workload and extra-cockpit scan, and errors in operating the equipment. The training programs would also be examined, as well as the impact of automation on crew coordination ("cockpit resource management").

The Boeing 757 was chosen as the "test vehicle" for this study, partly because of its shorter stage lengths, and hence greater experience of crews operating in terminal areas, with more departures, arrivals and approach/landing operations. It should be emphasized that this study was not intended to be a design review of the 757. The focus was on generic automation and human factors areas. Questions were posed to elicit information

from volunteer crews that addressed broad, we hoped aircraft model-independent issues. However, as the author noted in a previous field study (Wiener, 1985b), it was inevitable that crews would discuss minute details of their working environment, and hence some of the information may appear to be a review of the 757. In spite of this, the author feels that the findings of this study are representative of all advanced technology (AdvTech) aircraft, and are independent of the particular model studied.

Out of the study we hoped to gain an increased understanding of the usage of automatic equipment, problems faced by the crews, areas needing improvement in training programs, and a database of cockpit errors in operating the equipment, from which an attack on human error could be launched. We also hope to gain information by which our automation guidelines could be expanded.

### C. ORGANIZATION OF THIS REPORT

This report is organized in Chapters designated by Roman numerals. Chapters I through III are background, methodology, and biographic information on the volunteers. The heart of the study is in Chapters IV through X, which are organized as study topics, such as cockpit equipment and environment, training, etc. These sections are organized as follows: an introductory section, data tables and figures as appropriate, and direct quotations from the respondents. Section XI is a series of conclusions and recommendations based on the entire study.

The results of the 36 attitude scale items ("probes"), displayed as bar charts, are assigned to the appropriate sections. The assignment of the probes to the various chapters was based on their content, and not on any statistical clustering technique. For the reader's convenience, all 36 charts are displayed four to a page in Appendix 6. These graphs display the percentage of responses in the five response categories ("Strongly agree" through "Strongly Disagree"), by Phase 1 (1986) and Phase 2 (1987) of the study. Since these probes carry their own numbers (1 to 36), they are not designated by figure number in the text. Other figures and tables are designated by Roman numeral for the chapter and Arabic number for the figure or table, in order (e.g. Figure IV-1).

## II. STUDY METHODOLOGY

### A. OVERVIEW

The intent of this study was to extend the scope of the two previous automation field studies (Curry 1985; Wiener, 1985b) to cover a wide variety of topics, and draw upon the experience of line pilots with a range of 757 flying time from those just completing their initial operating experience (IOE) to those with experience levels of over 3000 hours.

This study, which was conducted at two host airlines, referred to in this report as Airline-1 and Airline-2, focused on the following topics:

1. Operation of the flight management computer (FMC), mode control panel (MCP), and other automatic features of the 757
2. Errors and error management
3. Workload and workload management
4. Crew coordination and communication ("cockpit resource management")
5. Training and transition to the 757, and re-transition back to older models

This is primarily a study of line pilot opinion. The theory behind the NASA field studies is that line pilots constitute a vast database of operational experience, and this database is seldom tapped. This represents both a loss of resources to the aviation community and a source of frustration to the pilot, who often feels that his/her viewpoint is ignored.

Another source of information on field operations is NASA's Aviation Safety Reporting System (ASRS). However, this database is usually confined to errors, and largely errors in which the reporter might be culpable. The ASRS database and the data from the field studies have been described by the author as "two windows on the real world." Though the sources of data, methodology, and coverage are vastly different, there is a great similarity in the outcomes. This has been seen recently in the congruence of ASRS's study of altitude deviations ("busts") of high technology aircraft and the results reported in Chapter VI. The primary sources of information in this study were:

1. Interviews with management pilots, check airmen, and instructors.

2. Attendance by the author at 757 ground schools at both carriers.
3. Interviews with volunteer line pilots conducted by the author.
4. Questionnaires filled out twice (one year apart) by volunteer 757 pilots. These contained forms for:
  - a. An 36-item attitude toward automation scale
  - b. Open-ended questions on various topics
  - c. Biographical questions on 757 experience, prior aircraft and aircraft flown after the 757 for some
5. Jumpseat observations by the author both in simulators, and during line operations.
6. A special series of open-ended questions in Questionnaire 2, for pilots who had left the 757 for other aircraft ("backward transition" as it is called in this report).

## B. DESIGN OF THE EXPERIMENT

The research design called for two sets of questionnaires, mailed to the pilots one year apart, the first being in the summer of 1986. The questionnaires are shown in Appendix 2. The attitude-toward-automation (Part II) was identical in both questionnaires. Otherwise all questions but one were different. The one open-ended question repeated in both questionnaires dealt with errors that the respondent had made or observed in operation of the 757 (Chapter VI of this report).

### Questionnaire Development

Questionnaires were designed to elicit pilot opinions, experience level, and specific information and viewpoints. The 36-item Likert scale was adapted from the one previously used by the author in his field study on the MD-80 (Wiener, 1985b). Some probes were identical to those in the previous study, altered to conform to the 757 systems, and others were totally different.

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 is asked his degree of agreement/disagreement. The response scale contains an odd number of possible responses, typically five or seven levels from strong agreement to strong disagreement, with a neutral value in the center. The center response is somewhat ambiguous: it can mean "no opinion", "undecided", or a truly neutral or centrist position on the probe. In this study, five response levels were employed: "strongly agree", "agree", "neither agree nor disagree",

"disagree", and "strongly disagree". The response form is shown in Appendix 2.

The items are referred to as Item 1 through Item 36, and data are displayed as histograms. Most of the histograms simply report the percentage of responses to each probe at the five levels with Phase-1 and Phase-2 data on the same graph. Some statistical contrasts, such as opinions of captains vs. first officers, and pilots with DC-9 (hence two-pilot crew) experience versus those without, were tested, and those with statistically significant results are also shown as histograms.

Open-ended questions gave the volunteers the opportunity to spell out in detail their opinions or experience in response to a variety of issues (see Appendix 2 for a list). Also included on the Phase-1 questionnaire was a request that the respondent suggest a question that the author might ask during interviews. It was felt that these suggestions might be an insight into what the crews felt was important. The suggested questions are listed in Appendix 4.

The questionnaires were designed so that it could be filled out in one hour. Some respondents attached lengthy answers to some questions, often written on typewriters or word processors, indicating rather strong feelings about the topic. As stated previously, the Phase-1 and Phase-2 questionnaires contained several independent parts. These included:

<u>Topic</u>	<u>Questionnaire Phase</u>
1. 36 item Likert attitude scale	1,2
2. Biographical history - past aircraft flown and most recent before 757 school	1
3. Open-ended questions. Six on each, one of which appeared on both (errors witnessed)	1,2
4. Request for suggestions of questions to ask	1
5. Tabulation of types of approaches flown, (e.g. number of autolands, VOR, ADF etc.)	2
6. Special form for those who had left 757	2
7. Preference for aircraft in fleet	2
8. Suggest a question we should ask during interviews	1

The Likert scale items were identical on both questionnaires for comparison from Phase 1 (summer 1986) to Phase 2 (summer 1987). As mentioned above, the open-ended questions were different in

each phase, with one exception: the question on errors that the respondent had either committed or observed was present on both.

#### Data Handling of Numeric Data

Numerical data from the questionnaires were entered into a computer-based file, and statistical analyses were performed, and figures were produced, employing commercially available software packages for a personal computer (see Chapter XIII, Note No. 4).

For each of the 36 attitude items (P1 to P36), a figure is displayed, showing the Phase-1 and Phase-2 responses. These are displayed in the appropriate chapters. For each of the 36 attitude items, statistical tests were performed to determine whether there were significant differences.

- 1) Phase I and Phase II (Bowker test for matched groups). Only two contrasts were found to be statistically significant, indicating little movement in opinion from the first to second phases. One of the experimental hypotheses was that there would be movement in opinions of crew members from Phase 1 to Phase 2, as the crews became more experienced in 757 operations. Specifically, the author hypothesized that crew opinions would move toward a more favorable view of cockpit automation, particularly on the more global questions discussed in Chapter X. This hypothesis was not substantiated by these tests, which are discussed in Appendix 5.
- 2) Captains versus first officers (chi-square test for independent groups). Six contrasts were found to be significant, two in Phase 1 and four in Phase 2. Thus we can summarize that there were essentially no differences in opinion between 757 captains and first officers. Bar graphs displaying the data by "seat" (captain versus first officer) follow the corresponding bar graphs in the appropriate chapters in this report. These are indicated by the letter "A" following the item number (e.g. 31A), and the designation of "Capt." and "F/O" in the figure legend.
- 3) Pilots with and without previous DC-9 experience). In order to test the hypothesis that having had previous two-man crew experience would affect ones views in this study, the Airline-1 group only was subdivided into those who had previously flown the DC-9 and those who had not. No Airline-2 757 crews had flown the DC-9. Chi-square tests were performed on responses to the 36 items in Phase 1 and Phase 2; only three of these 72 tests (4 per cent) yielded significant differences. Bar graphs depicting the three significant contrasts are displayed at the end of this chapter, and are designated with the letter "B" following the item number (e.g. 24B). It is safe to say that the data did not produce evidence of differences between those with and without prior two-pilot (DC-9) experience.

Other statistical tests on the data are noted in the appropriate chapters. Intercorrelation matrices are shown in each chapter for the attitude scale items in that chapter, plus the variable, HIT (hours-in-type in the 757). See Chapter XIII, Note. No. 9

#### Data Handling of Open-Ended Questions

Non-numerical responses, such as replies to the open-ended questions, were individually read, analyzed, and classified by the author. Much of the analysis of these free text responses was subjective. Direct quotations were chosen to represent a variety of viewpoints. There was no attempt to make the number of quotations on any viewpoint represent the proportion in the database. They were selected for inclusion on the basis of representing a variety of opinions.

The quotations are as close to verbatim as possible. The author performed "light editing" to make the quotations more clear, improve punctuation where needed, and put them into complete sentences. Where words are underlined for emphasis, these were the choices of the respondent, not the author. In a few places editorial insertions were made for clarity, and these are delimited by the symbols < >. Where ever possible, results were tabulated and presented prior to the body of direct quotations. The four-digit number at the end of each quotation is for cross-referencing.

### C. PANEL FORMATION

#### Request for volunteers

Initial meetings were conducted jointly with management and representatives of the Safety Committee of the Air Line Pilots Association at both carriers, during which a written proposal from the author was discussed. At each carrier, the two parties agreed to cooperate on the project, and a joint letter signed by management and the Safety Committee was drafted. This was attached to a detailed brochure which explained the purpose of the experiment, the need for volunteer 757 crews, and what would be expected of a volunteer. The last page was a sign-up sheet asking for some information on the 757 flying experience of the volunteer, total flying time, and whether he was an instructor or check airman. Included was an envelope addressed to the author. These packages were distributed to all 757 line pilots, and crews going through the ground school at the time of the recruiting effort. 201 pilots agreed to join the panel. A distribution of these pilots by airline, seat (captain vs. F/O), and domicile are shown in Figures II-1 and II-2. A statistical summary of flying experience is found in Chapter III.

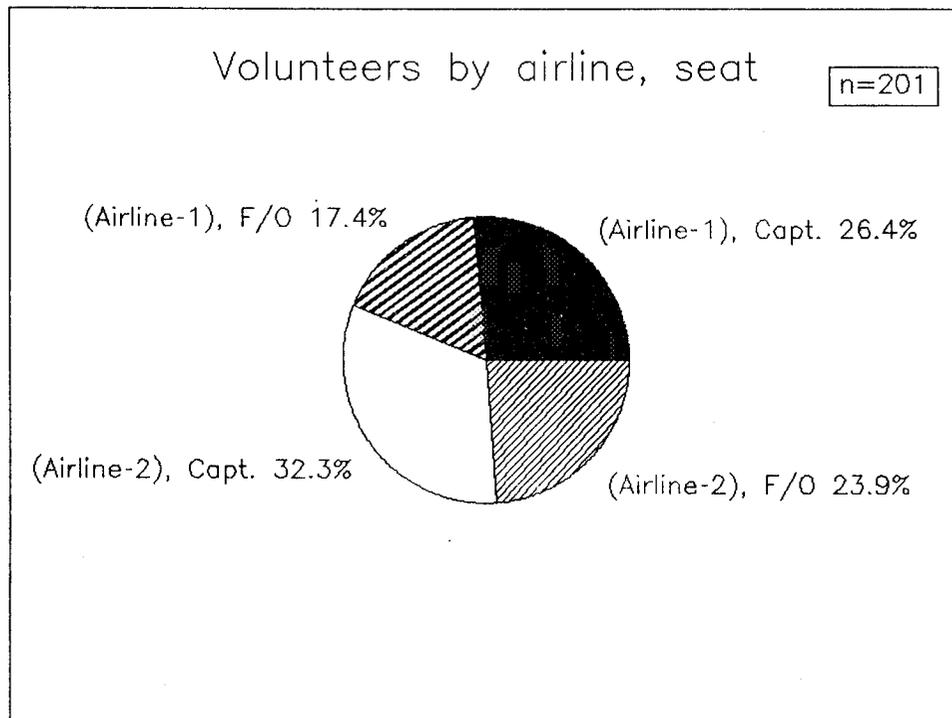


Figure II-1. Distribution of volunteers by airline and seat.

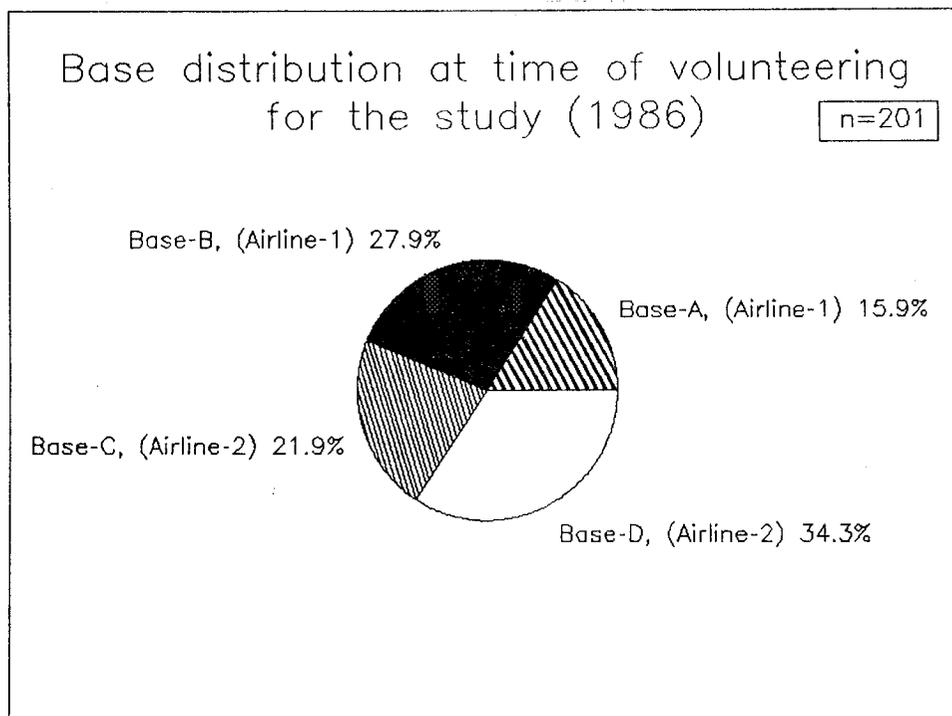


Figure II-2. Distribution of volunteers by base.

## Confidentiality

Volunteers were assured of confidentiality. This was implemented in the following way. When the pilot volunteered by sending in his form, he assigned himself an six-character code of letters and numerals of his choice. The information on the form was encoded into two data files: one contained the volunteer's name, address and telephone number. The other contained the ID code, and the biographical information. Both files were then sorted so that they could not be matched. The volunteer was sent a self-adhesive tag with the ID code to keep as a reminder. The ID-to-name keys were kept by the author only until all of the volunteers were in the database, and then they were sent to the Safety Committees. They have since been destroyed.

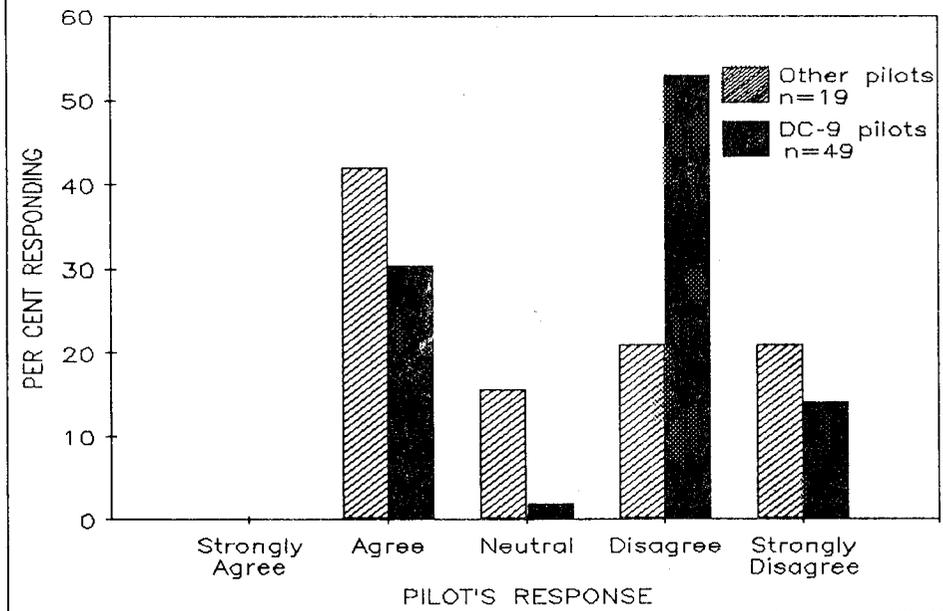
The ID-code block contained eight characters: up to six for the volunteers' self-assigned code, the final two being a code for the airline and base for data handling purposes. On the two subsequent questionnaires, the respondent entered the ID code at the top, so that they could be matched. This system had its drawbacks. A number of questionnaires were received without ID codes, and there was no way to contact the sender. Of the 166 responses on Questionnaire 1, and 133 on Questionnaire 2, only 106 matches could be made. In spite of this, all of the data could be used except in the analysis of shifts of opinion from Phase 1 to Phase 2, which required matched groups. Only the 106 matched pairs were used for these tests.

During the face-to-face interviews, the author of course knew the name of the interviewee, but did not record it with the remarks. Thus once the interviews were completed, no remark could be attributed to an individual. All formal interviews were conducted at the four crew bases in a room set aside for this purpose. Either one or two pilots were interviewed at a time. In a few instances, more than two pilots participated at the same time. Several 757 pilots who were not volunteers on the study panel came in and asked to be interviewed, and they were accepted.

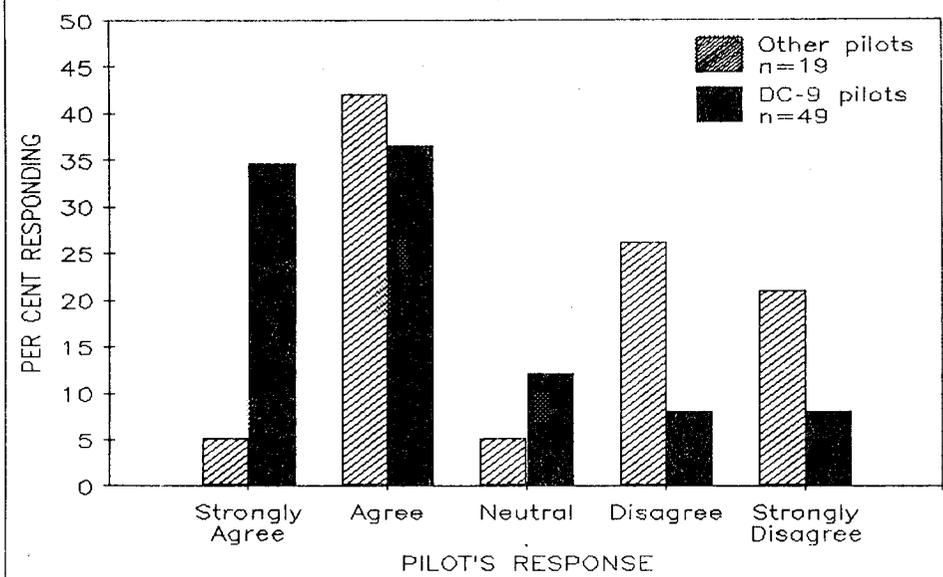
The conversations which took place during jumpseat trips could be considered informal interviews; no record was kept of flight numbers, dates, or crew names. In most cases no notes were taken during flight. In a few instances, where it was considered valuable to retain some information in detail, the author asked permission of the crew to write down what he had just seen or heard, and permission was always granted.

There was no attempt to quantify the information garnered from interviews, jumpseat or simulator observations. This information became part of the data which influenced the discussion and conclusions in Chapter XI of this report, and perhaps elsewhere.

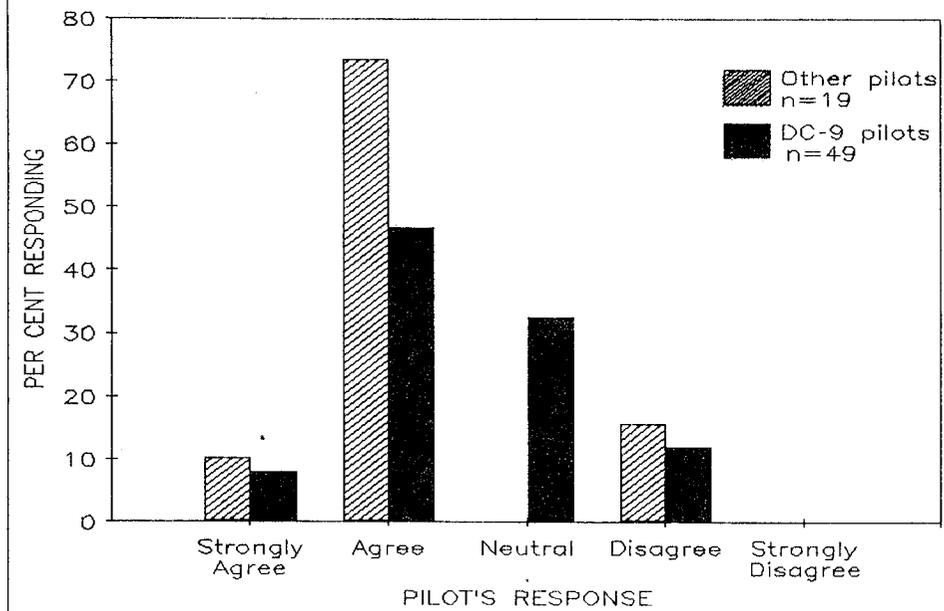
24B. Training for the B-757 was as adequate as any training that I have had.



26B. With the automation available today I prefer the two-pilot cockpit to the three-pilot cockpit.



29B. I use automation mainly because it helps me get the job done.



### III. FLYING EXPERIENCE OF VOLUNTEER PANEL

This section contains data on the flying experience of the panel members at the time they volunteered for the study in 1986, filled out the Phase-1 questionnaire in mid-1986, and the Phase-2 questionnaire in mid-1987. Data are reported on total flying time, time in type (B-757), and past seats held at their airline. In a few cases, respondents added seats held in other airlines, corporate flying, and military transport aircraft, but these data are not reported here. Flying experience with other than the present airline is therefore reflected only in the total flying time data.

The sample sizes are indicated on the graphs. Note that the sample size of 201 refers to all of those volunteering for the study. The sign-up form included the information on seats previously held (Table III-1) and total flying time at the beginning of the study (Figure III-1). Sample sizes of 166 and 133 refer to the number of completed questionnaires received in Phases 1 and 2 respectively, and is reflected in Figures III-2 and III-3 which report the time in type (B-757). The sample sizes are summarized in the table below.

<u>Data</u>	<u>Source</u>	<u>N</u>
Total flying hours	Sign-up sheet	201
Seats previously held	Phase-1 questionnaire	166
Seat prior to 757 [1]	" "	
Time in type (757)	" "	
Time in type - Phase 2	Phase-2 questionnaire	133
Seats held since the 757 [1]	" "	

#### Total Flying Time

Total flying hours at time of volunteering for the study are displayed in Figure III-1. The median for this distribution was 11,000 hours. It is noteworthy that 15% of the crews had less than 2,500 hours. Although this is possible, we believe that it may be due to an error in the interpretation of the question, which may have led some of the crews to fail to include their

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[1] Reported in Section V (Training), Table V-1.

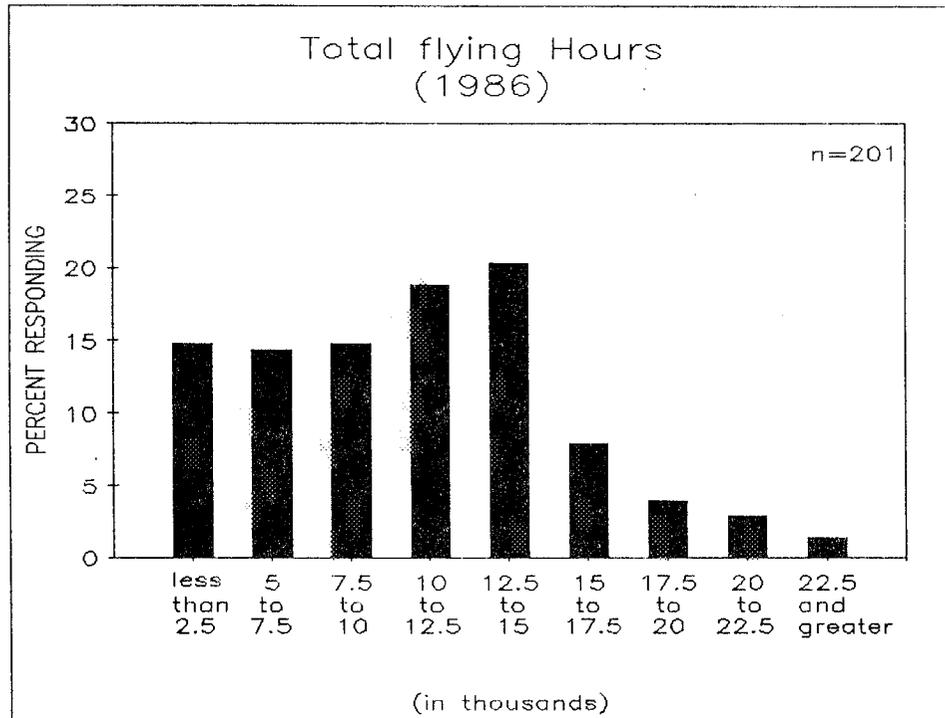


Figure III-1. Distribution of total flying hours of volunteers at time of joining the study (early 1986).

flight engineer time in response to the question "total flying time, all aircraft." We have since asked several pilots if they would include engineer time in response to such a question, and we have obtained mixed results. The author regrets the ambiguity in these data.

Previous Seats

On the Phase-1 questionnaire, crews were asked to check each seat on each aircraft in their company's fleet that they had occupied at any time. Number of hours was not requested. These data are displayed below in Table III-1. The Phase-2 questionnaire requested information on the seat held immediately prior to attendance at 757 school, and also for, those who had left the 757 for other aircraft, the seats held after leaving the 757. These data are displayed in Section V (Training) in Table V-1 and V-7.

TABLE III-1. All seats previously held at present airline (n = 201). For data on seat held immediately prior to 757 school, see Table V-1 (Training).

## SEATS PREVIOUSLY HELD

	CAPTAIN	F/O	S/O	TOTAL
DC-9	36	28	—	64
B-727	81	113	124	318
A-300	4	7	13	24
L-1011	0	26	11	37
DC-10	7	42	35	84
B-747	4	40	42	86
<b>TOTAL</b>	<b>132</b>	<b>256</b>	<b>225</b>	<b>613</b>

### Time in Type (B-757)

Figures III-2 and III-3 display the numbers of hours in type in the B-757 at the time of the Phase-1 and Phase-2 questionnaires. The median time was 500 hours for Phase 1 and 1,100 hours for Phase 2.

The growth in hours in type from the first to the second phase was reduced somewhat over that which a pilot would normally acquire in the roughly 14 months that separated the two phases. This was due to the fact that at one airline many of the newly trained 757 pilots had to return to their previous seats for a number of months before 757 seats opened up. Thus they did not obtain a full (average) 14 months of 757 time between their two questionnaire phases. Note also that the time between questionnaires varied between pilots, depending on how quickly they sent them in. The 14 month figure is the time between mailing out the two questionnaires. By normal crew scheduling at the time of this study, a full time 14-month schedule on the 757 should have yielded about 700-800 additional hours.

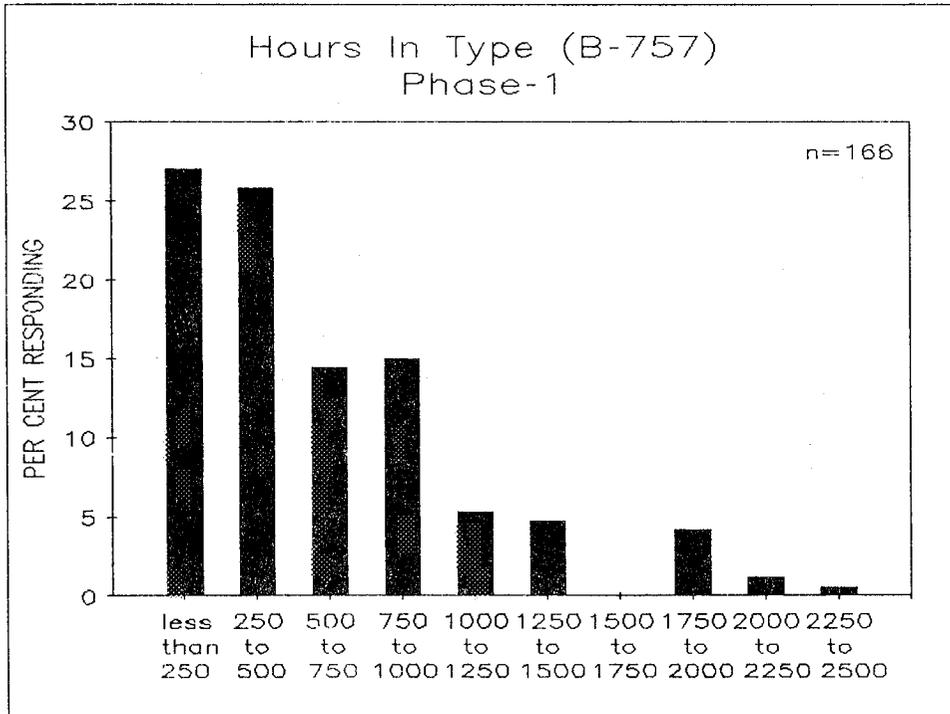


Figure III-2. Hours in type, Phase 1 (mid-1986)

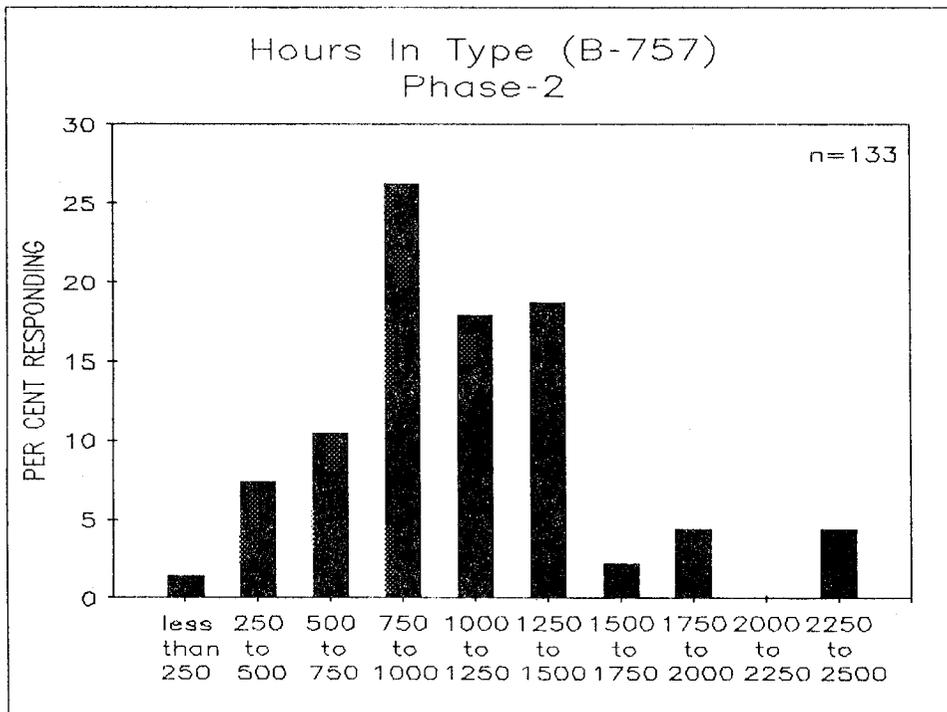


Figure III-3. Hours in type, Phase 2 (mid-1987)

## Discussion

The data presented here support a generalization about the 757 pilot at the time of this study. From the data on both the flying hours and the previous seats one can conclude that the 757 is essentially a mid-seniority airplane, flown largely by former 727 crews at the two host airlines. The data in Chapter V, Table V-1 indicates that close to 60% of the crews entering 757 training came directly from 727 seats, and the data in Table III-1 shows that considerably more had at one time in their airline career flown the 727, partly because at both carriers, second officer in the 727 has been the usual starting position for new hires. Over half of the total seats occupied (318 out of 613) were in the 727, and 124 of the 201 pilots volunteering for the study had served as flight engineers in the 727.

At both carriers, the 757 pay schedule was not considerably higher than that of the other narrow-body aircraft. The big jump in pay occurs in moving from a narrow-body to a wide-body aircraft. For this reason the 757 represents a way station in seniority progression to the wide-bodies, resulting in many pilots serving only very short tours on the 757. The departure of crews from the 757 to other aircraft is discussed in Chapter V on training. The 757 also afforded an opportunity for a number of 727 second officers to become first officers, rather than going through the usual seniority path of first officer on a DC-9 (Airline-1) or a 727 (both carriers).

A surprising number of the 757 crews in this study (38) came from wide-body aircraft. Eleven were second officers, upgrading to the right seat of the 757, but the remainder were captains and first officers, presumably taking a cut in pay to fly the 757. To the extent that we could determine it, there appeared to be two explanations for this: 1) the desire to fly a more modern aircraft; and 2) the desire to stop flying long legs and international schedules.

In summary, the 757 crews did not represent the usual progression up the normal seniority ladder. As mentioned, a number of pilots, including captains of wide-bodies, moved to the 757, and a number of 727 second officers leaped over more senior first-officers who could have bid it. Even those who came from other first officer seats did not do so for seniority or salary advantages, as they could have remained in the DC-9 and 727 right seats until ready to move to similar positions in the wide-body aircraft. Most indicated to the author that they bid the 757 for one reason: the desire to fly a high technology aircraft before moving to more lucrative, but less technologically attractive wide-bodies. A similar motivation to fly the most advanced technology aircraft in the fleet had been noted in the author's previous study of pilots transitioning from traditional DC-9s to MD-80s (Wiener, 1985b).

#### IV. COCKPIT EQUIPMENT AND ENVIRONMENT

##### A. INTRODUCTION

In this section we shall discuss cockpit equipment, how it is perceived by the crews, their likes and dislikes, and use of the automation. A large amount of data from the two questionnaires will be reported. This section is intended to be a general overview of automation, as well as a detailed look at the cockpit environment. The section contains four parts:

- B. General likes and dislikes about the cockpit environment, and automation in general.
- C. Specific questions and comments on programming the FMC, and on programming duties in general.
- D. Features that would be missed and not missed if the crewman were to leave the 757. This section is perhaps another way of asking the questions explored in part B.
- E. Tabulations of usage of the various modes of instrument approaches, and automatic features, including autoland.

The movement toward automation has largely been built on three basic assumptions:

1. Automation would reduce workload (and therefore also fatigue), and would replace the duties of the second officer.
2. Automation would reduce human error by replacing human activities with error-free devices.
3. Automation would therefore be uncritically accepted by flight crews.

The designers, certification specialists, and purchasers often took these not as assumptions, but as given facts. Beginning with the work of Wiener and Curry (1980), these assumptions were challenged. Our early work indicated that:

1. Workload was not universally reduced. In fact it appeared that a paradox existed: workload seemed to be reduced when it was not heavy or critical, and may be increased by automation when it was already heavy or critical. Workload is discussed in detail in Section VIII of this report.
2. Accident and incident experience, and the ASRS database, while not allowing a statistical comparison of error rates,

raised serious questions about the proper use of automation by the crews, and pointed toward a potential for automation-induced errors. Indeed, it appeared that automation might be reducing small errors, and creating opportunities for large ones. Section VI of this report is devoted to a discussion of human errors in automation.

3. Field studies showed that many pilots were quite critical of automation, both as a concept, and as to specific applications and usages.

The data reported in this section summarizes the viewpoints of 757 crews regarding the automation, specific cockpit equipment, and the overall environment of the cockpit. Following Table IV-1 are seven figures reflecting general crew attitude toward automatic flight features.

#### B. LIKES AND DISLIKES

On the first questionnaire, crews were asked the following [1]:

**1-1. List the features or modes of the 757 automation, instrumentation, or avionics that you like or dislike. Explain why if you wish.**

The results are given in Table IV-1 below. (Note: some of the "why" information is covered in other sections of this report dealing with specific features and modes.)

-----

[1] Throughout this report, the questions are numbered by two digits: the first is the questionnaire phase (either 1 or 2), the second is the question number (1 through 7), e.g. 1-2 indicates the second question on the Phase-1 questionnaire.

TABLE IV-1

LIKES

Item	Times Mentioned
GENERAL AUTOMATION	
Everything (so stated)	14
Everything, when it all works	2
Automatic functions (in general)	11
Autothrottle	25
Autopilot	14
CWS mode	1
Multiple autopilot	1
Autoland (and low vis. approach capability)	14
VNAV	22
LNAV	21
Navigation instrumentation and concept	7
Amount of information available at all times	11
EICAS	10
EFIS ("glass cockpit) in general	24
Flight director	7
FMC (general)	21
HOLD page and holding capability	7
DIR INT page and capability	7
PROG page	6
FIX page	2
NAV DATA page	2
Concept of pages	1
Route-2 capability	1
CRZ page	1
Abeam fix capability	1
Stored company routes (Airline-2)	3
Stored gate positions	1
Ease of programming route	4
Ability to program to avoid weather	1
Autotuning of VORs	2
HSI (general)	17
HSI map mode	52
HSI radar plot with map	21
Ability to scale map	1
Wind vector	13
Map display of airports and nav aids	11
Green arc (point on map reaching altitude)	1
Ability to see point where will intercept ILS (Loc)	1
Map plan mode	4
Track predictor display ("noodle")	1
ADI (in general, and esp. mode info on ADI)	10
Ground speed readout	5

## OTHER DISPLAYS

Redundant analog and digital instruments	2
Display of performance data	1
Continuous update of fuel and arrival information	1
Color coding of system status, engine instruments	2
Time (ETA) display	1
Distance to go display in FMC	1
Instruments easy to read	4
IVSI (emphasis on "instantaneous")	1
Altitude alerting system	2

## CONTROLS/MODES

Ability to program at the gate	3
Speed mode	1
Heading select	1
Pressurization controls	3
Ability to cross hard altitudes accurately	1
FLCH (flight level change) mode	2
No need for lat/lon of W/P to be entered by keyboard	2
Ability to override FMC with MCP (e.g. FLCH)	1
"User friendly" software	1
Center ILS head to program both F/Ds	1
Altitude capture	1
Ability to go to 300' RVR some day	1
Go-around and missed approach programming	2
Ease of intervening in programmed flight with MCP	1
Dual com head and sel call	1

## PERFORMANCE

Smoothness of auto flight	7
Airplane performance and power	2
High altitude capability	1

## COCKPIT LAYOUT/WORKLOAD/EASE OF WORK

Mode control panels and layout	4
Cockpit layout in general	3
Ease of en route planning	2
Ease of route insertion	1
Cockpit lighting	1
"Semi-heads-up" while using autopilot	1
Low workload at cruise	1
"Color coordination" of cockpit	1
Outside visibility	1

## SYSTEMS

Exceed limitations/duration recording for maintenance	1
Electrical systems	1
Fuel systems, controls, and displays	1
Automatic systems (other than flight systems)	5
Automatic cabin temp control	1
IRUs (IRSS)	4
Auto-tuning of VORs	1
Fuel saving procedures	1
EEC/thrust management systems	2
ACARS (Airline-2)	1
Alternate gear/flap lowering (simplicity of)	1
APU	1
Auto speed brakes	1
Autobrakes	1

## DISLIKES

Item	Times Mentioned
<hr/>	
GENERAL AUTOMATION	
None (so stated)	7
F/D and A/P need speed hold for descents (like 747)	1
Never get to use "basic functions" (NDB, VOR, ILS display modes) except on check ride	1
No manual capture of LOC and GS in F/D mode	2
Automation creates complacency	1
Autothrottle on takeoff	1
Automation useless in terminal area	1
Too much time with head in cockpit	2
FMC	
Slowness of FMC to respond to input	21
FMC resynchs too often	3
Poor performance of fuel projections	1
Poor performance of holding page	2
No efficient way to intercept radial outbound	1
"Insufficient Fuel" message comes on too often	1
Direct intercept (to distant waypoint) wipes out intermediate waypoints; difficult to reprogram	3
Too much programming	5
One airway intersecting another difficult to program	1
Database (FMC) will not be current on weekly basis	1
Step climb unreliable	1
Descent information unreliable	1
Descending in VNAV in holding pattern is difficult	1
Unnecessary steps to put alt. in MCP, then program it via CDU into the cruise page	1
Some numbers on FMC cannot be erased	1
Can't get ILS-DMES when in map mode	1
FMC underestimates top-of-descent point	1
Descent logic in general	1
LNAV programming logic	1
VTRK error should be on Page 1 of PROG Page	1
Can't cross-check position with VORs in auto position	1
"BITE check OK" message appears too often	1
Top-of-descent point lost if Xing restrictions added	1
Descent forecast page unnecessary	1
Can't capture glide path from above	3
VNAV logic in descent (esp. drag required)	8
DISPLAYS	
Non-availability of FMC maintenance pages in flight	11
Weather radar -- various complaints: low intensity on HSI map, too much red; underestimates intensity	30

F/D - would prefer V-bars (like FD-109) - Airline-1	1
F/D V-bars should be filled in (not outlined) - Airline-2	9
F/D - calls for extreme corrections	1
F/D - misc.	2
Magenta/cyan poor choice of color contrasts	1
Auto-squelch on com radios	2
HSI should show all selected airways	1
Aural warnings too loud	1
Blinking displays	1
LOC on ADI (sensitivity)	1
ILS display mode	1
Lack of aural tone on altimeter alerter	8
Need more territory displayed behind own aircraft on map	2
Map display should be 360 degree compass rose	2
Com radio frequencies on LCDs hard to read	1
Airways should be identified on map	1
ADF is on wrong needle	2
Should have voice messages for advisories	2
Incorrect EICAS messages	1
Can't separate code ident from voice on nav aids	1
Engine gauges should not have "hollow" arrows	1
Need larger scale on map display	1

#### CONTROLS/MODES

VNAV -- (specifically below 10,000')	5
VNAV -- various complaints	3
VNAV -- takes too long to program crossing restriction	3
VOR and ILS frequency selectors difficult to set	3
Transponder toggle switch too small	1
Control of airspeed in FLCH	3
Need separate mike for cabin PA	1
Need third com radio for guard channel	1
No synch feature to eliminate engine beat	1
Single ILS head; subject to failure; need two at LAX	2
ADF performs poorly	2
Need bank angle limitation in LNAV at cruise	3
Not clear what the autothrottles are doing	1
VOR head - too much spinning and lag	1
Need a pitch control knob on autopilot	1
Layout of autothrottle controls on MCP	1
Parameters for altitude deviation too loose	1
No turbulence mode on autopilot	1

#### PERFORMANCE

Autothrottles unstable, surge, too much movement	8
Too much draft/crab in autoland	1
Climb/descent should allow more lead time	2
Altitude capture at low level (esp. after T/O)	1
Excessive vertical speed in last 1000'	1
Excessive bank angle intercepting course	3

## COCKPIT LAYOUT/WORKLOAD/EASE OF USE

Excessive "head down" time due to programming required	7
Remote location of side panel	2
Fuel gauge location	1
Too many annunciators and lights _ could be on CRTs	1
Mode displays on ADI should be at top	1
Too many lighting controls	1
Headsets and boom mike uncomfortable	1
Air noise in cockpit	2
Two-man cockpit	3
ACARS - various complaints - don't like on same scope with radar; nuisance messages; cumbersome (Airline-2)	10
Too many identical switches	1
Circuit breakers too hard to reach	1
Door warning light too high overhead	1
Oxygen mask fits too tight	1
VHF should have press-to-talk on glare shield	4
Sun visors	1
Alt and hdg knobs (MCP) should have fast & slow slew	1
Location of RDMI	1
Need light to indicate "video on" in cabin	1

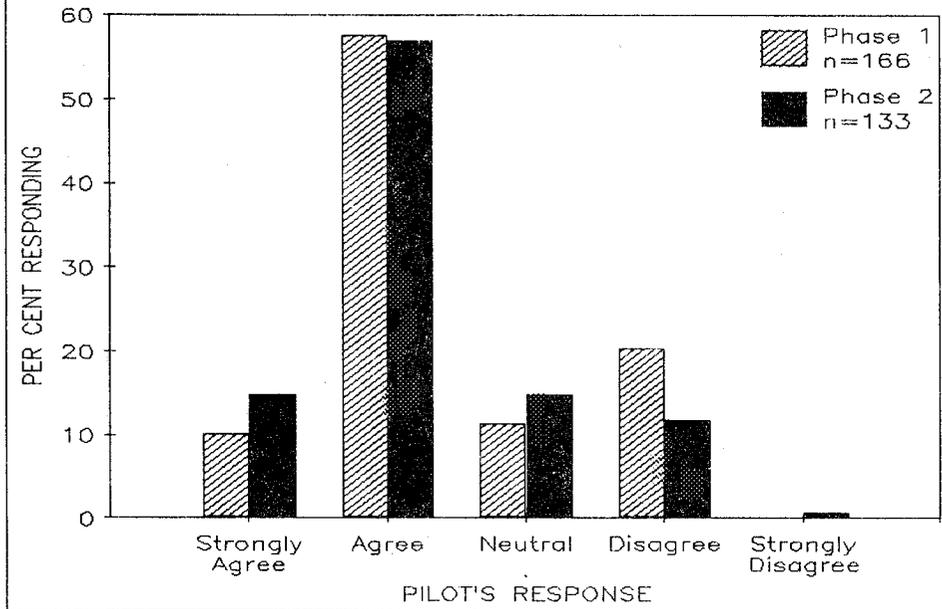
## SYSTEMS

No mechanical "last ditch" way to lower gear	1
Need override of EEC for EPR in case of engine loss at V-1	1
Autobrakes too grabby on manual release	1
Electrically caused problems that can't be duplicated for maintenance	1
Lack of systems monitoring instruments for trouble shooting	1
No safeguard for fuel imbalance - just warning	1
Brakes too touchy	2
Rudder trim constantly changing	3
Need better cooling in E&E compartment	1
Yaw damper too sensitive	1
Need more information on system status (e.g. packs)	1

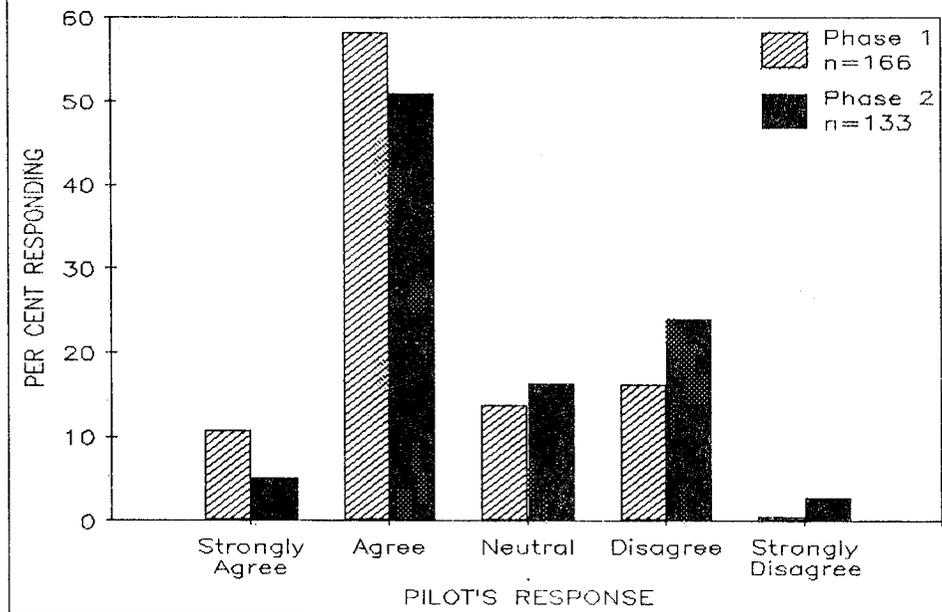
## POLICY

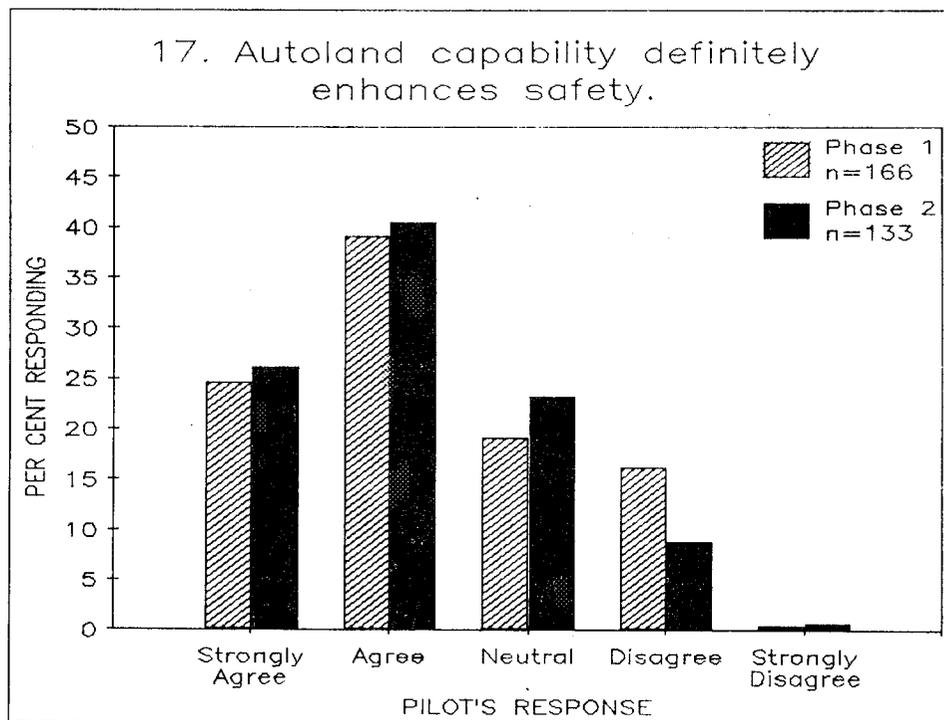
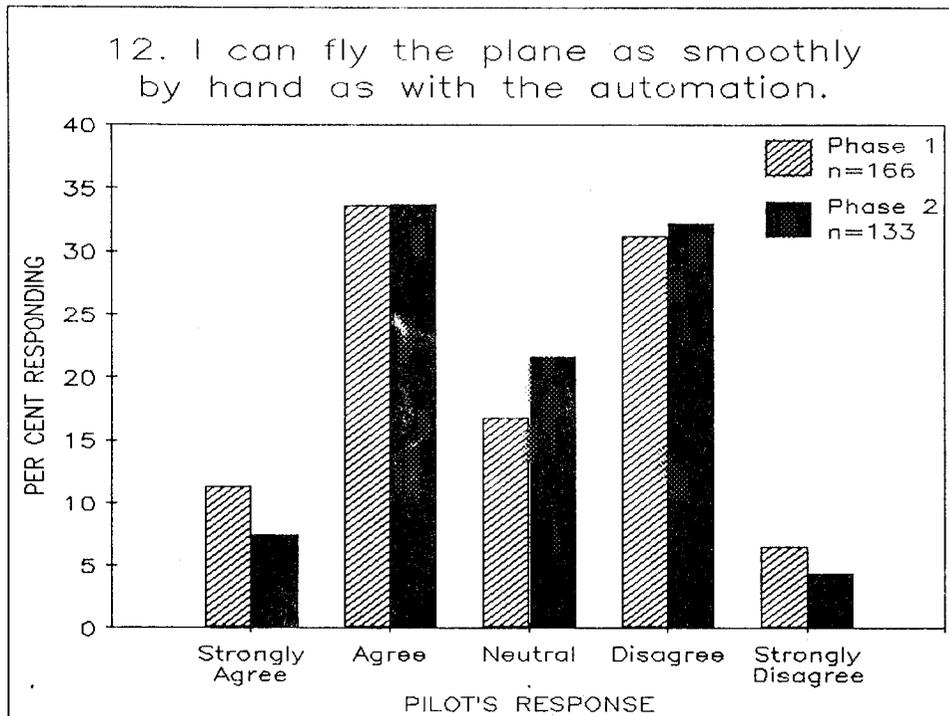
Excessive company tasks not related to flying	1
Not enough emphasis on basic flying skills (A/S, alt.)	1
Dispatching with one generator or APU out	1

7. I always know what mode the autopilot/flight director is in.

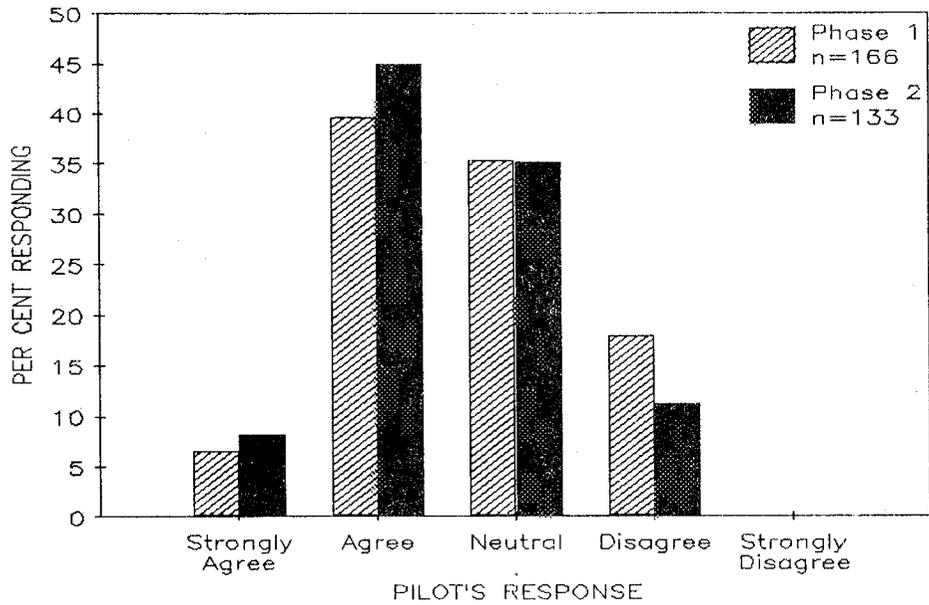


11. In the B-757 automation, there are still things that happen that surprise me.

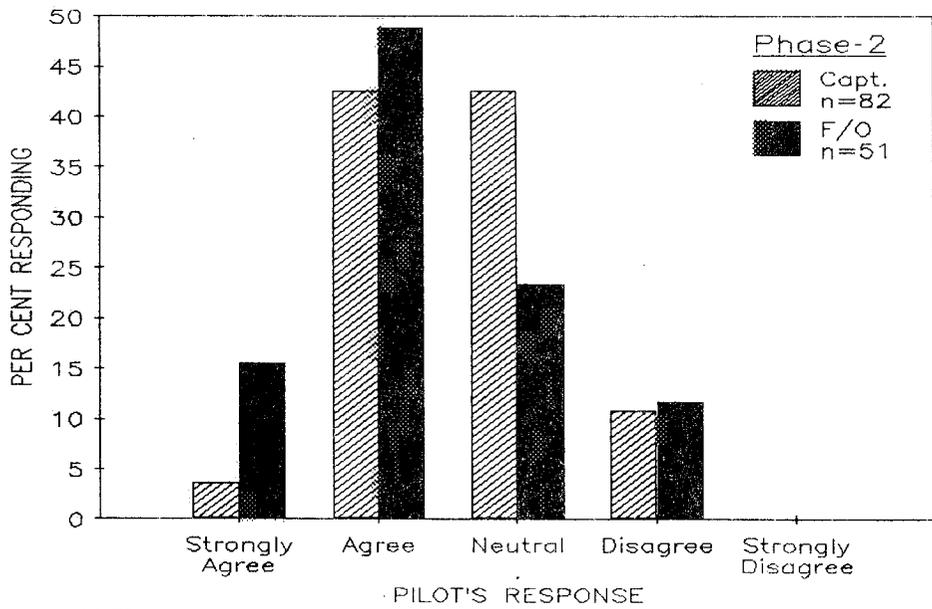




15. I feel that I am "ahead of the plane" more in the B-757.



15A. I feel that I am "ahead of the plane" more in the B-757.



### C. PROGRAMMING DUTIES

The Phase-2 questionnaire contained an open-ended question about programming the FMC, and programming duties in general is discussed. (Note: crews often use the terms FMC and CDU interchangeably.) The motivation for this question was the oft-stated view that excessive programming duties were required; that this often resulted in high workload and distraction from extra-cockpit scan in the terminal areas; and that programming could be eliminated or simplified. This will be discussed further in Chapter VIII on workload. The term "programming" is not exactly correct in the context, as it includes data and parameter entry as well, but it is the term most often used for any CDU input.

Since the introduction of the advanced technology aircraft, which require a high degree of FMC programming, there has been considerable controversy surrounding this activity, particularly on departures and arrivals from terminal areas, which often require a heavy programming workload due to rapid ATC changes. Most frequently mentioned is the arrival to Los Angeles International Airport (LAX), where frequent runway changes occur between the time when the crew receives the ATIS runway prior to descent, and when the final runway assignment is made. Pilots often refer to this as "musical runways." Typically one runway is assigned on the ATIS, and the crew programs this into the FMC. Sometimes crews, in anticipation of a runway change, will program a second approach into RTE 2, so that all they will have to do is activate that route and reset their ILS receiver for the new runway.

But it is not unusual for "musical runways" to occur, with changes beginning as they join the arrival, and continuing all the way down to near the outer marker. (See Figure IV-1, the 29 PALMS profile descent into LAX, next page). The runway programmed in RTE 2 may or may not ever become activated.

Various views are held on how to handle this, especially as the flight progresses closer to the final approach fix, and the opinions are quite polarized. One view says that solutions to ATC changes should be programmed and automation, particularly LNAV, VNAV, and approach coupling, should be exploited to the fullest. Those who hold this view generally feel that persons not exploiting the automation have simply not gained the necessary proficiency level.

The other view holds that in a two-pilot aircraft, descending into a terminal area (particularly LAX, due to its heavy traffic, frequent TCA violations by VFR aircraft, and aircraft flying VFR in questionable VMC conditions), at least one pilot should be looking out of the window at all times in VMC conditions. The CDU, it is felt, tempts both pilots to go "heads-down" and become overly involved in programming duties. The critics hold that

JEPPESEN DEC 9-88  
DME or RADAR REQUIRED  
ATIS Arrival 133.8

10-2E

IL/DCT/IS

PROFILE DESCENT

LOS ANGELES, CALIF  
LOS ANGELES INTL

CIVET PROFILE DESCENT (CIVET, CIVET1)

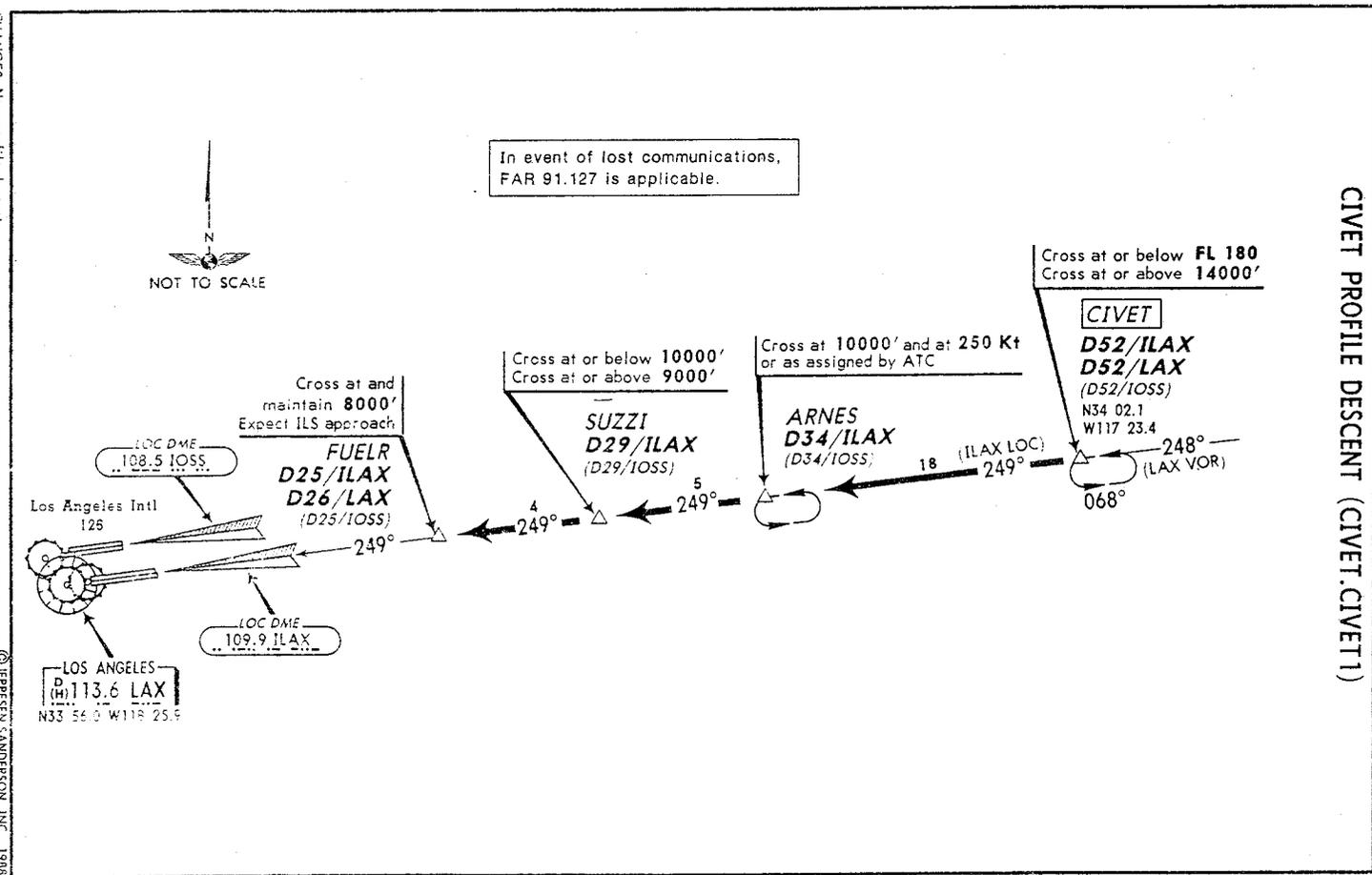


Figure IV-1. The CIVET profile descent to KLAX.

under such conditions, the FMC induces an excessive workload, for little actual advantage in completing the approach. They believe that safety considerations dictate that they "click it off" and proceed in autopilot or flight director mode resetting the ILS head as required by runway changes. Those who hold this view also feel that their training over-emphasized the use of automation in such circumstances. Curry (1985) recommended that this problem be confronted by giving the crews "turn it off training."

There is not likely to be an early or uncritically accepted resolution of this question. It is interesting to note that as crews become more experienced in the 757, they tend to move toward more extreme positions on this question. The first side develops perceptions of high crew proficiency and machine efficiency, and makes full use of the automation; the other gains experience which convinces them more and more that good piloting judgment calls for less CDU programming and more "basic airmanship."

Interviews gave the impression that this is one area that seems to separate the captains from the first officers, though the data presented below do not support this. In interviews it is quite apparent that many captains express the latter viewpoint, and specifically mention their concern that the first officers are "computer happy," and sometimes try to "program their way out of trouble" to the detriment of situational awareness. It is seldom that the author hears first officers complain of too much programming going on, or recommend that one "click it off" when workload accelerates. First officers often speak of the captains' conservatism toward accepting new technology, as illustrated by their reluctance to program solutions to problems.

This may in part be an age and educational difference: the younger pilots grew up and received their education in the computer age, and many flew military aircraft with high degrees of automation. The older captains are less comfortable with, and less enamored with, computer solutions to anything, and tend to put their trust in superior airmanship, training, judgment, discipline, and experience. Observing from the jumpseat, one quickly gains the impression that the first officers are more attracted to, and more proficient in the use of the FMC. Often the captains feel that they need to restrain the first officers' zeal for programming.

The table and comments which follow are in response to the following question:

2-6. What changes in the method of programming of the CDU or additional features, pages, prompts, etc. would you like to see? Do you feel that the programming tasks could or should be simplified? In what way?

Some of the more frequently mentioned comments are listed in Table IV-2.

Table IV-2

<u>Response</u>	<u>Times Mentioned</u>
It's OK as is; simple enough; no changes needed	29
Too much time programming below 10,000 feet	9
More information needed for approaches (MDA/DH etc.)	6
Computer should update faster	13
FMC computer should display approach speeds	3
FMC should be more helpful for diverting	3
Latitude and longitude should be displayed on map display	2
Visual approaches should be in database	3
"Abeam" waypoints should remain in memory in case of change in direct routing	3
ILS should be auto-tuned with runway selected in FMC	4
Should be a way to program intersection of two airways	4
FMC should calculate and display V-speeds	3
Maintenance information should be available to crew	3
Latitude and longitude should be displayed on FIX page	3
All waypoints (fixes) on a route should be in FMC	3

## Crew Comments

It would be helpful to have the ability to program a +/- distance/altitude from any fix on the LEGS page in same way it can be done for active W/P. 4001

Get rid of excessive intersections and data that clutter the HSI. 4002

Fix the descent/speed problem. The aircraft will not slow up as the pilot expects. Put state boundaries on the map (switch selectable) 4004

Immediately after training emphasis should be placed on flying the airplane, not on programming the FMC, especially for inexperienced first officers. Because of heavy emphasis on FMC work in training, some pilots think the plane won't fly without considerable programming. 4007

Some changes require multiple page entries; these could be simplified. 4010

We need to be able to select two ILS frequencies and just throw a switch like the 727. New, younger people get wrapped up in not having a route discontinuity at the end of the segment. Just leave the boxes blank and put in the proper runway later. 4013

When you select VNAV from T/O power, it should go automatically to climb EPR. Also need a prompt "unable to comply" with subsequent altitude restraints after the first one, e.g. descending from cruise altitude to 10,000 at 40 miles out and then 8000 at 38 miles out. There's no indication that the plane won't be able to make both restrictions. We need this information early so we can advise ATC. 4014

I would like an emergency mode. When selected, the A/C symbol (triangle) would be positioned in the middle of the map display, and any airport long enough to accommodate the 757 would be displayed. I would also like to be able to select a fix on the RTE page, then select an airway into or out of that fix and have the FMC fill in the previous/next waypoint. 4016

Only problem is inability to interact with ATC. 4018

Pilots should be given current runway and arrival procedures as early as possible, before descent to lower altitudes (10,000). This would allow programming in airspace where conflicts and traffic are less of a problem, and allow pilots' full attention on weather and aircraft avoidance. Local approach information should be accessible through ACARS, rather than only through ATIS. Little or no programming should take place below 10,000. Training continues to emphasize programming the FMC on approach or within the TCA. This is an unfortunate emphasis which causes poor habit pattern formation. 4019

I can always spot a new pilot on the plane because he is spending far too much time on the CDU with his head down. 4020

Our system of stored company routes <Airline-2> is a big time saver. 4021

1) Often we are given vectors to intercept an airway. It would be nice if there were some way to show an airway in our area, much like calling up a fix. 2) When diverting, it would be nice if the FMC could be easier to program to accommodate a diversion, i.e. by resetting new field elevation in the pressurization panel, sending an ACARS message to the company. 3) When a particular approach is selected, why not have the FMC tune the approach facilities, ILS and ADF frequencies, and inbound heading. 4) The FMC knows how much the A/C weighs. Why not have the airspeed bugs (especially on electronic airspeed indicator) set automatically for the configuration? 5) The FMC knows the temperature, altimeter setting, and with pilot-inserted wind could calculate max runway weights for T/O and landing. 6) In each case there must be provisions for the pilot to quickly and easily override the automatic features of the FMC; i.e. changing ILS frequencies etc. 4022

No change. I feel our 757 training department has done an excellent job. Emphasis should be on all pilots, especially pilots with limited experience, to stay out of the CDU when near an airport. 4024

Need ability to draw lat or lon on the map. ATC sometimes asks us to call when we cross a certain lat or lon. (This happens when we are not under radar control). No way to find it out from map. 4026

The biggest complaint is difficulty in changing runways after runway has been programmed. A pilot is programmed to put data in the FMC every time there is a clearance issued. The head goes in the cockpit and nobody may be looking outside. If the runway could be changed with just one button push it would help. 4029

Too many steps to program "abeam" positions. Also the VNAV program gets behind on descent unless you "lie" and give it greater tailwinds or lighter headwinds on DES page. 4030

Data base could be expanded to include more information on instrument approach procedures, e.g. DH/MDA. We need a smaller scale on the map for landing to depict taxiways, e.g. ORD. This would simplify taxiing and maybe prevent runway incursions. 4031

Need some indication on LEGS or PROG page that you have actually exited holding (other than simply EXEC light extinguishes. 4033

When a different altitude is selected in the MCP when you're on CRZ page, it should automatically go to altitude slot in the CDU, not to the scratch pad. Also LEGS page should advance by itself

when inserting "abeam" positions and one gets to the bottom of the page. 4035

Would like vertical deviation written next to arrow on the HSI; airspeed indicator in ADI; and direction and velocity of wind on HSI. 4036

The NAV DATA page could also provide spelled out names of navaids, for example, if you enter IRW instead of seeing lats and lons for the two points, it should say: 1) Will Rogers Oklahoma City VOR; 2) Some localizer in Canada. Also, once a direct route has been selected and abeam fixes entered, the fix W/Ps should be held in memory, so if another direct route is selected, the abeam can be displaced over the new course, and not have to be reentered. 4040

HSI map should display the airway you are on, i.e. J-79 should be displayed next to the magenta line. I would like to see wind speed display next to arrow on the HSI. 4041

Put in visual approaches (e.g. DCA 18 and the 13/31 at LGA). 4042

Paper flight plan and the FMC often don't agree (e.g. DTW-SFO). If dispatch sends us a route, we shouldn't have to build it. 4043

Should be programmed to prevent aircraft from descending through 10,000 feet regardless of mode. 4045

CDU is straight-forward and user-friendly. 4046

Should be able to view maintenance pages in flight. 4047

ACARS and CDU should be better integrated; e.g. load should go directly into CDU. ILS should be tuned by CDU when you select an approach. 4050

First give me a QUERTY board <standard typewriter keyboard>, then put it on an extension cord so I don't have to type one-handed. How about menu-driven software? Organization of prompts should be more intuitive. Our company's procedures are cumbersome and needlessly complex. The company doesn't get full benefit of automation. This results in a loss of operational flexibility and safety. 4061

Standard arrivals (STARS) should be totally correct or should be eliminated. We have a frequent problem with incomplete stored arrivals. 4063

Change the wording on the HOLD page to read "Exiting Hold"; it now reads "Exit Armed." 4064

CDU information should be in different colors, to make critical numbers stand out. 4066

Need ability to go directly to any page, rather than through other pages. 4069

On PROG page 1 I would like to see the wind readout and SAT temp in place of Econ Spd and To Step Clmb on that page. We often need to look at gross weight to determine how high we can climb. That would be nice on the PROG page. Our procedures call for the PF to be on the PROG page, and the PNF on the ACT RTE LEGs page. I would like to see Offset on the latter. 4070

EXEC light should be brighter. Relocate CDU to center pedestal. 4073

I'd like to be able to intercept a leg from... 3001

Eliminate VNAV and go to MCP for altitude control. Use VNAV to attain econ speeds only. 3002

TAKEOFF page is unnecessary and seldom used. 3004

Would like to see included in FMC: MOCAS <minimum obstruction clearance altitudes>, approach plates. 3006

Would like to see: gate at destination; station ATIS; clearance, ground control, and company radio frequencies at station. 3008

Would like the screen to give: V-speeds, buffet speeds and margins. 3009

Need to be able to put lat and lon on FIX page. 3014

VNAV profiles should limit climb/descent rate to 500 fpm in the last 1000 feet. Easier on passengers, less rapid power changes, and not cause pilots to "wonder" if it's going to level off in time. Would also help to flash mode change on ADI as well as color change. 3015

Should be able to program intercept leg to a fix as part of flight plans. 3017

Would be nice to have area chart for major airports available on map display. 3018

All waypoints <fixes> on all our routes should be in database. 3020

Need capability to program intersecting airways where no named point at intersection exists. Also confusion in co-located facilities, e.g. ZBV and ZBBNB are both on our charts. <CDU contains only ZBBNB> 3026 <See Chapter X, section on workload.>

It would help to have a list of the names of intersections of two airways (e.g. J42 and J48 is CSN40). We have to get out the charts and define the intersection. 3032

Need a better and quicker way to fly a given radial. Present method takes too long to set up and you usually end up flying it the old way. 3034

After EXIT HOLD has been executed, the holding pattern oval should disappear to eliminate concern about whether the airplane is going to depart holding, and if so, how. 3035

Too much use of VNAV, given ATC changes. FLCH works better. 3039

All aircraft in our fleet are not all the same. Some will not allow the cost index (CI) to be inserted first (only after CRZ ALT). Can't override mandatory altitude on LEGS page. Would be nice to be able to do that. Some aircraft will not take a + or - new waypoint unless it is from the active waypoint. 3042

Someone should invent a real-time turbulence meter. 3043

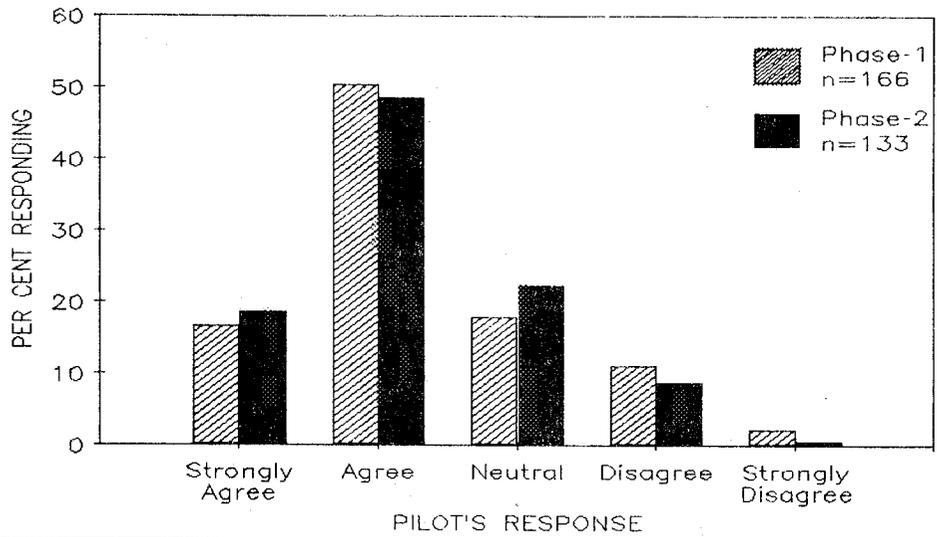
On reaching intermediate altitude (descending) the CRZ page goes blank. You have to reenter new altitude to regain FMC cruise speed control. If the clearance contains two altitudes, the problem is compounded because as the intermediate altitude is captured, VNAV is lost and the TOD point is passed over without a second descent. More "catch up ball." VNAV is almost useless between RIC and BOS; westbound is a different story. Three changes I would like to see: 1) A discrete light on any time the speed brake handle is deployed. It's easy to miss it on a level off. I see this happen at least once a month. 2) Allow flight crew access to maintenance information on the EICAS. 3) A discrete light on any time the fuel cross-feed valve is open. Every 757 pilot has been caught on this one. 3049

Building of approaches should be eliminated. 3051

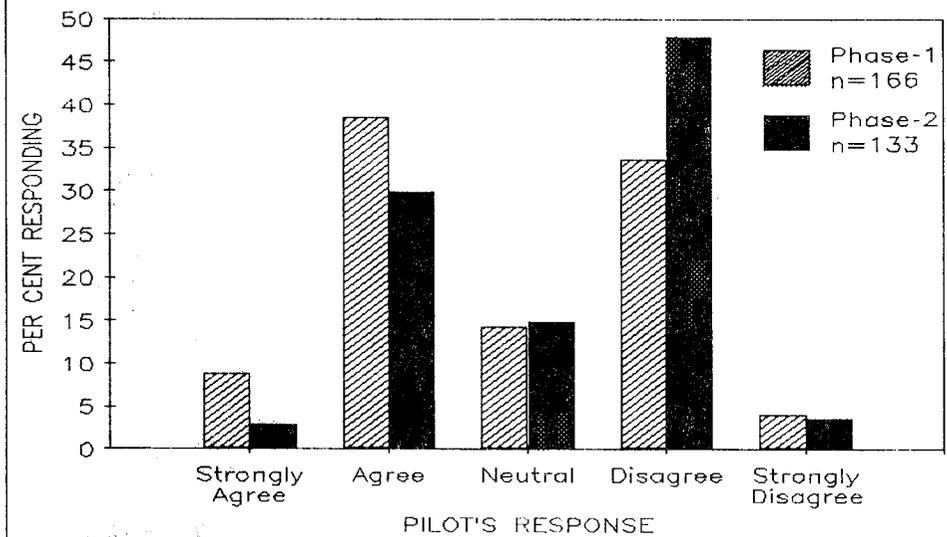
Should have a warning bell and light for inadvertent turning off of the autothrottle. More extensive data on non-precision approaches would also help. 3053

Documentation for holding patterns needs improvement. 3057

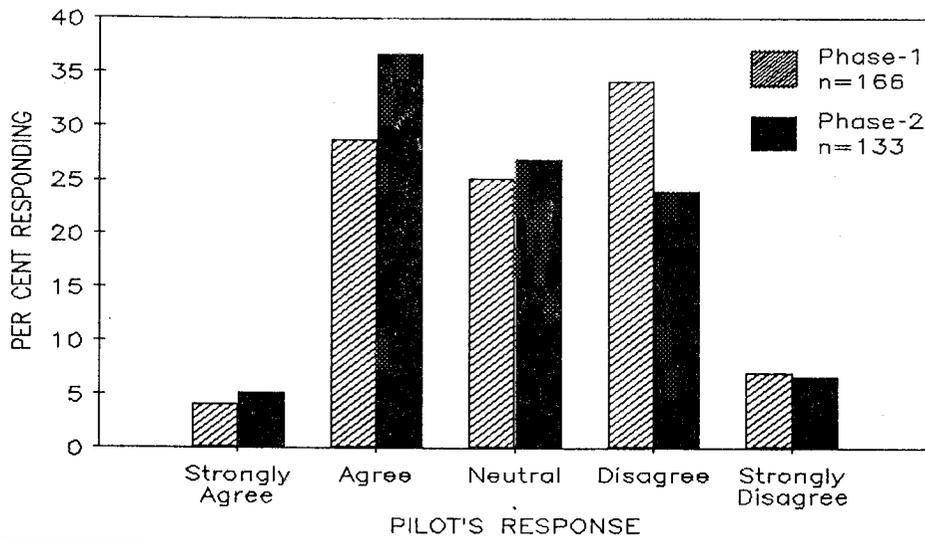
10. Automation frees me of much of the routine, mechanical parts of flying, so I can concentrate on "managing" the flight.



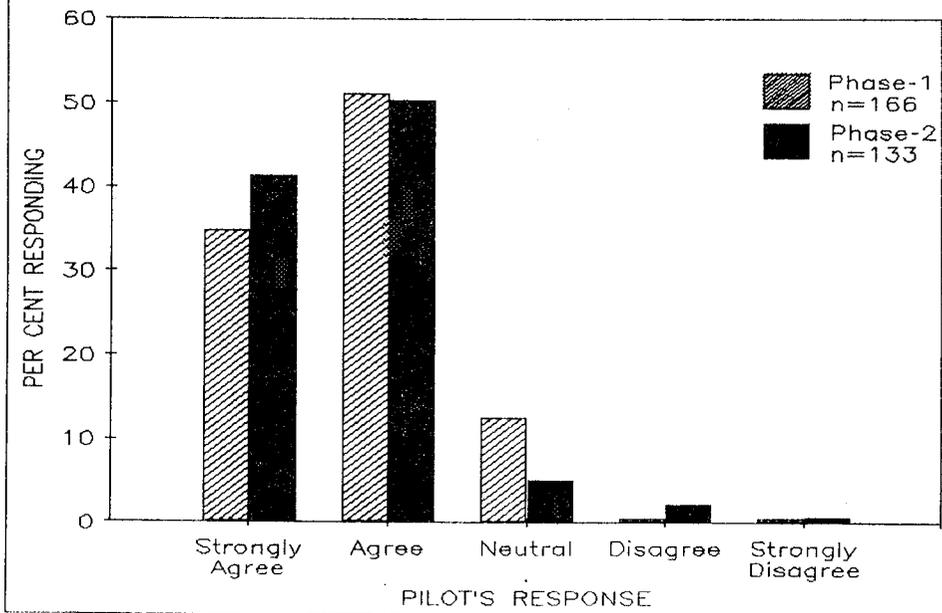
16. I spend more time setting up and managing the automation (CDU, FMS) than I would hand-flying or using a plain autopilot.



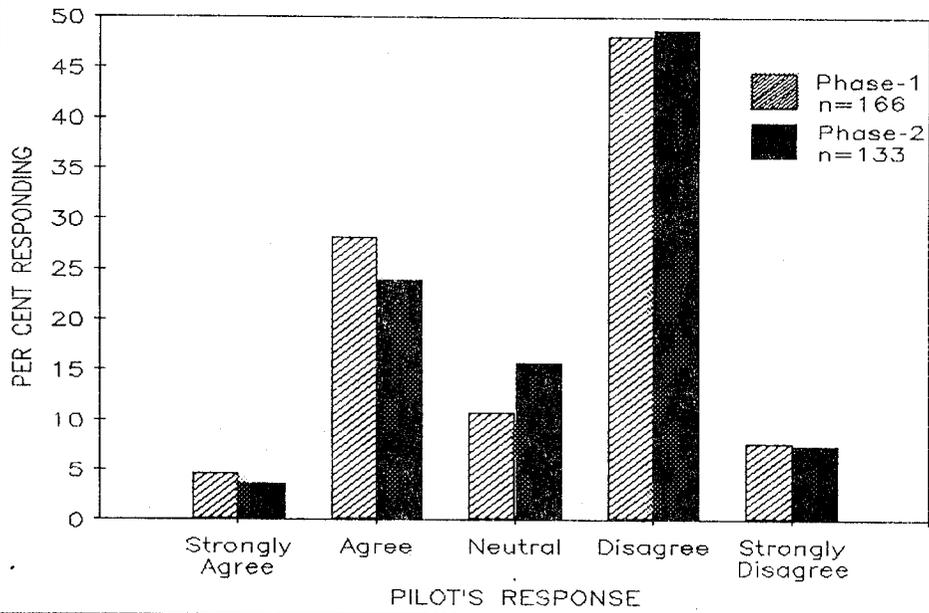
21. Flying the B-757 in terminal areas such as Washington and New York is easier than it was with the older planes.



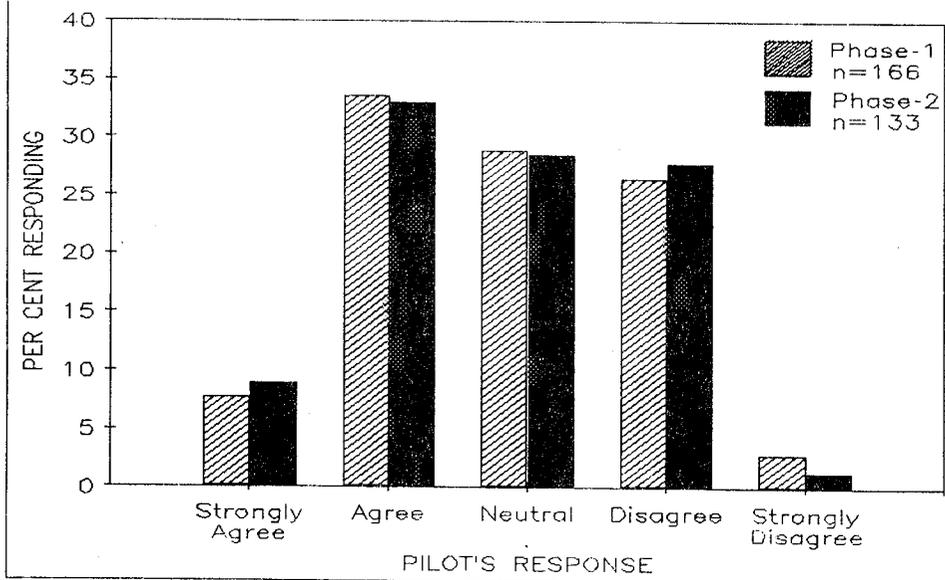
23. The "glass cockpit" instruments and displays are a big step forward.



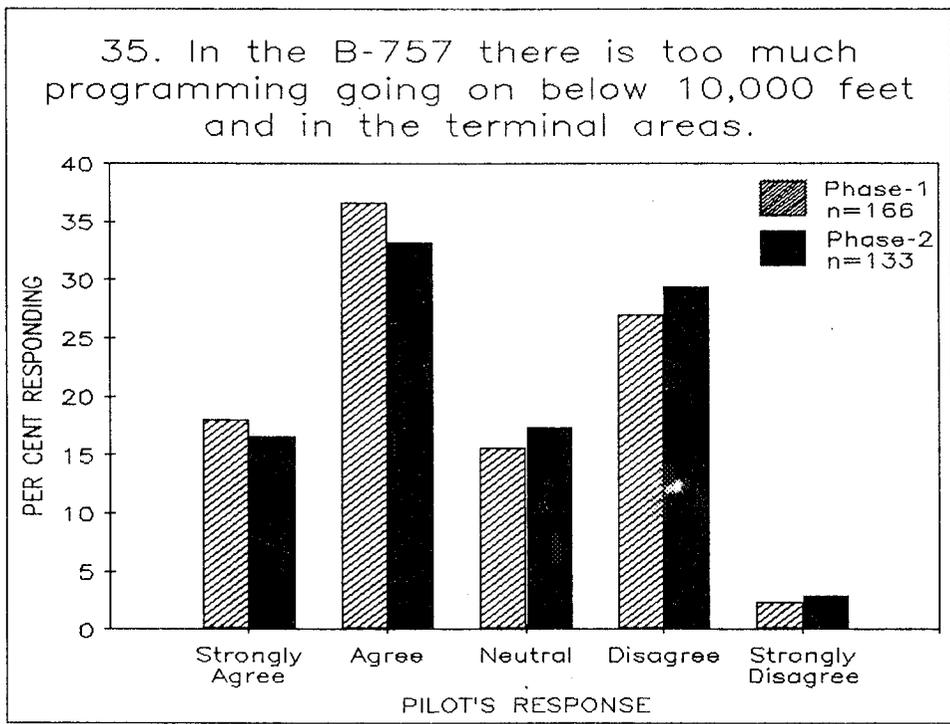
25. I am concerned about the reliability of some of the modern equipment.



32. Planning and selecting alternatives are more important in the B-757 than they were in other aircraft.



35. In the B-757 there is too much programming going on below 10,000 feet and in the terminal areas.



D. FEATURES THAT WOULD BE MISSED OR NOT MISSED  
IF ONE WERE TO LEAVE THE 757

As mentioned previously, the 757 tends to be a short-term assignment for flight crews. In the following question we asked the volunteers to imagine that they were leaving the 757 for a less automated aircraft in their company's fleet.

The results to the question below are given in Table IV-3, and the specific comment which follow. This question provides an insight into what the crews saw favorably and unfavorably about flying an advanced aircraft.

2-2. If you were to leave the 757 for an older model aircraft, what features would you miss the most? What would you be happy to leave behind?

TABLE IV-3  
FEATURES THAT WOULD BE MISSED

	<u>Times Mentioned</u>
DISPLAY SYSTEMS	
HSI map mode	43
HSI (in general)	7
HSI map - nearby airports	5
HSI map - wind vector	3
HSI map - green arc (altitude projection)	5
HSI map plus radar overlay	4
HSI map - track line	1
HSI map - runway center line	1
ADI (in general)	4
ADI - ground speed readout	1
EFIS ("glass cockpit") [1]	11
ETA at destination	2
EICAS [1]	10
Flight director	3
Situational awareness (from EFIS instruments)	3
Large instruments	2
AUTO-FLIGHT	
Automation (in general)	21
FMC (in general)	33
FMC direct intercept capability	7
FMC HOLD page	3
FMC - ability to plan and visualize flight	7

-----  
[1] See notes at end of tables.

FMC - crossing restrictions	1
FMC - entering waypoints by letter (not coordinates)	1
Cockpit in general - "the whole package"	4
Altitude capture capability	2
VNAV	7
LNAV	9
Autothrottle (and EEC)	11
Autopilots	7
IRS; navigation systems in general	19
Fuel management systems	3
Autoland; Cat II and Cat III capability [5]	3
Automation allows time for extra-cockpit scan	1
FLCH mode	1
TOD planning	1
MCP	1
ACARS [2]	5
Stored routes [2]	1

#### HANDLING AND PERFORMANCE

Handling, performance, and engine power	21
High altitude capability	6
Fuel capacity	1
Flex takeoff capability and reserve power	1
Short runway stopping capability	2
Reliability of Rolls Royce engines	1

#### BASIC SYSTEMS

Air conditioning systems	2
Auto pressurization and heating/cooling	2
Reliability of systems in general	1

#### COCKPIT LAYOUT AND ENVIRONMENT

Quiet cockpit	3
Roomy cockpit; comfort; color scheme	4
Good outside visibility	2
Simplified checklists	1
Simplified manuals	1
Simplified weight and performance charts	1
Simplicity of cockpit layout	2
Newness and cleanliness of cockpit	1

#### MISCELLANEOUS

Better trips	1
Pride of flying "state-of-the-art" aircraft	2
Passenger comfort	1
Two-man crew	2

FEATURES THAT WOULD NOT BE MISSED

	<u>Times Mentioned</u>
None (so stated)	25
<u>Avionics/automation</u>	
Computer "glitches" [3]	3
Programming demand at low altitude	2
Way the compass heading is displayed	1
Autopilot/Flight Director	1
Autothrottle system	2
Possibility of programming errors	1
Two-man crew	20
Excessive workload in terminal areas [4]	7
Tendency of both pilots to be programming at once	2
Auto squelch on radios	2
Weather radar (esp. in light rain; esp. on higher scale)	3
"Surrendering my experience and judgment to a computer"	1
Ability to lose all instruments including standby	1
No manual backup on autothrottle	1
Need to analyze what the plane is doing	1
ACARS	1
Single ILS head	1
Speed brake used excessively due to ATC, often forgotten	2
FMS not good in today's ATC environment	1
High workload during malfunctions, short legs, or entry into complex TCAs	1
Lack of aural altitude warning	2
EFIS	1
Slow response of FMC	1
<u>Performance</u>	
Landing - too easy for tail to strike; no tailskid	2
Landing - nose wheel characteristics	1
Loss of aileron effect at low speed	1
"Springy" ride in choppy air	1
Need for rudder trim in descent	3
Dutch roll during turbulence	1
Two engines only	1
<u>Basic systems</u>	
Lack of information on systems in flight	5
Malfunctions of systems	1
Over-sensitive brakes	1
Erroneous status messages	1

Cockpit layout and comfort

Effect of low humidity at high altitude	2
Seat (too short; not enough room for crew meal tray to avoid yoke; too little movement; yoke blocks view of HSI)	8
Sunscreens	1
Cockpit noise	6
Needs mike button on side panel	2

- 
- [1] Some responses of simply "glass cockpit" may apply to EICAS as well as EFIS
  - [2] This capability in Airline-2 aircraft only
  - [3] "Glitches" actual word used
  - [4] "Below 10,000 feet" specifically mentioned in most responses
  - [5] Cat II and III approaches not flown by Airline-2 at time of this study.

## Crew Comments

(Note: where respondent indicated he was no longer flying the 757, the new seat is listed in parentheses at the beginning of the comment.)

I would miss the FMC and the HSI presentation most, and the flexibility it provides with mundane navigational duties. I would miss the performance margins the aircraft offers (i.e. takeoffs are usually done with reduced power, but more is available if needed). I have never been concerned about the necessity of an abort in this aircraft, while in other transport aircraft I've flown an abort at V-1 may not have been successful due to runway remaining. 3004

I would definitely miss the IRS and the map functions. Navigation would require much more attention, so I would miss LNAV. Crossing restrictions and TOD would require more planning, so I would also miss VNAV. Loss of wind velocity vector would make wind shear detection more difficult. Fuel use and ETA at destination would require much greater effort. I would miss the pride of flying "state-of-the-art" equipment. 3008

(Capt., A-300 and B-727) I am happy to leave the two-man crew behind. Experience will soon prove that too much safety is compromised going to the two-man crews exclusively. The system is too complex, the traffic too heavy, and the pressure on crews to fly 12, 13 or 14 hours too fatiguing. Would a third man have prevented the near disaster to Delta's 757 at LAX <two engine shutdown at low altitude>? 3013

(Capt., A-300). I miss the simple layout of all systems. Whatever drawbacks the 757 may have, in no way is it as distracting as the S/O reading checklists, fighting flight attendants over temperature control on the 727 or A-300. 3018

I will not miss the landing of a 757. It is entirely too easy to have a tail strike in this aircraft. It is ridiculous for an aircraft designed today to be this critical on landing. For many pilots, this is more important than automation. 3021

Would be happy to leave behind the possibility of misprogramming or having the other pilot programming without informing me of what he is doing. Especially serious when he is flying the aircraft at the same time. 3026

The automation leaves us free to scan for other aircraft more than most aircraft. Flying the 757 requires more crew coordination than most aircraft. The tendency of the PF to come back into the cockpit to program is very strong; training to avoid is not nearly emphasized enough. 3027

I would miss VNAV and LNAV most. Tracking a VOR leg and figuring time to climb to any altitude and start descent are things I

gladly let the computer do. They usually are more accurate than I ever was, but interestingly, not always! When it's needed, there is no substitute for autoland: I need visual cues, it doesn't. But I dislike surrendering most of my experience and judgment to a computer, especially when it's judge, jury, and executioner. 3033

I cannot think of any features of the 757 that I would want to leave behind. The aircraft was well designed as any first generation aircraft, and has few if any faults. Exception: having to put in rudder trim on climbs and descents. 3034

(Capt., retired from 757) My other main airplane for 15 years was the DC-9. I liked it fine, but I can't think of anything on it that isn't better on the 757. 3038

The airplane has the best of all worlds: automation, semi-automation, and hand flying. 3039

(Capt., DC-10) I missed the map feature of the HSI, esp. the runway center line profile, and the green arc <altitude predictor> for descent planning. Also miss the holding pattern aids, alternate airport information. I don't miss the single ILS head and the two-man cockpit. Low altitude FMC work should be prohibited! 4007

(F/O DC-10 and Capt., 727) I enjoyed the automation. I made it work for me, however I never lost sight of basic airmanship and always monitored raw data. I found no aspect of the airplane that I would be "happy to leave behind." 4009

(Capt., DC-10) I left the B-757 and I was happy to get the third pilot back. I really notice how helpful the extra set of eyes and hands are during higher workload times. I do miss the glass cockpit, especially the map display and descent arc, and the quick availability of VORs without fumbling with a map. I do not miss the company busy work and checklist fumbling on the 757. I notice that I have more time to monitor the F/O when he is PF on the DC-10. 4011

It is the most fun fixed winged A/C I have flown (old helicopter pilot). I put in a DC-10 captain bid because of the money and chance to fly to Europe. It will be hard to go back to needle, ball and airspeed. From the cockpit door forward there will be nothing I will be happy to leave behind. I love the whole aircraft. 4015

(F/O, DC-10) I have just checked out in the DC-10 (F/O). I definitely miss the FMC. I found the DC-10 autopilot and flight director system cumbersome and antiquated when compared to the 757. Navigation <DC-10> is less accurate, more cumbersome, and there is more room for error using the INS system on the DC-10. I also miss the EICAS for systems monitoring and trouble shooting. 4021

(Capt., 747) I miss the ADI, HSI and the FMC. These are tremendous tools for the pilot. I did not like the "limit EPR" function of the EEC. Out of SEA one day I lost the right engine at 140 feet above the field at near max gross weight. I wished I had had the capability of overriding the EEC in order to obtain more than "limit EPR" power. 2024

(F/O, 747) I enjoy flying the 757. I also fly the 747. I miss the MCP, FMC, simple autopilot functions, and the map. There are no features I am happy to leave behind except the two-man crew. The three-man crew enhances safety, especially regarding ATC transmissions, altitude busts, and handling emergencies. The design flaw that really sticks out is the lack of a mike button in the corner of the glare shields. 4026

(Was bumped off 757 for one month and took 727 F/O training, then returned to 757) I did not leave it by choice. I missed the map display most, next the precision of the ADI. The ease of navigating with the FMC vs. and INS is a tremendous boost, e.g. going direct some place the 757 uses 3-letter identifiers instead of ground coordinates...less chance of error. 4030

(F/O, 747) I miss everything. Of course the 747 is a piece of ancient junk, so it's not a fair comparison. If I had gone to the DC-10, which I have flown, I would probably have to say that I would have missed the EICAS and the EFIS and the amount of information available on the CRTs. Also the autothrottle on the 757 is very nice. 4041

(F/O, 747) One of the neatest features of the 757 is the FMC's ability to meet crossing restrictions. If you program everything correctly, it really saves you a lot of mental gymnastics, and you can concentrate on other things. I would be happy to leave behind the two-man crew, automatic or not. It just gets too busy at times. 4045

Systems that relieve workload in one area tend to increase the workload in new areas. 4049

I would be happy to leave the two-man crew behind. My experience as a instructor and a line pilot on the 757 indicates that during an emergency there is less attention to looking outside and also to careful perusal of checklists than with three crew members. In addition, I have seen more personality conflicts in two-man than in three-man crews, which led to problems during emergencies. 4057

I would be happy to leave behind some of the people in the left seat. In other aircraft you have another person to combat the left-seater if he is a "five striper." 4064

## E. EQUIPMENT USAGE

On the Phase-2 questionnaire, crews were asked to enter into a blank the number of times they had made various types of approaches or used various capabilities of the aircraft. These are shown in graphic form in the next two pages. At the time of this study Airline-2's 757s were not authorized to descend to Category II and III minimums, so some of these graphs reflect only Airline-1 data.

The term "man-made" refers to waypoints that are not stored in the FMC database, but are "built" from stored navigation points by the crew, usually employing the place-bearing-distance capability.

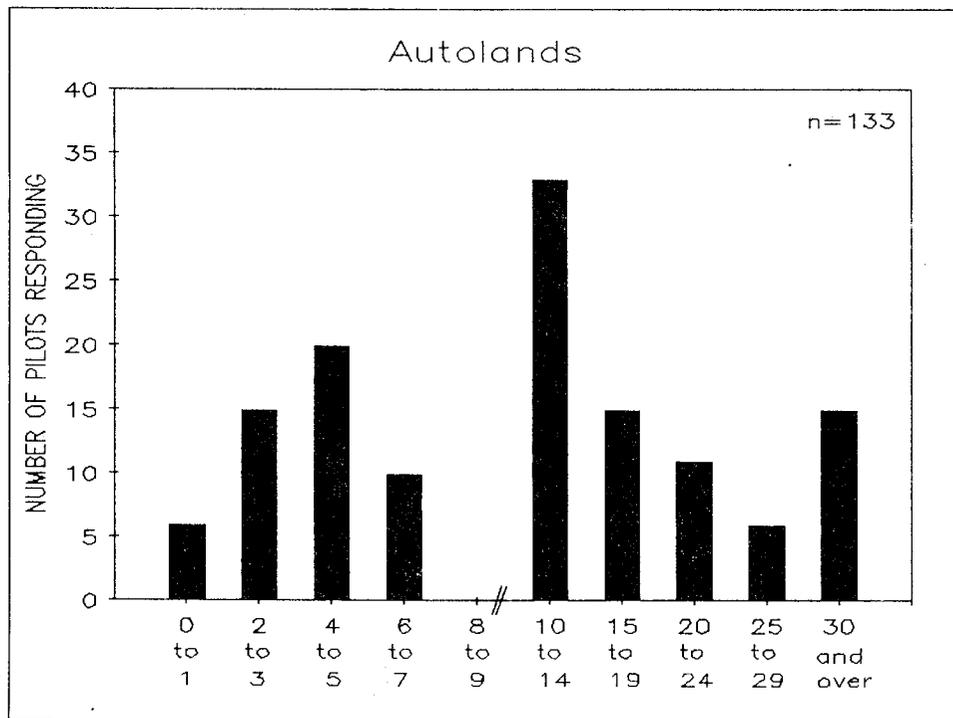


Figure IV-2. Number of autolands.

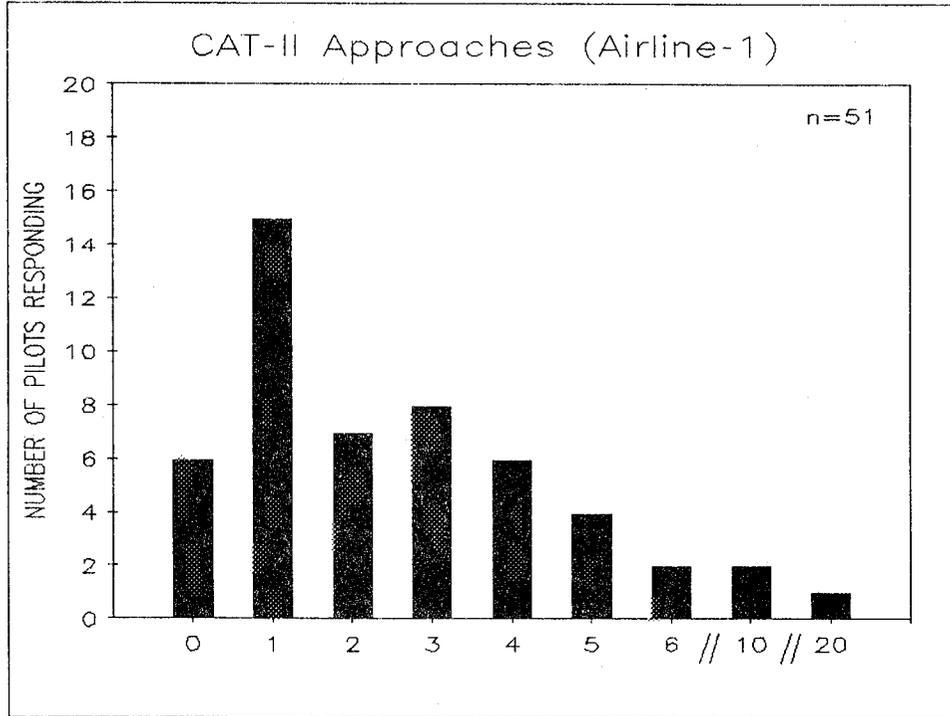


Figure IV-3. Number of Category II approaches (Airline-1 only)

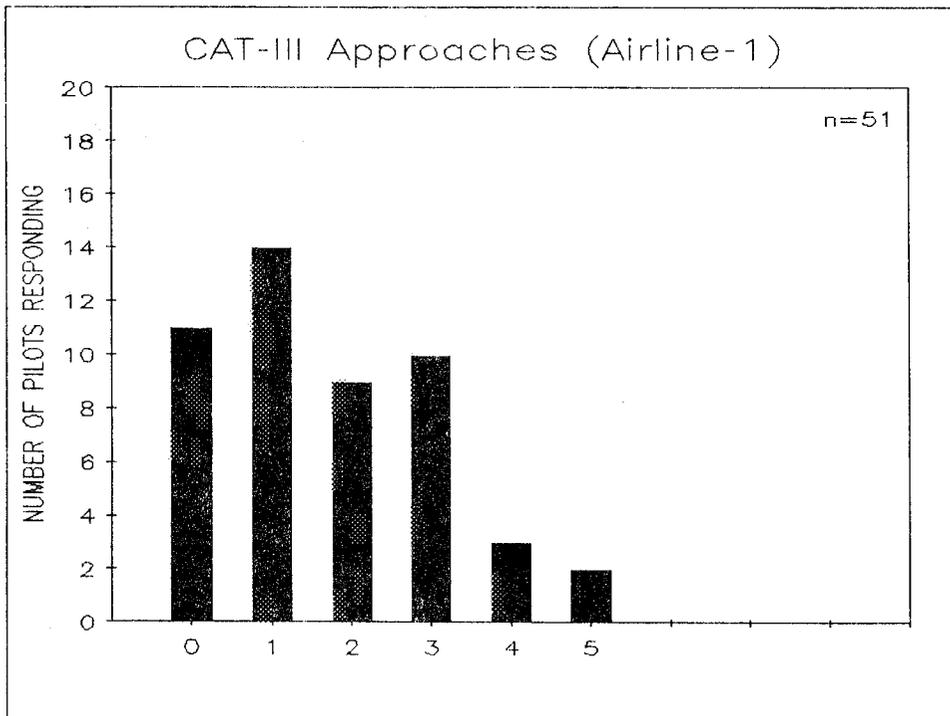


Figure IV-4. Number of Category III approaches (Airline-1 only).

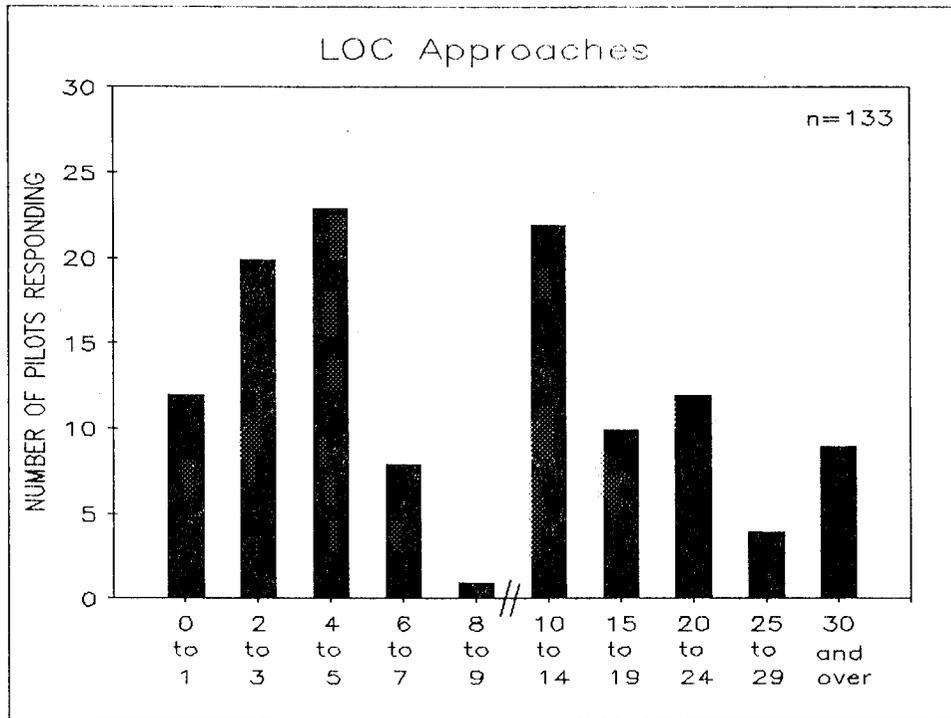


Figure IV-5. Number of localizer-only approaches

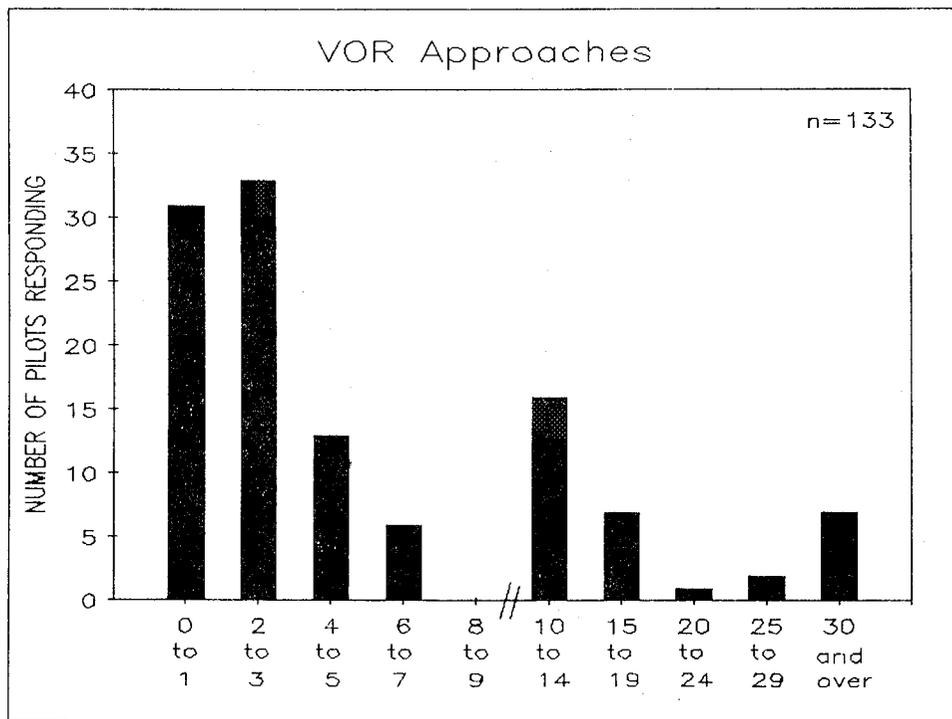


Figure IV-6. Number of VOR approaches.

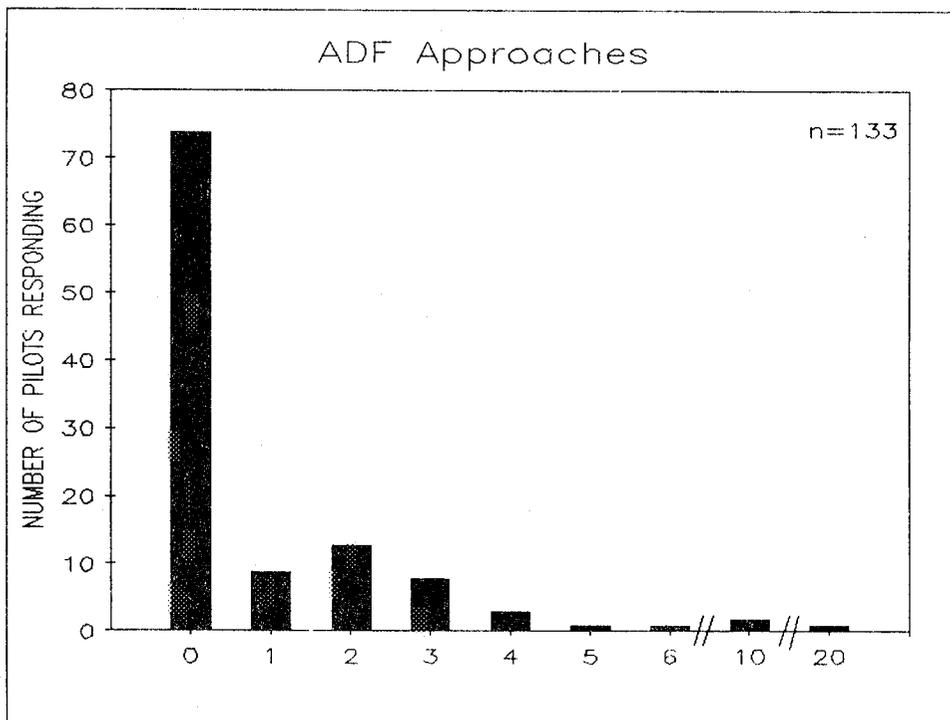


Figure IV-7. Number of ADF approaches

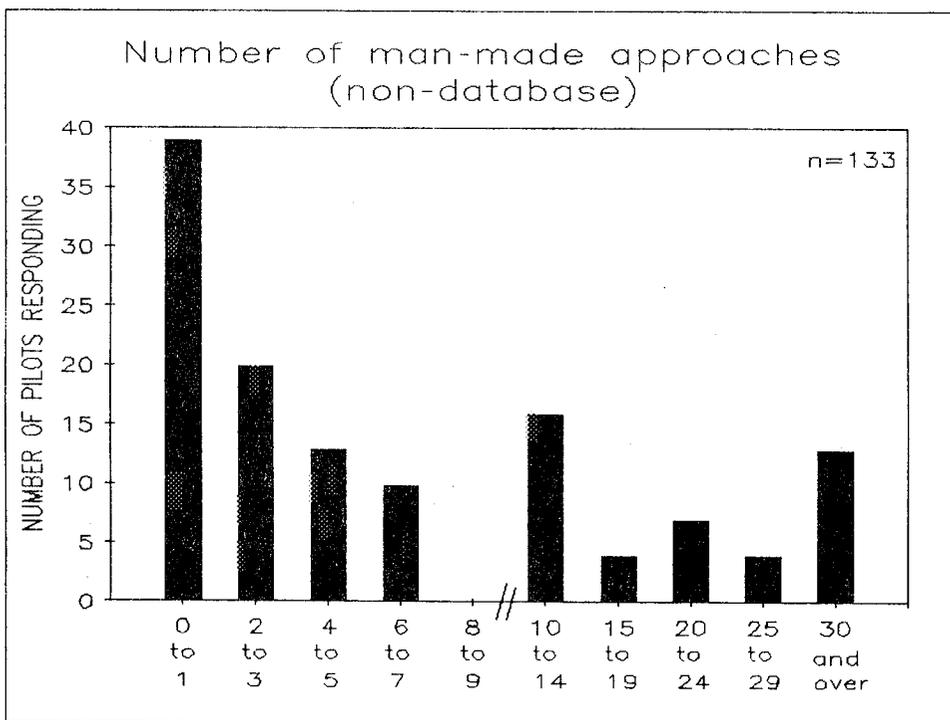


Figure IV-8. Number of "man-made" approaches.

TABLE IV-4

Intercorrelation matrix for attitude probes in this chapter.  
 HIT refers to hours-in-type (B-757).

PHASE 1

	HIT	p7	p10	p11	p12	p15	p16	p21	p23	p25	p32	p35
HIT	1.00	-.17	-.14	.08	.07	-.13	.26	-.29	-.08	.25	.18	.12
p7		1.00	-.01	-.32	-.02	.22	-.13	.12	-.01	-.08	-.09	-.11
p10			1.00	.01	-.19	.41	-.21	.28	.24	-.14	-.07	-.21
p11				1.00	-.03	-.22	.13	-.12	-.02	.06	-.08	.17
p12					1.00	-.23	.14	-.16	-.16	.03	-.06	.19
p15						1.00	-.23	.37	.24	-.19	-.12	-.29
p16							1.00	-.42	-.39	.28	.16	.35
p21								1.00	.26	-.25	-.15	-.38
p23									1.00	-.32	-.11	-.25
p25										1.00	.13	.27
p32											1.00	.18
p35												1.00

For n=166,  $|r| > .15$  necessary for significance  
 at the 0.05 level

PHASE 2

	HIT	p7	p10	p11	p12	p15	p16	p21	p23	p25	p32	p35
HIT	1.00	.01	-.05	-.01	-.01	-.06	.06	-.27	-.11	.06	.08	-.04
p7		1.00	.15	-.35	-.02	.18	-.05	.04	.13	-.03	.01	-.18
p10			1.00	-.08	-.04	.47	-.22	.34	.37	-.19	.12	-.34
p11				1.00	-.08	-.08	.02	.01	-.15	.13	-.03	.19
p12					1.00	-.10	.06	-.09	-.02	.01	-.05	.14
p15						1.00	-.26	.31	.24	-.18	.16	-.23
p16							1.00	-.34	-.24	.27	.11	.35
p21								1.00	.28	-.19	-.06	-.38
p23									1.00	-.47	.01	-.20
p25										1.00	.27	.38
p32											1.00	.22
p35												1.00

For n=133,  $|r| > .17$  necessary for significance  
 at the 0.05 level

## V. TRAINING

### A. INTRODUCTION

In this chapter we shall examine a wide range of issues dealing with training of flight crews for high technology cockpits. These topics will include transition training, initial operating experience (IOE) on the line, retention and loss of skills ("loss of scan"), and finally "reverse transition" for those crew members who left the 757 for other cockpits. Since at both airlines which participated in this study the 757 was the only "advanced technology" cockpit, those who left would be transitioning back to less automatic aircraft. In some cases they would be returning to aircraft that they had previously flown, in some cases not.

The subject of air crew training is considered critical in the airline industry, both for its importance for safety of flight and for its economic implications. Airline flight training is sometimes considered synonymous with simulation. This is a unwise, since the simulator is only a technological tool for achieving a desired result at maximum safety, reasonable cost, and regulatory conformity. Training must include a consideration of curriculum, educational psychology, instructors, training techniques, materials, equipment, philosophy, and policy. For an overview of pilot training, see Caro (1988).

It is in the training departments that not only are crews prepared to fly the aircraft, but standardization and company operating procedures are introduced as well. Standardization is the foundation of cockpit safety.

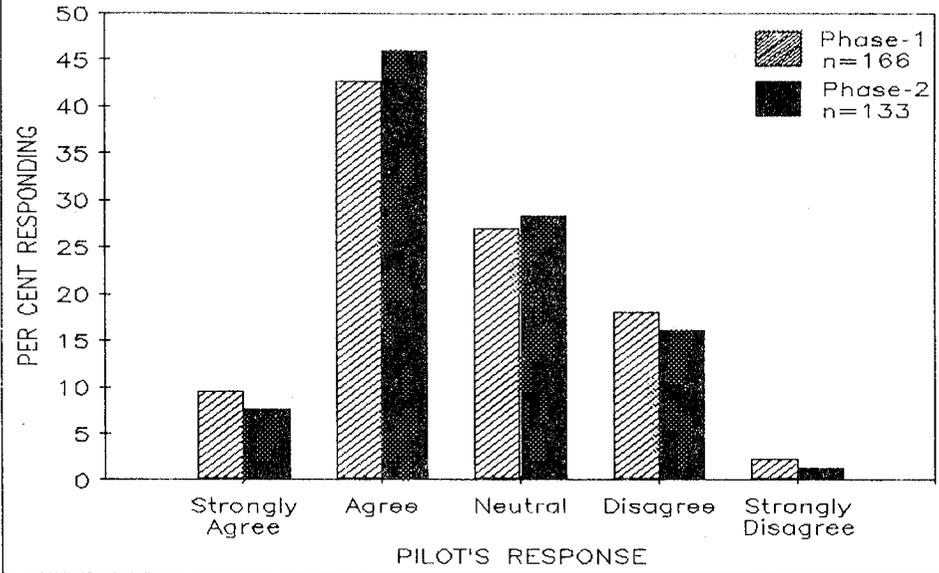
In recent years new topics and techniques have been introduced as part of the training packages. Most carriers have introduced Line Oriented Flight Training (LOFT), developed by airlines in collaboration with NASA, as a means of adding realism of operations to simulator training. Prior to the LOFT movement, realism was considered largely in hardware terms, as "fidelity of simulation" became the goal of simulator developers. "Fidelity" referred to the degree to which simulators looked like and flew like the aircraft. The concept did not extend to fidelity of operations. LOFT has enabled instructors to provide training under highly realistic conditions encountered on line flights, rather than a cascading of abnormal conditions that has characterized simulator training in the past.

A companion movement has been the introduction of cockpit resource management (CRM) into flight training. LOFT has been an enabling mechanism to provide realistic training in CRM. More will be said about CRM in Chapter VII, Crew Coordination. For an up-to-date discussion of LOFT and CRM, see Foushee and Helmreich, 1988.

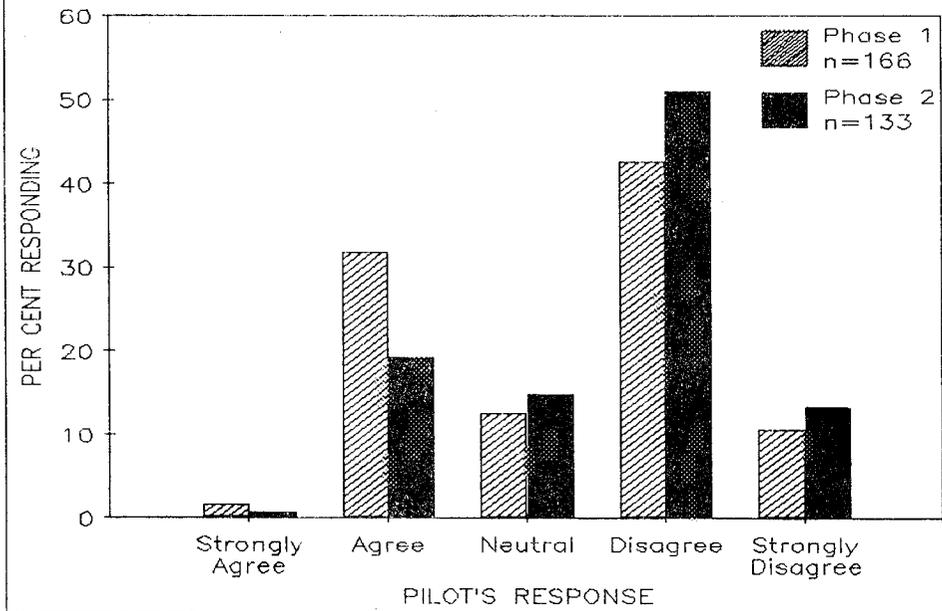
Cockpit automation offers new challenges to training specialists for the following reasons:

1. Presently most pilots are encountering advanced technology cockpits for the first time. In this report, advanced technology cockpits are those which contain EFIS instrumentation and CDU/FMC based flight guidance. The first generation in the airline industry includes the Boeing 767/757 and the A-310.
2. Some initial resistance has been shown, particularly by older pilots, though in general pilots have reacted enthusiastically to the new technologies.
3. Operation of the automatic equipment is particularly difficult to teach and demonstrate in the classroom, due to its dynamic and interactive nature. Real-time training devices which can overcome this are extremely expensive, and therefore much of the training is simulator-intensive. In response to this, a generation of intermediate simulators has been developed. These are called variously cockpit procedures trainers (CPT) and cockpit systems simulators (CSS). While they download some of the training from the more expensive Appendix H, Stage II and III simulators, the CSS-level trainers are often used inefficiently, with most of the capabilities lying idle while crews learn to program on the CDU, and CDU-MCP relationships. Often one will see a multi-million dollar CPT with most of its remarkable capability standing idle for long periods while the crew performs drills on the CDU.
4. Automatic flight is probably qualitatively different than flight in traditional cockpits, though this is yet to be proven. New skills must be developed and practiced. These might be described as "cognitive skills," including an emphasis on planning, alternative selection, and predicting and monitoring the performance of the automation. This is more than traditional scanning and monitoring: it requires management and supervisory skills, and a greater effort to maintain "situational awareness", which can easily be sacrificed in highly automatic operations.
5. There appears to be a wider range of performance in the training programs (higher variance). In any training program there are faster and slower learners, but in the training for the advanced cockpits the differences seem to be more extreme. This is perhaps because it is not just another aircraft, but a qualitatively different experience.
6. The combination of the deregulated environment and the expansion of the airlines has brought a rapid movement of pilots through training programs. The training departments are working long hours in an effort to meet the demands, and simulator time has become a commodity in great demand. Even airlines with well equipped training centers are shopping around for simulator time wherever they can find it.

5. Younger pilots catch on to the new systems (like the CDU) faster than older pilots.



34. There are still modes and features of the B-757 FMS that I don't understand.



7. The modern aircraft are all two-pilot cockpits. Many pilots are encountering two-pilot turbojet operation for the first time, and this can represent a severe cultural change.

8. Training specialists have no place to turn for guidance on the question of training for automation. Though the human factors profession has recognized the problem, it has not been forthcoming with much in the way of guidelines and assistance.

9. Due to the factors mentioned in No. 6 above, there is also a steady flow of pilots departing the advanced cockpit for less modern cockpits, which will be discussed at the end of this chapter. This in itself may be a challenge to training.

10. Pilot opinion runs strong on the subject of training. They tend to be severe in their evaluation of training programs. Pilots' morale and acceptance of new aircraft and technologies is driven by their perception of the quality of their training.

11. Pilots are concerned about their potential for skill degradation (often called "loss of scan" by the pilots) under automatic flight, and see the prevention of this as partly the responsibility of the training departments, partly their own responsibility.

12. The overloading of the ATC system impacts on airline training. To a great extent, flight crews are called upon to compensate for the inadequacies of ATC. This problem may find no relief until the end of this century when new systems come on line.

TABLE V-1. Seat held prior to 757 training.

## SEAT HELD IMMEDIATELY PRIOR TO 757 SCHOOL

	CAPTAIN	F/O	S/O	TOTAL
DC-9	20	6	—	26
B-727	61	32	9	102
A-300	0	0	6	6
L-1011	0	2	3	5
DC-10	6	3	5	14
B-747	2	8	3	13
TOTAL	89	51	26	166

## B. TRANSITION TRAINING

What follows is a documentation of pilot opinion and experience with training and transition to the advanced cockpit, and reverse transition of a sizable number of the volunteers.

**1-7. Question: Which seat in which aircraft did you occupy immediately before going to 757 school? Do you think this made a difference in your easy of transition? If "yes", please explain.**

See Table V-1 (previous page) for results of the first question.

(Replies to second question: 52 % replied "yes"; 48 % "no").

TABLE V-2

Paraphrase of replies of those who stated "yes" and gave an explanation.

	<u>Times Mentioned</u>
Great similarities to former plane (mostly 727); Already knew company procedures; my flying skills were current, so could concentrate on differences; didn't have to learn to fly	16
It was an easy transition since I was already a captain; I was used to making decisions and flying as capt.; particular aircraft makes little difference	16
I was already familiar with two-man procedures (mostly DC-9 pilots)	14
Had prior time on DC-10; L-1011; B-747 etc.; automation, INS, Omega, MCP similar	15
Knew 2-man coordination; not dependent on third man	4
Transition was easy due to F/O time in other aircraft	4
I found it hard to adjust to 2-man operation	2
The big change is not the airplane, but S/O to F/O	2
I'm a 727 pilot; would have been easier transition from a DC-9	2
S/O experience was helpful, esp. learning 757 systems	2

## Crew Comments

(Aircraft designated at the end of the comment is the seat held immediately before transition to the 757.)

There is a great deal of similarity in design and operational characteristics between the DC-10 and the B-757 in most phases of flight guidance and autoflight. Also, basic flight characteristics are similar. (DC-10 F/O) 2001

If I hadn't had a few years of experience of flying captain, the complexity of the new technology combined with an initial upgrade would have been distracting. (727 Capt.) 2009

My company has an initial "up and out" rule. Having already qualified as captain took the pressure off. The two-pilot aircraft requires that the captain be much more assertive. Previous captain experience helped to identify this. (727 Capt.) 2011

Only in that the 727 keeps a person more current in approach procedures, landings, and scan etc. The experience in the 747 and DC-10 was a big help in transition to the FMC and MCP. (747 Capt.) 2014

Since the 757 was the first F/O seat I was checked out in, there were no habit patterns or procedures peculiar to other aircraft that had to be broken or adjusted for in the 757. For example, the pilot's eye view, handling characteristics, and automated flight systems of the 757 are the only ones I am trained on, and so the only ones I am used to. (727 S/O) 2015

At times the 757 cockpit workload is somewhat busy. It is very similar to the "paperwork" workload put on our second officers. Since my flying skills were still somewhat current, and my S/O skills very current, I had a smooth transition. (727 S/O) 2022

I believe that is easier to transition because having been the captain on another aircraft, I found it more natural to make decisions and put them into effect. As a copilot, I found that I was relying on the captain to make decisions that thus I was rusty at flight management techniques. Having been able to sharpen my management techniques on another aircraft smoothed my transition, as I was able to make my decision and carry it through quickly. I understand that other individuals upgrade to captain for the first time on the 757 sometimes took considerable time deciding which course of action to take, which added considerably to their difficulties. (727 Capt.) 2028

International flying on the 747 for a F/O results in few landings per month (as few as five landings and takeoffs), in an aircraft with characteristics which are substantially different from the 757. Moreover, the 747 airports of entry usually have different entry procedures, and other handling characteristics than those used by the 757. (747 F/O) 2044

The biggest job for the captain of an aircraft is to be a captain. This does not have to be relearned with aircraft type changes. (727 Capt.) 2051

The main job of a captain is to manage resources to complete a successful flight. The time as 727 captain was very educational in this regard. It should be noted that my DC-10 F/O time was more helpful as regards the automation of the 757. (727 Capt.) 2056

The new technology in this aircraft made the check-out a little more intense than in previous aircraft. Having already been captain qualified in another aircraft (727) eased the transition somewhat. In my opinion, anyone transitioning to the left seat of the 757 from the right seat of an older aircraft would have an extremely difficult time without having first flown as a captain on some type of air carrier high performance aircraft. (727 Capt.) 2064

Improved instrument scan, profile planning, aircraft slowing capabilities, and flying approaches are skills that are improved upon in the 757 after learning somewhat similar techniques in the 727. The confidence built in the 727 allows me to make more knowledgeable inputs to the control and information loop as it to crew coordination. The new systems in the 757 require participation and decision making by both pilots in practically all phases of flight (on the ground and in the air). This ability began in most other aircraft seats, but is most importantly and actively used in the 757. (727 F/O) 2072

The 757 program was so busy qualifying me on the airplane that not enough attention was paid to the fact that it was my initial copilot upgrade. People in my situation should be targeted for more scrutiny regarding knowledge of basic ATC and company procedures as they are on the 727. (DC-10 S/O) 2087

Being familiar with two-man crew procedures decreased my reliance on the third crew member. Increased workload during descent/approach/landing phases requires careful coordination of effort with two-man crew. (DC-9 Capt.) 1001

I never felt so comfortable so quickly in any new aircraft than in the 757. It is difficult to explain, but in a design like the 757 it seems that every action in the cockpit, every pilot function, every need has been thought through extensively and designed to be a straight forward task, simple to perform. Countless simple duties are made easier, e.g. the ease of use of the altitude reminder or the autobrakes compared to other aircraft. In summary, Boeing aircraft seemed to be designed with common sense. (727 Capt.) 1002

15 years on the DC-9 have given me total confidence and ease with the two-man crew, so no real transition here. Also, the basic autopilot functions are not all that different. This left the new locations of controls to be learned...pretty quick and easy,

and the computers of course. (DC-9 Capt.) 1015

The school is more intense for a new captain. Having been a captain is a confidence builder. (727 Capt.) 1028

It was the same crew position, same role, same responsibilities, only the machine was different. So all I had to learn were the specific aircraft systems and procedures. (DC-9 F/O) 1035

Transition was easier than if I had transitioned from a non-Boeing aircraft, or from a F/O or S/O seat. I would not recommend the 757 to a new captain unless he flew it first as an F/O. (727 Capt.) 1040

It would have been easier coming from a more automated plane, like the L-1011 or the A-300. (727 F/O) 1042

I found that pilots from the 727 had the added problem of increasing their scans to include systems (formerly monitored by the S/O). Example is check to see that cabin is actually pressurizing after T/O; fuel flow etc. On a two-man crew, this is automatic, having ridden right seat mother-in-law (check airman) time, I see that transition from 727 is a little more <than expected>. (DC-9 Capt.) 1056

1-5. What did you think of your training for the 757? What topics should receive more/less emphasis? Any comments on training aids and devices that were used, or needed?

TABLE V-3

The following table is based on overall evaluations of the training where these were given. These were usually stated in the first sentence of the reply, probably in response to the first question. Generally the words used in the table below to categorize the response were those used by the respondents.

Excellent/best training I've had/best training program in the company	33
Good, or very good/no problems/well done	24
Fair/satisfactory/adequate	11
Poor	10

TABLE V-4

Specific comments regarding overall view of training.

Numbers in parentheses are number of responses with this content. Note: the terms CPT and CSS are interchangeable in this report.

CPT was excellent; CPT "a must"; good preparation for simulator (24)

More "hands on" needed with FMC (CDU); training device (part-task simulator) needed for FMC (CDU) (28)

Slide-tape devices poor; boring; poor quality; contain errors (9)

Course too intense; 1-2 more days needed (25)

Liked the system of going through as a two-pilot crew ("partners") (5)

Too much "cramming"; low retention (4)

Should have jumpseat ride in 757 before training (4)

Manuals poor; contain errors; incomplete or poorly written; not in proper format (7)  
Training course should begin with a conceptual overview; design philosophy (4)

Video tapes would be superior to slide-tapes (4)

Important to have access to manuals before attending school (4)

More emphasis needed on systems (14)

Pilots should be assigned to plane immediately after training; not be sent to another aircraft first (3)

More emphasis needed on "flying the plane", less on "nuts and bolts"; more on manual operations (6)

Ground school schedule too inflexible (3)

Program tends to be "self-taught" (3)

Boeing simulator not fully compliant, ours was (3)

Early class instructors not well enough informed, but problem seemed to vanish later (3)

Need more hand-flying in simulator (2)

Need some open discussion between instructors and students (2)

Need crew coordination and communication training (2)

More training needed on FMC (CDU) functions (5)

Need more training on abnormals (2)

PLATO training is worthless (2)

Need one more CPT session after school is over

Instructors should be present at all times when slide-tape instruction is in progress (to answer questions as they occur)

Circuit breaker index should be provided

More needed on VNAV

Need training devices at all 757 bases, not just training base

More simulator work on approaches

Too much emphasis on "magic" <automation> (7)

More training needed in simulator on ATC changes in a terminal area, and going to a manual approach

Should get orientation tour through actual plane before school

Need more emphasis on landing techniques

Manual should have a list of all EICAS messages

Need more raw data flying in the simulator

Use of FMC during missed approach not well explained

Training needed on handling electric "glitches"

Should have a LOFT ride in the middle of the simulator course, as well as at end

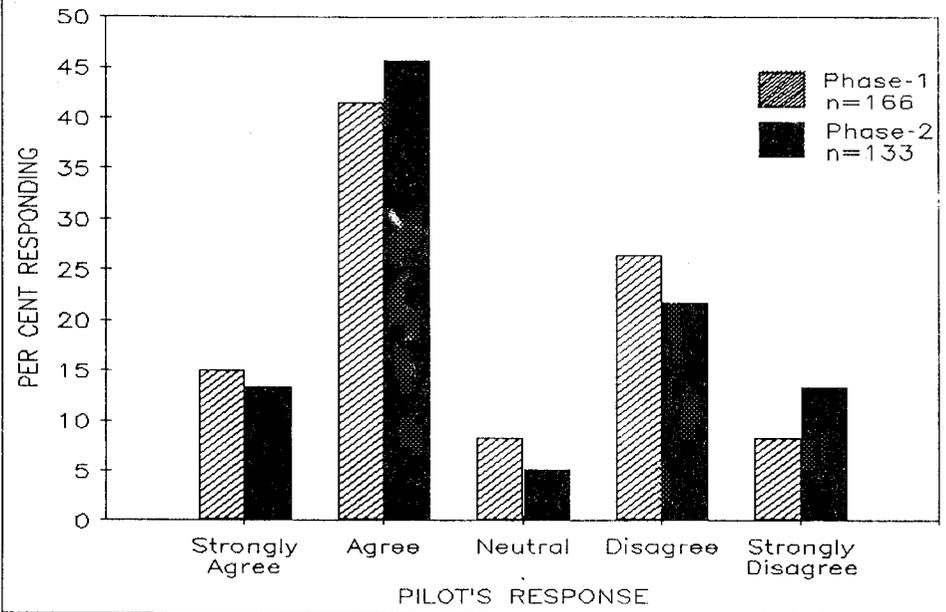
A weak partner affects the quality of your training

Need more information on what automation does in the event of engine failure in climb

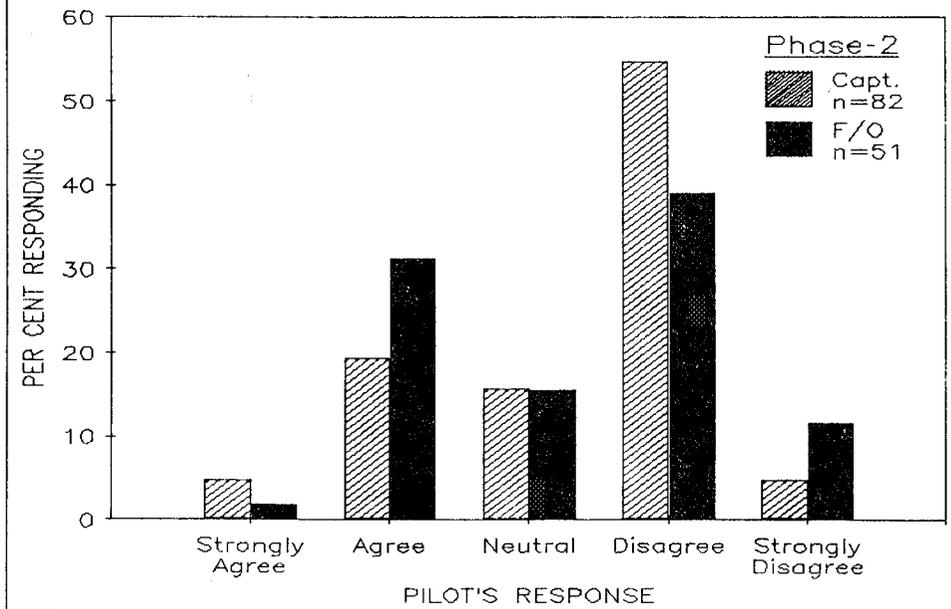
Too much time spent on "unusual situations" (e.g. building approaches) and not enough on everyday operations

Need time in the schedule to allow repeated viewing of slide-tapes

24. Training for the B-757 was as adequate as any training that I have had.



24A. Training for the B-757 was as adequate as any training that I have had.



## Crew Comments

I thought training in ground school and simulator were excellent. If time had permitted, I would have liked a little more training in normal operations. I thought the training in emergency procedures was excellent. 1016

I thought that my 757 training was a terrible, traumatic ordeal closely akin to the USAF Aviation Cadet training of the early 1950's. Aircraft systems, normal and abnormal procedures, were easy. FMC and autopilot, MCP and their relationships with one another were very difficult. Lack of FMC/MCP training aids required us to study the flight manual and attempt to relate its rather abundant information to rather brief periods of instructor telling us that the flight manual was for the full-up system, which ours was not, and we should ignore all the documentation except what he told us. I felt that a much better training syllabus could have been developed, and training aids made available so that we could have "hands-on" study at our own pace during periods of "free time." 1001

It was almost like a self-taught course. I would have liked an old-time instructor classroom type. 1004

The training was good in the 757. I liked the crew concept, and the CPT training to learn the FMC before getting to the simulator. The point that should be stressed is that if automation isn't doing what you want it to do, turn the magic off and flying it like any other plane. Too many checkrides are almost total automation checks. 2095

The ground school curriculum was backwards. No pilot feels at ease in an airplane he knows nothing about. Yet, from Day One the emphasis was on the FMC-CDU, with the aircraft left for the end. With the student first comfortable in the aircraft, the FMC-CDU could probably be taught in two days. 1010

Training was adequate for showing "how" to operate the airplane, but there was almost no "why" training. In most cases, the instructors themselves don't know "why". 1035

I went to school when the aircraft was relatively new. There is no question in my mind that it was the worst school I've ever attended at the company. I feel that Boeing did a very marginal job instructing the people who went to Seattle. I feel well qualified and knowledgeable about the aircraft, but a lot of this was on-the-job training and some from ground school bulletins and tech references. I understand the 757 much better now. The FMC should be taught in the classroom, going through the CDU page-by-page, with the appropriate training aids available. The first period in the simulator should be spent examining the autopilot, MCP, and working with the different buttons. 1037

All pilots should ride jumpseat on a three-day trip prior to

going to school. Training was fast and furious, and even though I "passed" and did well, I didn't feel comfortable and that's important to me. 1042

757 training, ground and simulator, grossly over-emphasized automation. A great deal of time was spent learning aspects of the FMC that are unusable in the ATC environment. The FMC is a sub-system, not God. Ground school gives equal emphasis to all aspects of the FMC without regard to operational reality. It's really a simple, easy-to-use system, but it's not taught that way. 1045

There was too little emphasis on aircraft systems. The CDU work would have been easier to grasp if it had been taught in an operating environment such as LOFT. I suggest that pilots ride the jumpseat for a couple of days to see the "big picture" before they attend ground school. 1048

I really don't see how it can be changed much. So much came at me so fast that for the first few months, every trip was a relearning experience. 1054

Training on the 757 was intense! Perhaps because the 757 is such a departure from what is considered "normal" by most pilots, there was a very flat learning curve for the first week or so of training. It was not unusual to hear complaints of the physical and mental demands imposed by the program. Personally, I found the school was the most demanding I have ever had, with no free time to deal with personal affairs, an ever-increasing distraction. 1061

It was the best training program I have been through. Real organized. Enjoyed the reinforcement from audio visuals to lectures to CPT. CPT was a must for training. For me it also made the transition from S/O to F/O quite easy. 2005

Good. No problems. High pressure, but I enjoyed the check-out. As I prepare for my second 6-month check, I do notice that I seem to be losing my system knowledge. May be the result of total immersion training. 2006

My training was too structured. I knew 28 days in advance when I would be taking my type rating ride. I think training should be to proficiency, not training to fill the squares. More training on VNAV would have been nice. My training on VNAV was poor. It took several months before the subtle differences between VNAV Speed and VNAV Path were clear. A program for a home computer, where one could just sit and play with the FMC, would have been helpful. 2011

The only real problem I had was not enough approaches. This has been corrected, because our simulator will use snapshots and we can pop right back for more. With Boeing's simulator, you might as well fly the whole pattern. I was able to do twice the work on my last check that we could have done at Boeing. 2012

I felt the 757 program was well structured. The program made more sense having had access to the manuals three weeks prior to the class. 2013

The training on the 757 was much too intensive. We were asked to read 70-100 pages per night. Most pilots received their manuals two weeks in advance; one base did not. Also, most of the captains hadn't been in school for 25 years, and it was very difficult for them to study 7-8 hours a day after class. They ended up feeling stupid and having their confidence destroyed. Checking out in 757 was no more difficult than any other airplane. Combination of training aids and stand-up instruction was very good. 2017

The training was interesting, hectic, and went fairly smoothly, considering the new aircraft and the limited knowledge of our instructors. The complaint you hear is that at our company, the 757 is a small, junior airplane, and the training department is just not that interested. Nothing like when the wide bodies were new. 2018

757 training was unique for us. I feel it was excellent, and more demanding for self study. The CPT is a must as an aid. By the time of your check ride, you're fully prepared for anything that may be required. 2023

Overall ground training was good. Slide-tape was inaccurate, and instructors said they had trouble getting corrections made. My biggest problem was over a month delay between school and getting my IOE time, then another month before getting assigned to the 757 permanently. Meantime had to fly other aircraft and return to 757 each time. Continuity was poor, and leads to loss of retention and reinforcement of previous training. 2024

I wasn't overly impressed by the crew training. There are still many functions of the FMC that are not understood by all of our pilots, and sections of the flight manual that are wrong. Today there are still friendly arguments in the cockpit about how this or that is designed to function or what the information on a certain gage is telling the pilot. The FMC should be explained in depth, and every line on every page explained in detail. Sitting in a hard chair and watching slides several hours a day cannot be called effective training. It is possible to take video tapes of actual parts of the aircraft in action, for example gear doors, slats and flaps operating. On the first day of training the student should be given aircraft familiarization on the actual aircraft. 2028

I felt training was outstanding. Breaking the training into 1/3 lecture, 1/3 slides, and 1/3 CPT was very effective. I feel more emphasis should be given to landing techniques, especially in light of the number of tail strikes we and others have had. 2035

Slide-tape is vastly inferior to live instructors. FMC on our aircraft was fully compliant, Boeing's was not. More practice on the FMC would have been useful. Two-man crew coordination problems are frequent. A good review of high-altitude meteorology would help us. A good explanation in our manual of all EICAS messages would help. 2038

Outstanding! I felt better prepared and more comfortable sooner than on any aircraft I've flown in 12 years. The CPT is indispensable! The opportunity to practice what you've read or seen in class aids rapid, lasting learning. 2052

Training was very well done. Too much emphasis on lecturing about each specific mode of the FGS, one at a time. Material is very dull when presented this way. Needs to be presented in various hypothetical flight regimes, with a more integrated approach to FGS and FMC operation. The CPT is an excellent aid, and greatly streamlines simulator training. 2067

C. INITIAL OPERATING EXPERIENCE (IOE)

1-2. Describe any problems that you had during your IOE (initial operating experience) and early months of flying the 757. Are there still areas you have trouble with, or don't understand?

Note: some of the replies to this question overlap those to question No. 1-5 on training. The intent of this question was not a critique of the training program, but to learn specifically what problems the crews encountered in their early experience with the 757. In cases where the response was specifically related to the training program, it was considered in connection with 1-5. A number of responses to this question were blank. It is difficult to say whether this should be regarded as "No problems" or "No comment" (see below).

TABLE V-5

List of perceived problem areas in Initial Operating Experience. Numbers in parentheses are number of replies if more than one.

No problems (so stated) (36)

Too much time spent programming; slow at programming, especially responding to ATC changes; difficulty finding right CDU page (18)

Confusion over modes, esp. vertical modes (14)

Too much time had been spent in training on computer, and not enough on basic flying of airplane (7)

Interfacing to ATC (18)

Slowing the aircraft and descending ("getting it down") (13)

Too much head-down time (7)

High workload initially (6)

Trouble getting used to two-pilot environment (4)

Schooled on old computer; had trouble adjusting to fully compliant computer when it came into service (3)

First officers programming too much below 10,000 (3)

Too many ways to do a given task; too many options (2)

Reactions of autothrottle (2)

Usage of brakes (too sensitive) (6)

Building non-precision approaches on the CDU (2)

Gaining confidence in and staying ahead of automation (5)

Difficult learning to use ADI mode annunciations instead of looking at the MCP (2)

Crews are not hand-flying plane enough to get feel of it (2)

Maintaining vigilance for failures

Learning that I needed to know where I was on my charts

Programming crossing restrictions at a fix

Lock-in of localizer frequency

Forgetting to retract spoilers (3)

Rudder trim constantly changing during climb/descent (3)

New terminology

Too much pitch change with power change

Trouble with landings; judging position of nose wheel on landing; judging rotation/derotation (4)

Speed and speed intervention modes

Abnormals manual is ambiguous and time-consuming; poor manuals in general (2)

Crew coordination; lack of standardization of "who does what" (2)

My rough positioning of flap handle caused LE and TE lockouts; problem lasted for two or three months

Very high workload if one pilot is weak (2)

Still not confident in radar (2)

Still not sure what some FMC information means

Still not sure how IRUs work

## Crew Comments

Initial aircraft operations were easy and pleasant because of the attitude of the "baby sitter" <check airman>. Relieved of the extreme pressure of "Tension Tech" <training program> and "checkitis" and seeing that equipment was reliable and easy to use plus the pride of operating most modern equipment in the industry makes flying the 757 more fun than work. 1001

Lack of standardization of crew members duties and who is to do what when operating with autopilot on vs. off. Both crew members reaching for the mode control panel at the same time to change the altitude select or heading, etc. Our manual covers this subject, but not enough emphasis given during ground school or IOE. 1008

The design of the 757 is clear and straight-forward, making the actual operation of the aircraft problem-free. I feel that the only real problem is in the operation of the aircraft in the present ATC system. The programming of the FMC is too slow and diverts time that should be used in operating the aircraft. This is not a problem en route of departure as much as in arrival traffic. The system needs a more efficient way to update the arrival displays to tell me the changes imposed by ATC. 1025

The shift to automation and the two-man crew was more radical than I expected. I very often was not sure what was happening when using full automation, particularly VNAV mode. Went frequently to manual modes until I had confidence in systems and my understanding of them. It took longer than most transitions to feel comfortable with the airplane and new concepts. Part of this I believe was due to training. I feel that the airplane (basic) should be taught first and FMC applications taught last, mostly as an aid. Our training seems to teach the airplane around the FMC. I also feel that two more days of ground school added to normal curriculum and dedicated to the automation would be most beneficial. I began feeling comfortable and confident after approximately six months. I have been flying it now for just over one year, although it occasionally throws me a new look, I prefer it over any aircraft I've ever flown. I have recently gone back to the 727 and given my druthers, I'd fly the 757. 1026

My biggest problem isn't with the 757 automation itself, but rather on increasing reliance on the visual simulator and rote movements for teaching landings. In my opinion, no pilot should be allowed to fly passengers, even with a check captain accompanying him, until he has made a minimum of three (preferably more) takeoffs and landings in the real aircraft. Total simulation is a totally unacceptable teaching method, especially in an aircraft with such great differences in cockpit height at touchdown and individual handling characteristics. The

worst, i.e. hard, landings I've ever ridden through was as a S/O on a wide-body with a captain on his first flight transitioning from a much smaller narrow body. The best visual simulators do not really give a realistic view of the cues a pilot uses for critical phases of flight. 1027

The biggest problem is remaining vigilant for unannounced system failures, especially VNAV, LNAV failures and errors. The computers work so impressively well most of the time that they inspire more confidence than should be prudently placed in them. 1035

No problems, just amazement. Yes <still areas not understood>, but it's a matter of not enough experience. Best learned by doing it, and the various crew members each other. Sometimes ATC can run me into disconnecting everything. Thus far, my mind/hand/feet combination is faster than my monitoring-programming capabilities. 1052

The FMS is so complex, it takes quite a while to feel comfortable in its use. However, for me, this becomes a positive thing because it reduces the tendency for complacency. 1053

I had to discipline myself to not devote too much time programming the CDU below 10,000 and thereby neglecting my traffic scan. 1060

When I went through school, I was told that it was impossible to lose all flight instrumentation. Yet that's exactly what happened to me in July 1987, due to an IDG speed sensing problem. The aircraft was without any instruments for about 45 seconds in the weather. Basically, I believe that the schooling in the aircraft should utilize the FMS/CDU as separate training aid, and let the students experiment with same. In this way, full capabilities of the equipment can be realized. 1067

Getting down and slowed. The 757 loves to fly. The flight director shows climb when you're above the glide slope and haven't captured. Can cause you to level off to capture rather than to keep going down to capture if you're not watching it. 2012

I've had only one major problem and it could have been dangerous. Going into LAX for the first time, getting all set up to land on 25L, then at the last minute they switch us to 24R. We spent too much time trying to program, and we came in too high and had to go around. I believe that habit <frequent R/W changes by ATC> is an accident waiting to happen. 2017

On a new aircraft, it's easy to become "head down" far too much. This is a great aircraft for a mid-air collision. The major problem on this aircraft is that if one of the pilots is weak, it becomes a solo flight with high workload. The weak pilot can fowl things up with just a few keystrokes. 2018

The pitch attitude of the aircraft is quite deceiving. After coming off a wide-body (DC-10), I had a great tendency to start the round out early. 2019

Only problem is that my copilot got frustrated and upset when I asked him to fly a manual approach into LAX. 2020

I had a tough time believing that the automation was going to do what I programmed it to do (e.g. capturing altitudes, proceeding direct to fixes, etc.). I found myself turning off the A/P, placing the aircraft where I wanted it, and turning the A/P back on. 2022

I had difficulty getting the aircraft to follow the VNAV path. This was probably because the instructors didn't understand how the aircraft was supposed to function or why. When I started my IOE, I expected the aircraft to fly the VNAV path, and I rather rudely learned that in the real world that's a joke, and you have to resort to FLCH, VNAV speed, or vertical speed modes, and use speed brakes at some point in every approach in order to make your altitude. As a result I had considerable trouble in IOE getting the aircraft down the way I expected VNAV to do it. 2028

Yes! What information is available from what page of the CDU and when? Example: VOR/ILS frequencies? Field elevation? 2033

We had the tendency to mess around with the CDU too much, especially at low altitudes. It's difficult to accept that it's just a 727 with fancy stuff, because all the emphasis in training was on automation. I am still in the "early months" of flying, was checked out sporadically, and now face a six-month check with less than 100 hours. Skill retention is very poor with low time. 2034

In the event of a malfunction below 10,000, one pilot is flying the aircraft. The other is taking care of the problem. You have two sets of eyeballs inside the cockpit, and nobody outside. This also happens if you have a change of runways and are re-programming -- very unsafe! 2036

The only problem was getting acclimated to the two pilot environment. My training over the last 18 years has been in the three pilot loop. Now, one pilot flies and the other is solving the problem, with nobody to cross check. I must say that if it is handled properly, and both pilots are up to speed, a two-pilot aircraft can be handled as safely and efficiently as a three-pilot aircraft. 2043

No problems so far. Our training was superb! The use of the CPT in ground school was very helpful. This training and simulator prepared me better than any flying program I've ever had. The IOE went along very well, as have my line trips. I do feel that I've lost some of my sharpness and knowledge of the 757 by not flying it continuously since finishing the simulator. 2052

I feel that after 11 months, I'm still learning about different ways of doing things. I received my IOE from the jumpseat and I was not happy with that, given the vastly different nature of the glass cockpit. All IOE should be done from the right seat. 2054

During departures and arrivals, the workload became excessive with the slightest change to our flight plan. It was difficult to make the copilot leave the FMC alone below 10,000. Both problems have been cured by experience. 2056

My biggest problem was the lack of a second officer, especially with a brand new F/O and busy terminals and low weather. Once you accept the fact that there are only two in the cockpit, it makes the operation more efficient. Maybe you pay more "attention" to what is going on, since the third person isn't there to back you up. I learn something about something on every trip. 2070

No problems. Training cannot cover all the idiosyncrasies of the FMC, but intelligent operation, along with adherence to standard ops procedures, makes learning them more enjoyment than problem. 2076

Both the F/O and myself had trouble putting our holding pattern right in the CDU after takeoff. We took off from DCA. The first waypoint was Martinsburg VOR. We were cleared to hold before we got to the first waypoint, and we couldn't get it into the HOLD page, so we flew it manually. We also had trouble putting in a revised routing in the air. We were cleared to intercept a jet airway and we couldn't put it in the RTE page because we didn't start with a point behind us. Both of these took place in our first week. 2082

During first 100 hours missed approach at LAX due to high minimums. Workload was high, particularly since ATC did not expect a miss, although we warned them (RVR 5000', ceiling 100') We were cleared to hold at an unfamiliar VOR. Flight attendants called three times, company one time, after workload reduced and we were in holding pattern. I remarked to the F/O that I hadn't looked out of the window for 20 minutes. He hadn't either. Moonless night, VMC conditions. 2084

No problems except too long between training and flying the aircraft. You lose a lot of what you learn unless it is reinforced through usage immediately after training. I waited almost three months. 2093

Most of the problems on the 757 are ATC and crew workload related. There are times that you are rushed with not enough hands to do it all. For example, on approach to LAX we had a "leading edge disagree" message. We requested a 360-degree turn to make time for the alternate procedures. With all the radio frequency changes there wasn't time to properly do and cross

check the procedure. In about four minutes, we were given four frequency changes to do a 360. It took one person to work the radios and left little time to look for traffic. 2096

## D. SKILL LOSS AND RETENTION

2-1. Do you feel that you have experienced any problem with loss of proficiency (skills loss, or "loss of scan") due to automation? Did you have any concern about this? If so, what did you do to prevent it?

(Note: for further information on this topic, see the next section of this chapter dealing with crew members who left the 757 for other aircraft. Many commented on the absence or presence of skill loss as they transitioned into less automated aircraft.)

TABLE V-6

For those who gave a clear-cut answer to the first question above, their responses are tabled below.

Yes	32
Somewhat/slightly	11
No	51
Unable to say	2

### Specific Problem Areas and Assets

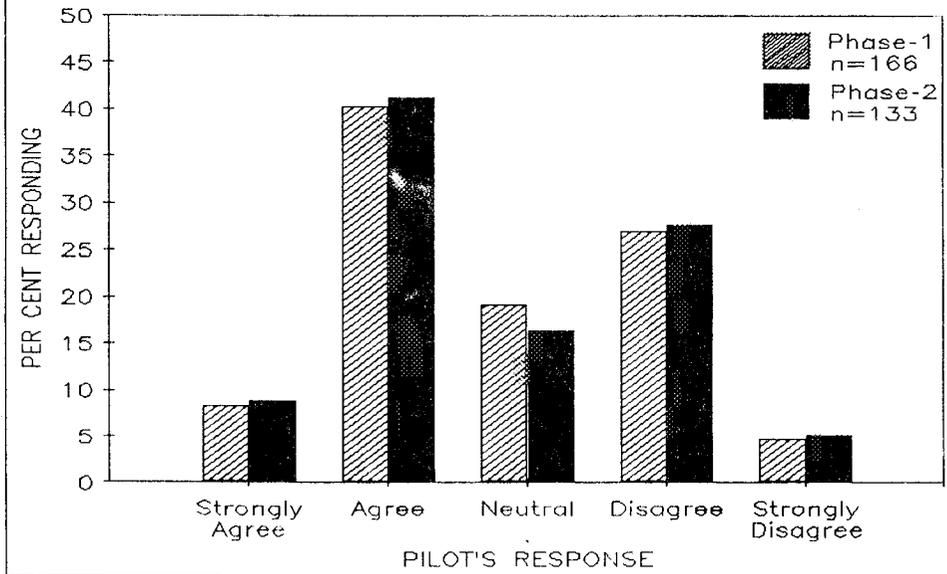
Inattention on auto capture of altitude  
Too much reliance on map mode (HSI)  
Larger ADF and HSI made scan easier  
Loss of memory of VOR frequencies, distances, radials  
LNAV, VNAV if used too much could lead to skill loss  
Loss of airspeed and EPR awareness after too much use of automation  
Failure to monitor is the trap  
"normal human laziness"  
Scan is easier in 757  
Feelings of "lack of security" if map display or IRS is lost  
Spent too much time looking at ADI, since most information needed is there  
Had to fly 727 one month and noticed loss of scan  
Too many altitude excursions in auto flight  
When I returned to 757 after period on 727, it took 4-5 months to get up to speed on FMC  
Noticed skill loss when I went to A300 (capt.), especially in entering holding patterns  
Any loss I attribute to age, not automation

Methods for avoiding loss of proficiency

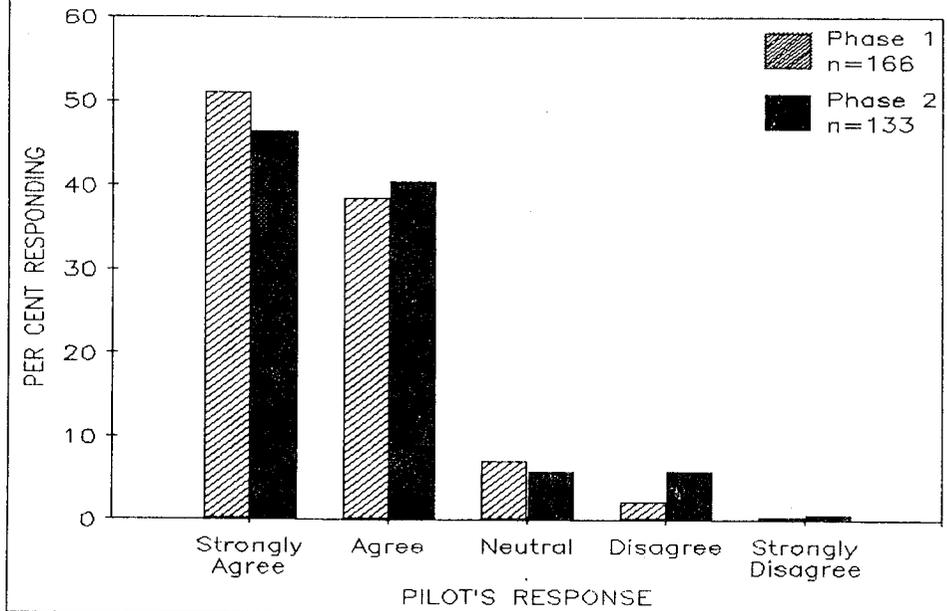
Hand flying in general	32
Hand fly below 10,000	10
Hand fly 15-20 minutes each leg	1
Hand fly to 10,000 or to cruise, and down to 10,000	3
Hand fly manual mode of LNAV	1
Fly trips using only RMI, VOR, ILS modes of HSI	1
Hand flying works, but defeats purpose of automation	1
If VMC, land manually	2
My military reserve flying (C-141)	1
I fly light planes	2
Raw data approaches (no F/D)	3
Hand fly to 10,000 and all approaches after localizer capture	1
My scan returned with little trouble when I went to DC-9	1
Alternate one leg automatic, one leg manual	1
Alternate one approach automatic, one manual	1
Use VOR compass rose display	1
1) hand fly; or 2) bid another aircraft	1

(Note: many mentioned the "pleasure" of hand flying the 757)

2. I am concerned about a possible loss of my flying skills with too much automation.



9. I prefer to hand-fly part of every trip to keep my skills up.



## Crew Comments

(Note: those respondents who had left the 757 for other aircraft, and also those who had returned, are indicated in the parentheses preceding the comment)

It takes self-discipline to prevent a loss of skills. I feel if you fly the aircraft as designed, it would tend to make you reliant on automation. Manual flying and mental planning is discouraged by the design. 3003

I don't feel that I've lost any of my flying skills in the five years I have been on the 757, because I have always made a policy of hand flying as many approaches as possible. When I say hand flying, I mean both the A/P and the autothrottles disconnected. I also make it a policy of advising the F/O verbally that I am disconnecting the A/P and A/Ts. I think this is very important from a safety standpoint, so that both pilots will always know what configuration the A/C is in. 3007

The potential for loss exists, but will not occur if you hand fly now and then. I often shoot raw data (no F/D) practice approaches and also use VOR and ILS modes <of the HSI> as well during approaches. Unfortunately, the "lack of time (\$)" during initial training and when getting simulator checkrides usually precludes the chance to get enough hand flying in other than full A/P or F/D modes. Naturally the economics is important, so we always operate in that mode. 3015

(A-300 capt.) I prefer to hand fly in busy terminal areas...helps the F/O keep watch outside, and by using raw data and switching to VOR mode it helps my instrument scan. 3018

(Retired) The flight instrumentation <of the 757> is so superior to those of the past "Basic T" format that the scan requirements are not nearly as critical as yesteryear. No problem. As far as skill loss, any pilot who has five or more years piloting transport categories should be able to disconnect and continue with no one noticing the transition. That's what periodic recurrent training is all about. 3025

I notice a feeling of insecurity when the map display or the IRS fails. This feeling soon disappears when using a manual back-to-basics mode for a while. I try to hand fly as much as possible using manual throttles. Lack of autothrottles would be the most missed feature if I went back to 727 or DC-9. 3028

Yes. Every 757 pilot I know has the same concern. I like to turn off all automation and fly using raw data at least once a month. By doing this, I know that my scan and proficiency have declined. This will force me to work much harder when transitioning to a non-automatic aircraft. I think that raw data

flying should be a part of the training program and periodic instrument proficiency checks. 3032

It is a concern - some hand flying proficiency may be lost. The plane can be hand flown for proficiency if desired. No doubt automation gives a better balance to the total flying requirements. Monitoring is the problem that has to be constantly fought. Automation gives a sense of security that is not always as it appears. 3039

(A-300 F/O) I don't feel that I lost any proficiency flying the 757, nor did I have any such concern. The airplane is such a pleasure to fly that I hand flew it as much or more than previous A/C I have flown. 3043

(A-300 F/O for three months, then returned to 757) I was somewhat concerned with the "I can't fly any more, but I can type 80 words a minute syndrome" <refers to use of CDU keyboard>. Can't really say it was a problem. I flew the A-300 for three months and had no problem. Biggest concern is that when I check out as captain (I'm 70 numbers away) that I will be going from the most automated (757) to the least (727 or DC-9). 3045

(727 F/O) I was concerned about this, but after two years (and 1000 hours) on the 757 I went back to the 727 and had no difficulty transitioning "backward". 3046

I feel that I definitely lost flying skills on the 757. Also, I have lost the skill to scan. This will be a problem for me when I upgrade to captain on the DC-9 or 727. I have flown some trips using only the RMI, VOR and ILS display modes on the HSI, and this helps some. I also hand fly to cruise, and below 10,000 unless it's a coupled approach. You know the saying: "I can't fly any more, but I can type 40 words a minute." 3047

(L-1011 F/O) Yes! That is the reason I left the 757. I was afraid that my check-out in the 727 would be very difficult. 3052

(DC-9 Capt.) Automatic altitude capture tends to encourage inattention in this important transition, including setting cruise power. Transition back to older aircraft requires more attention to detail, and less management. 3057

(DC-10 Capt.) I feel you develop a "different kind" of skills on the 757. You must use the autopilot to a greater degree in terminal areas to free up your eyeballs for external observation. If you have poor skills in either hand flying or auto work, you will lose a set of eyes that could be used for looking for traffic. Certainly scan skills are not as sharp but they are not required. 4007

(747 Capt.) No, but only because I refuse to use automation below 10,000 unless necessary. I feel that the automation is good, but its use should be discretionary with the pilots rather

than required on a routine basis. 4010

(DC-10 Capt.) I left to return to the DC-10 after two years on the 757. I found my descent planning and approach speed and flap management had deteriorated considerably. All other stick and rudder skills seemed OK. 4011

(747 F/O) I noticed a loss of scan in transitioning to the 747, but part of that is due to the increased information on the 757 HSI and ADI. It takes more scanning and thought to stay oriented in the 747. Some loss of scan can be prevented by hand flying the 757. 4014

No, but our airline does not require us to use the auto flight system below 10,000, and I do not. If we were required to use the automation, my answer would be quite different. 4016

Yes. The first few months on the line I used the autopilot-flight director 90% of the time. When I saw that my hand flying skills were deteriorating, I began to do more hand flying below 10,000. (Not necessarily the safest, since the see-and-avoid is reduced considerably while hand flying the 757). 4018

While at first the pilot may tend to "loaf" and let the automation handle approaches and/or maneuvers, he soon learns that the automatics require a greater degree of monitoring and attention. Awareness for me occurred about six months after check-out and is reinforced monthly. The net result is not a loss of scan or skills, but rather an enhancement. The major difference lies in the fact that automation provides its own agenda of cues that the pilot must be aware of, while in other aircraft the pilot selects his own cues which provide the most satisfactory performance for him. 4019

(747 Capt.) No! I feel that the automation of the 757 actually aided the pilot. There is a wealth of information in the ADI and HSI which is generated from advance technology that is available to the pilot that we never had in the previous airplanes. Use of this data, along with hand flying at lower altitudes, will keep the pilot proficient. 4024

(747 Capt.) No. I feel that automation does not in any way contribute to the loss of skills or scan. It does relieve the workload (if allowed to) in the critical airport terminal areas so more time can be spent with the eyes outside the cockpit. I might also add that I feel that every time one goes through an extensive training program such as checking out on a new aircraft, an upgrading of skills and scan occurs. 4027

When I check out on the 747 it will take some effort to get used to older methods of navigation, especially since there is no more display to assist in spatial orientation. 4032

It takes longer to learn pitch and power requirements because the autoflight is used so much. Scan tends to break down because I

seem to be programming or discussed the aircraft more while the autopilot is flying. I'm not worried about it because I hand fly a portion of every leg and my systems and equipment knowledge is improving. 4033

I think my scan is better on the 757, but worse on the 727. I hand fly more than I used to when I first went on the 757, but I find that I used the automation a great deal more late at night or at the end of a long day. To improve your scan, you must hand fly, which is getting dangerous in the crowded environment. 4042

(747 F/O) If I feel "rusty" I just hand fly from T/O to cruise and cruise to touchdown; and others often don't use the F/D at all. When you move between aircraft as I do, you must maintain your basic skills and hand flying the aircraft is the only way to do it. 4045

I don't feel that I have lost any skill or scan. However I have noticed that in the course of 2 1/2 years that this problem is very subtle and can sneak up on you if you get in the habit of pushing buttons etc. At first I would hand fly below 10,000 and later it got to be below 9000, then 8000 etc. Eventually I would take the autopilot off inside the marker and land by hand. On occasion when hand flying below 10,000 I would overshoot a heading or sag a little below the assigned altitude. Once the altitude alerter reminded me, and once the co-pilot. During training this problem was pointed out. Now, after taking three six-month checks I note that all the checks have been with all the auto stuff working. In fact the instructor frowned when I did an ADF approach with the RMI needle. The emphasis seems to be on the automation for some reason. I have had several co-pilots tell me that some captains will not let them hand fly except for landings. I think training should put more emphasis on hand flying and raw data than is being done now. This should be done after initial check-out, during the six-month check or annual checks. Training should encourage hand flying more and keep emphasizing how subtle this "let the autopilot do it" problem is. 4048

The use of the autothrottles reduces your feel of the aircraft for pitch changes and power settings for different speeds and configurations. Using the automatic features of the plane to the fullest gives the pilot more opportunity to direct his attention outside the cockpit and provide for a more economical operation. 4055

(DC-10 Capt.) Additional, not supplementary, skills are required on the 757. These skills are operating the "magic." You should not practice those skills to the exclusion of others you've already developed. The vertical guidance/planning provided by the FMC can erode your planning skills, but that doesn't show up until you leave the aircraft. 4061

Yes, although NDB approaches are rare, it is much easier to build one in the FMC and fly it with the autopilot in LNAV than to

simply use the RMI on the 727 and no autopilot. If I had to step down to the 727, it would take quite a few hours before I would feel comfortable on that type of approach. 4069

Loss of scan or skill has not taken place because I do not allow it to. In a real world, automation is used less than in the simulator. On a proficiency check, there is less evaluation of airmanship because our airline will not allow the 757 to be flown like a 727 (i.e. FMC must be used, not raw data). 4073

E. TRANSITION BACK TO OLDER MODELS FROM THE 757

2-7 SPECIAL FORM FOR THOSE WHO HAVE LEFT THE 757

The following questions were on a special form attached to the Phase-2 questionnaire, with the instruction that only those who had left the 757 for other models were to fill it out.

A. Please list all aircraft and seats that you have flown since leaving the 757, and indicate which seat you occupy now. If you left the 757 and returned, please indicate.

B. What features of the 757 did you miss after you went to another plane?

C. Did you have any trouble adjusting to the older model aircraft? If so, please describe.

D. Based on your 757 experience, please describe your feelings about flying highly automated aircraft versus less automated aircraft.

A. Please list all aircraft that you have flown since leaving the 757, and indicate which seat you occupy now. If you left the 757 and returned, please indicate.

TABLE V-7. Tabulation of seats held at the time of the second questionnaire. Following this are comments by those who have flown more than one aircraft, or had left the 757 and returned. Note that of the 130 respondents to this question on the Phase-2 questionnaire, 94 (72%) had remained on the 757.

## SEAT HELD AT TIME OF SECOND QUESTIONNAIRE

	CAPTAIN	F/O	S/O	TOTAL
DC-9	2		—	2
B-727	10	1		11
A-300	2	3		5
L-1011		2		2
DC-10	6			6
B-747	6	3	1	10
B-757	58	36		94
TOTAL	84	45	1	130

The following is a list of assignments of pilots who indicated that they had moved off and back onto the 757, or were flying the 757 and another aircraft.

Off on 727 one month  
 747 F/O to 727 capt.  
 DC-10 F/O to 727 capt.  
 Off on 727 capt. 4 months  
 Alternating 727 and 757  
 Alternating 747 and 757 F/O

Alternating 747 F/O and 757 capt.  
DC-10 F/O to 747 S/O and F/O  
DC-10 capt., and 747 training capt.  
Alternating 747 S/O and 757 F/O  
Alternating 757 and 747 capt.  
DC-10 capt. to 747 capt. (2)  
DC-10 F/O to 727 capt.  
Alternating 747 and DC-10 capt.  
727 capt. back to 757 capt. to DC-9 capt.  
A-300 F/O 3 mo., returned to 757 F/O  
L-1011 F/O to A-300 F/O  
Alternating A-300 and 727 capt.  
727, with TDYs to 757

**B. What features of the 757 did you miss after you went to another plane?**

Results of this question are tabled below. In many cases a single response could have appeared in several places; an arbitrary assignment was made as well as possible.

TABLE V-8

<u>Response</u>	<u>No.</u>
Everything	2
Everything but two-man crew	1
Nothing	1
Automation; FMC etc.	16
Map mode of HSI	15
Navigation systems	7
Extra information (wind vector; time to chk. point airports, etc.)	4
IRS wind vector	5
Climb and descent arc	3
Fuel vs. time computations	2
Computed descent point	2
"Glass cockpit"; EFIS	9
Flying and handling characteristics; performance	6
Autopilot	6
Autothrottles	3
Quiet, comfortable cockpit	2
High altitude capability	2
Simplicity of layout of cockpit	2
Auto-pressurization, heating, cooling systems	2
EICAS	2
Engine power	2
Auto level-off	1
Capability to fly direct to a point	1
Visibility	1
Mode annunciations on ADI	1
Digital engine instruments	1
Mode control panel	1
Ease of instrument scan	1
FMC capability for making altitude restrictions	1
ACARS	1
System simplicity	1
Accuracy (non-precessing) of ADI	1
LNAV and VNAV	1

C. Did you have any trouble adjusting to the older model aircraft? If so, please describe.

Yes: 11  
No: 28

Crew Comments

Aircraft type in parentheses indicates aircraft respondent transitioned to after leaving the 757.

(747) I had a little trouble adjusting back to the old VOR presentation and more constant need to use charts with multiple radial fixes. 4010

(747) My cross-check was a little slow, and it was harder to stay oriented in terminal areas. 4014

(DC-10 and 747) No trouble. It's like going from a Porsche to a VW bug. 4027

(727) Smaller primary instruments. I couldn't see small pitch changes as easily. Less power, and couldn't climb as high to get over weather. 4030

(747) Yes. In the simulator I did not keep the second officer in the loop, and I was used to doing for myself. 4034

(747) No. I had understanding captains, who were also curious and are looking forward to the 747-400. 4045

(747) My scan was slow to adjust back to scanning all the instruments needed to follow flight conditions. 4046

(727) Yes. It was more difficult to maintain position orientation. Flying approaches well was harder due to the lack of wind information. Had to get used to making throttle adjustments. Aircraft could not be flown as precisely. Spent more time on basic aircraft control. 4047

(DC-10) No. In fact, the skills I learned in the 757, especially autopilot usage, were a benefit on the DC-10. 4061

(747) I rather enjoyed the increased navigation tasks. I felt more "involved." 4066

(A-300) I wondered where I was at for a while. Took some time adjusting back to flying radials and airways, etc. 3001

(A-300) Found some problem with getting scan back to top speed.  
3018

(L-1011) No, because the AFCS systems retain some similarities. I do think if you were on the 757 for an extended time there is a tendency to become "brain dead" in such basics as holding.  
3021

(A-300) A little...more buttons to push on the A-300 flight director and AFCS control panel. On 757, a much simpler setup.  
3029

(A-300) No. After watching "color TV" for three years, I didn't really want to go back to "needles banging around in cages," but it was no trouble at all. 3043

(L-1011) Yes! The first two or three simulator rides I didn't know where I was. Three times I got disoriented on an approach. After that it all came back to me. 3052

(L-1011) The 757 experience actually enhanced my understanding and handling of more antiquated avionics. 3053

**D. Based on your 757 experience, please describe your feelings about flying highly automated aircraft versus less automated aircraft.**

Note: the author made an attempt to classify and table the responses to this question into generally favorable and unfavorable, but this proved to be too difficult to interpret. Suffice it to say that the responses ran about ten to one favorable toward automation, with a considerable number of "mixed feelings." The specific comments listed below reflect the feelings on this question. Aircraft type in parenthesis indicates seat occupied at time of questionnaire.

#### Crew Comments

(A-300) I like the 757 automation. It has a tendency to keep one heads-down, but I can't say one way or the other if it made the job any easier. Sometimes I think we perform better if we have to work harder. 3001

(B-727) The transition to the 757 was radical. It took me approximately six months to feel comfortable in it. About another six months to feel that I had seen all the different looks it could give me and that I could handle them. I was 49 when I checked out on the 757. I prefer the automation now, but wasn't sure about it until approximately six months experience. I feel that with the automation comes a higher workload in the 757, but it does not require the third man. I would prefer to fly the 757 full time. 3009

(A-300) My personal belief is that the 757 carries automation too far. The tendency is to be tied up with last-minute program changes in the very environment which requires the most vigilance. Also in an attempt to eliminate the third crew member with automation, the crew is deprived of a human with which to watch for other aircraft and serve as a backup in abnormalities or emergencies. All too often, with a long list of C.I.s <carried items>, which may be very legal according to the MEL, the value of automation is virtually lost. The third crew member is not subject to these reductions in performance. 3021

(Retired) Automation properly programmed and applied is a great help to the pilot who uses it as a tool, not as an end in itself. I think the GPWS is an example of poor automation, because it is too sensitive, too restrictive etc., but maybe just another example of growing pains. Automation should never be used to replace judgment or common sense, which are the pilot's unique capabilities. And the pilot must always use the computers with alertness and awareness. 3038

(A-300) The pilot gets more into programming and monitoring, but still can hand-fly all he wants. I'm sure that all future airliners will have but two pilots and an array of even more

automated flight and other systems and better performance. I enjoy it <automation> and look forward to more of it. 3043

(L-1011) I liked it, but would have liked to have known more about the 757 before going to the line. Training was much too compressed when I went through the program. Too much time on computer and not on the plane or flying. But "time is money" and emphasis is to get us back on the line fast. 3052

(B-747) I enjoy the 757 and its systems. I find the 3-man crew more appropriate on the wide-body aircraft. I would like to see the FMC and glass cockpit on the 747-400, but I see a problem. Many promises were made to add additional equipment for international flying, such as SatCom, automatic position reporting with improved ACARS, etc. It is now apparent that the costs are too high for many of those features. The -400 will be introduced with the same frustrating problems we have with the present wide-bodies, but we will have to handle them with one less person. Every problem you have on the 757 will be multiplied on the -400 due to the fact that every leg will be 12-14 hours and no chance to maintain proficiency. 4002

(DC-10) I enjoyed the experience of flying the 757, particularly as I gained more experience (500+ hours). The less automated (3-man) cockpit is a more forgiving environment due to the extra eyes and hands. There is little room in the 757 for a weak or complacent pilot. But with a good professional crew it has to be the best machine around! 4007

(B-727) I always felt extra good going to work when I flew the 757. 4009

(B-747) I loved the automation as long as I can decide when and when not to use it. I desire to maintain my own flying skills and would not want to see required usage of the automation. 4010

(B-727) Highly automated - you work quite hard, intensely to 10,000 feet, then it gets very boring. Basically nothing to do till descent. Three or four hours of this with a smoker or one with a personality conflict can turn into a very long trip. Less automated - the workload (727) is more even. You have something to do all the time, rather than heavy, then light loads. The attention span seems to be better with this situation. 4022

(B-747) I can't wait for the 747-400. I feel that it's a dramatically superior cockpit environment and even at peak workload times, a feeling of less tense atmosphere exists. This is because one has a greater "handle" on all aspects of the flight regime, and I feel this is directly attributable to the flight instrumentation. 4027

(B-747) To fly automated aircraft, you need to constantly use all functions to keep refreshed. Because there are so many options, it is easy to forget. I found this to be a problems bouncing between the two (757 and 747). I was never as

proficient as I should be. 4029

(B-747) I enjoyed the 757, but Boeing should consult more with day-to-day line pilots before they release something on us. After all, we're the ones that have to use it -- every day. 4034

(B-747) I think that the automation has come of age. I liked it. The reality is that when something does go wrong (system malfunction) you better have a sharp partner. Each pilot becomes isolated during a problem. One flies, one handles the problem. Neither particularly knows what the other one is doing. So you must trust your crew members 100 per cent. No checks. For that reason I feel that the F/O on the 757 should also take the six-month refresher training. 4044

(DC-10) As with any tool, you learn which features will help you and those that can make more work for you. The only way to learn how to make automated features work for you is by experience. When you go through training you feel that you're working for the FMC. It takes (at least me) 500 hours before one can appreciate what automation can do for me and realize its limitations. 4051

(B-727) More automation, more to go wrong, and in many, many more ways. Some of the autopilot errors defy human explanation. 4062

(B-727) Automation is a must if we are to fly larger and larger airplanes with only two pilots. Like it or not, that's the way the industry is going. Part of being a professional in this business is being adaptable to changes. If automation provides an identifiable increase in safety, then I'm all for it. 4066

TABLE V-9

Intercorrelation matrix for attitude probes in this chapter.  
HIT refers to hours-in-type (B-757).

## PHASE 1

	HIT	p2	p5	p9	p24	p34
HIT	1.00	.14	.09	.12	.30	.15
p2		1.00	.13	.41	.02	.09
p5			1.00	.04	.08	.11
p9				1.00	.02	-.09
p24					1.00	-.05
p34						1.00

For  $n=166$ ,  $|r| > .15$  necessary for significance  
at the 0.05 level.

## PHASE 2

	HIT	p2	p5	p9	p24	p34
HIT	1.00	.04	.12	.02	.31	-.01
p2		1.00	-.01	.23	-.03	.15
p5			1.00	.19	.18	.04
p9				1.00	.14	-.07
p24					1.00	-.25
p34						1.00

For  $n=133$ ,  $|r| > .17$  necessary for significance  
at the 0.05 level.

## VI. COCKPIT ERRORS AND ERROR REDUCTION

### A. INTRODUCTION

The impact of automation upon the production and the prevention of human errors remains controversial. One of the justifications of cockpit automation is that it simplifies the task, removes the human from much of the labor, and therefore prevents at the source the production of human errors. Undoubtedly there is much truth to this. However, it may be equally true that automation induces certain types of errors. There is reason to believe that while reducing small errors, computer-based systems may invite large blunders (Wiener, 1985a, 1988).

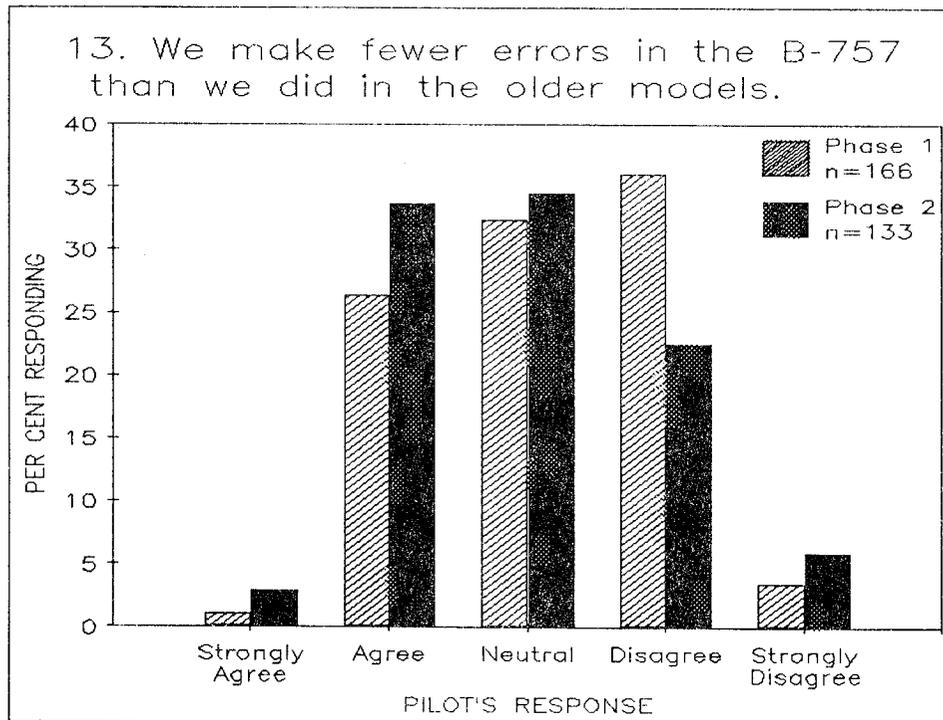
To date there has been no study that could adequately compare error rates in traditional versus high technology cockpits, nor will this study be able to do so. It appears that the modern systems may be at the same time eliminating and producing errors; that certain types of errors are reduced, and others are enabled. The important point is not necessarily whether traditional versus automated cockpits produce more errors, but understanding the errors induced by advancing technology, and how these may be eliminated or controlled. "Controlled" in this context means that errors which are not eliminated may be trapped by the system and not permitted to affect the system's output. More will be said of this later.

The role of warning and alerting systems must also be considered, as they are part of error control. Clearly the 757-era warning and alerting systems (e.g. EICAS) are a great advance over the hodgepodge collection of warnings and alerts found in traditional aircraft. The advanced display systems in the new aircraft play an important role in error control. For example, the map mode of the HSI, intended primarily as a navigation display, stands also as an invaluable sentinel by making errors more evident. If a gross route error (e.g. incorrect VOR or waypoint) were entered into the CDU during route construction, it would probably show up dramatically on the map as a severe course change, and alert the crew to the error. Detection of waypoint errors in conventional autonavigators (e.g. INS, Omega) is far more difficult because the waypoints are determined and displayed numerically, not spatially.

The "plan" mode likewise allows the crew to step through the route, view it on the HSI, and visually detect a gross error. This ability, to visualize a course error, is a great advance in safety over the crew's ability to detect keyboard entry errors in automatic navigation systems where only numeric outputs can be checked. It is foreseeable that future cockpits may also include a vertical navigation "map" which will display present and target altitude as a cross-sectional display, and hopefully reduce the number of altitude deviations.

We should distinguish here between simplification and automation. The first line of defense against human error is system simplification. An example would be fuel management in multi-tank, multi-engine aircraft. Traditional models have contained complex relationships between fuel sources (tanks) and destinations (engines or other tanks), with complex crossfeed and pumping operations, all prone to human error. It has not been unusual to have engines flame out due to fuel starvation when there were ample fuel supplies on board, due to mismanagement of the fuel systems. One approach to this might be automation, but a far more effective beginning could come by simplification of the routing systems. This is particularly important since the task of fuel management has traditionally been assigned to the flight engineer, and with the elimination of that seat from modern cockpits, simplification has taken on new urgency. Recent aircraft designs have done this, producing tank-to-engine routing that requires little management, and hence error reduction. For example, the A300-600 contains an elaborate, fully automatic system of dynamic relocation of fuel supplies during flight. In these cases, Airbus designers have opted for automation rather than simplicity.

An example of both simplification and automation is the management of cabin pressurization. This has benefited from both simplified task demands, and automatic control and backup



systems. Previously, in aircraft with no automatic backup, the failure of the primary system has imposed an extreme workload on the first officer who must manually control pressurization during descent.

Crews have expressed ambivalence about the benefits of automation in error reduction, as one can see in the figure above. Many praise the error-reducing qualities of automation and particularly the backup benefits of the CRT displays, but an equal number have expressed concern about the ease with which they can enter errors into the system via the CDU or MCP, particularly during periods of high workload. And many fear the development of "complacency," a poorly defined term, yet one heard often in discussing automation with flight crews. The fear is essentially that the tasks have become over-simplified, and with constant use of automation, and owing in part to the high reliability of the advanced systems, pilots' alertness may at times falter. Many crews are quite self-critical on this issue, and admit to their own failures to "stay in the loop" during automatic flight.

Almost none question the reliability of the systems; their concern is with their own ability to manage them. As mentioned above, some see the high reliability of the new aircraft systems as a possible contributor to their own complacency.

Much has been written on the nature of human errors, and the literature on the subject is replete with attempts to classify errors. An excellent review of human error in aviation can be found in Nagel, 1988. For our purposes, we are concerned about essentially two types of errors:

1. Slips, such as keyboard errors, or incorrect settings in the altitude alerter on the MCP.
2. Conceptual, or cognitive errors, meaning errors of basic understanding of the systems and the implication of one's actions, e.g. confusion over autopilot/flight director modes.

Errors of the first type are common in virtually any type of system, from homes to automobiles to aircraft. The second type are more typical of advanced systems, in which there are complex modes to be understood, and a variety of means (modes) for achieving a task (e.g. descending an aircraft). For example, in response to the question below, several pilots reported that on final approach they had dialed 00000 into the altitude alert window during descent in Flight Level Change (FLCH) mode, which they later realized was an extremely dangerous practice. (See report No. 1033 under "Vertical navigation - FLCH mode" and report No. 1015 under "Programming: MCP etc." below).

The self reports compiled below are a valuable database of possible cockpit errors. The author has attempted to classify them into various categories of actions; the categorization is

obviously arbitrary. The question on errors committed or observed was the only one repeated on both questionnaires, and hence a large database of incidents ensues. Many of the responses dealt with altitude deviations ("busts"), which was also the subject of a question on Questionnaire No. 2, due in part to the large number of such errors being reported from advanced technology aircraft to NASA's Aviation Safety Reporting System. Those responses dealing with altitude deviations from all three questions are grouped together, following the other responses.

B. REPORTS OF COCKPIT ERRORS

3. Describe in detail an error which you made, or observed, in operating the automatic features of the 757 that could have led to an incident or violation. How could it have been avoided? (equipment design? training? crew coordination?) Please describe specifically what was done.

The responses to this question were read and sorted into various categories. Many of the responses were not categorized, as they dealt not with specific incidents, but general conditions or problems which the respondent felt could lead to error. Information from these responses were used elsewhere in this report. The frequency of occurrence of those that could be classified is given below. In a few cases, incidents were entered into two categories. Following this table are representative examples in the pilots' own words.

TABLE VI-1

The table below displays the number of responses by error categories. The categories themselves are arbitrary and often over-lapping, and the assignment of responses to the categories is also subjective. Due to the nature of the 757 flight guidance system, any report is often the result of errors in the use of several equipment features (e.g. autopilot and autothrottle) in combination. Therefore, the reader should not regard these frequencies as statistical estimates. In a few cases, reports were tabulated under two categories.

<u>Error Type</u>	<u>Frequency</u>
Steps out of sequence, or not in timely manner	14
Incorrect data inserted, or data not updated	24
Failure to remove data, or inadvertent removal	8
HSI mode, MCP, A/T, A/P, F/D setup or mode errors	28
Workload management problems, distraction, time for scan	19

Autothrottle setup, wrong mode, not engaged etc.	9
LNAV setup, failure to engage, mode confusion etc.	21
Vertical nav. - crossing restrict., level off etc.	18
Vertical nav. - FLCH, speed deviations etc.	17
Presumed equipment failures, unexpected events, need to monitor for the unexpected	18
Loss of situational awareness, over-reliance on automation, failure to monitor	6

#### INCIDENTS REPORTED

##### Steps performed out of sequence, or not in a timely manner

Flying CIVET 2 arrival into LAX and cleared for an approach at 10,000 feet and 250 kts., I selected APP mode and the airspeed increased to 290 kts. trying to stay on the G/S. You must get the aircraft slowed and flaps out early. This is one slick airplane. 2041

After having built up initial confidence (about 100 hours) I selected the proper route and performance data. Then, since I was certain of the probable arrival runway at the destination, I inserted the approach and appropriate hard altitudes. After takeoff and departure, when VNAV was engaged, it refused to climb above the selected hard altitude for the arrival selected. It was very confusing for a while. Moral: don't get too far ahead. Select approaches after reaching cruise altitude. 2001

Five miles from the ILS course on a 90-degree intercept, at Vma cleared for visual to one of the parallel runways. APP mode was selected with the expectation that the final would be intercepted as in LNAV, only to have the A/C proceed through the final while turning late to intercept. A/C approached the parallel runway final course. Fortunately, no conflict. Training didn't prepare me to understand that the A/C won't intercept an ILS final with the same parameters as LNAV. 2090

Preselected VNAV prior to T/O, thus setting up the possibility and likelihood of losing V-2 information to the command bars in the event of a loss of engine and subsequent disengagement of autothrottles. In this instance the pilot would have to "fly through" his command bar information to achieve a V-2 climb to level off. Pilots should be advised in training of this hazard, and instructed not to preselect VNAV before T/O. 1058

On approach to PHX on a VFR day we received an amended approach clearance to a different runway using the same nav facility (VOR) about 2-3 miles from FAF. While we had the original approach programmed into the FMC, we did not back up the approach with manual tuning. Our lack of preparation to take over manually caused us to overshoot our course and ended in a missed approach. 4018

Forgot to set 29.92 in altimeter through FL180. I recommend a small white light on the altimeter, illuminating when climbing or descending through 180. This would be a reminder, and would be reset by pushing it. 4028

#### Incorrect data inserted, or data not updated

The aircraft is harder to slow down and get down than most. On several occasions early on, I had to reject landings due to over-concentration on low altitude programming when ATC requested high speeds until close in. Also, I almost landed on 22R at EWR because wrong runway programmed. We were cleared to land 22L in low-vis with departures in progress on 22R. F/O saved the day at the very last minute. Also several ALT-CAP incidents at T/O with 2000 foot climb restrictions. Speed mode cuts at low altitude, catching us unawares. 1026

Holding radial rather than inbound course was inserted, which put holding pattern in wrong place. More emphasis on holding in training would be helpful. 1029

My first trip in 757 an experienced F/O (18 months on 757) updated the IRS's at MSY by inserting the IAH lat and lon. The FMC accepted the data and the map was displaced the distance between the two locations. I had no idea as to what the problem was. The situation was compounded by a complete loss of VHF com and a thunderstorm that closed IAH and HOU (alternate). Regained VHF com and went to AUS, low fuel. Next day I did all the FMC programming myself. 1043

I misspelled a W/P, which the FMC accepted. I was rushed and activated the route without stepping through the route to check leg lengths and headings. The only warning I got that something was wrong was the "insufficient fuel" message. 1057

Improper heading for ILS inserted in ILS head selector, causing the A/P when set on the LOC to turn in the opposite direction to intercept the LOC. On a parallel R/W this could cause lots of problems. 1031

A Mach number (without a crossover airspeed) was manually entered in the DES page. During what appeared to be a normal descent from the top-of-descent point, while preparations were being made for the approach, we received a Mach/speed warning. It was not immediately obvious what had caused the overspeed, but it was an immediate distraction. 1061

Due to very poor ATC communications in the LAX area, controller calling an intersection by the wrong name; he used the local nickname if you can believe that! We were pressed for time and the wrong ILS course was set in. In the 757, the wrong course will not take you down the LOC path. This should be made to operate like the 727, i.e. you will still follow the correct path, but have the wrong heading displayed. This was an IOE flight with a new captain. 2002

The load advise from a previous flight was used and loaded into our FMC for departure. It was the same flight number and only one "page" prior to our load advise on the ACARS display. The situation could have been avoided by more carefully checking all information on the ACARS message by both crew members - even though you are taxiing the aircraft at the time. We departed with the wrong information in the FMC, however the mistake was not great enough to cause a problem, i.e. the GW and CG were close to proper numbers. We corrected inputs in flight. 2068

Programming: Failure to remove data no longer appropriate, or inadvertent removal of data

Some of our arrivals in the FMC have vector provisions. These give the FMC a problem in calculating the descent profile. Almost everyone removes them from the STAR. If one does not remember that he has performed this deletion, and selects "HDG SEL" at the proper time, the A/C will not follow the proper STAR path. 2011

Flying SID out of EWR using the HDG SEL and VNAV, both of us forgot to check the LEGS page for altitude restrictions. Very busy terminal area, no time to be deleting altitudes or looking for "Climb Direct". The autoflight system will never violate the altitude set in the MCP. Let me set in the altitudes in the MCP and remove all hard SID altitudes in the database. 2051

We were descending with clearance to cross ZZ miles prior to YYY VOR at FL AAA. We had been requested to start descent early for traffic. I had put the descent restriction into the FMC because the F/O was occupied with other duties (ATIS, gate, radio etc.). I was descending at 1000 fpm to intercept the VNAV glide path from below. We were then cleared direct to YYY VOR. The F/O programmed the FMC accordingly but neglected to reprogram the descent information. I did not catch his error because I was occupied with turning the A/C to the new heading. Finally I realized the error and deployed the speed brakes and barely made the crossing restriction. The problem could have been avoided by each of us being more "in the loop" with each other and/or better communication or an internal FMC programming change so that descent restrictions are not lost when direct clearance is given. 2076

Forgot to put cruise altitude in FMC and at 600 feet on takeoff,

autothrottles started back to idle. Also, climbing out of LGA, flying by hand, autothrottles went toward idle going through 2500 because of restriction in SID which was not deleted. Reprogramming below 10,000 while on departures is difficult. 1068

Forgot to delete hold-down altitude in SID. Was hand flying and as the aircraft passed through the restricted altitude (which had been deleted by ATC) the throttles went to idle. 3044

See also No. 2052 under altitude deviations.

Programming: MCP, Autopilot, Flight Director, Autothrottle mode errors and omissions

Had F/D displays on and at the same time thought I had autopilot on. Didn't notice the small "F/D" in the ADI. Of course the plane didn't respond to any of my "programming". Just happened to catch it on a change of heading (instead of an altitude capture) or would have been an altitude bust. This could be easily avoided (besides me paying better attention to annunciators) by color-coding the ADI annunciators differently for F/D and A/P. 2029

Copilot made an autoland approach to a landing and roll out. During the latter part of the roll he gave me control of the aircraft. Not realizing that the aircraft had not been disconnected from the A/P, I attempted to exit the runway, putting considerable stress on the landing gear. Finally realized that the A/P was still trying to maintain center line. Problem was lack of experience and crew coordination. 2045

A mechanic was removing the No. 2 altimeter and I was standing out of the way watching. The F/O reached across the pedestal to assist the mechanic as he was having difficulty installing the altimeter. His arm must have touched a select button on the climb page, in this case we believe it was the S/E <single engine> climb speeds etc. After completion of the mechanical work I got into the seat and the F/O said that the route was in and needed to be executed. By this time (I think I was on the RTE page) I executed what I thought was a route activation. I looked at the HSI to verify this, but the route did not activate so I went through the steps again. This time it took. I said, "That's strange" but forgot about it. Everything was normal until climb power was called for and VNAV was selected. The power went to max cont. and VNAV disengaged. This confused us both. So I told the F/O to see if he could fix the problem and that I would fly the aircraft. We pulled breakers etc. but finally went to the DATA page, then the CLB page and found out we had selected S/E climb performance inadvertently and then executed it. Not sure how to prevent this error. Maybe the EXE light should not light unless the corresponding page is in view. 1006

A typical visual approach: airplane is on a high downwind,

throttles in idle (FLCH), and the MCP altitude twirled down to zero to avoid warnings. Turning on final and now in the groove, I expect to have A/Ts but do not - they never reached the MCP altitude to come out of hold, and the airplane gets slower and slower. By now I am remembering to punch SPD button to get A/T back, or advancing manually, but this combination surprised me three or four times. 1015

On approach to LAX 25R, ILS and glide slope captured. Runway changed to 24L about 10 miles on final. Mentally I was expecting this, so I just put in the new ILS frequency. The copilot reprogrammed the FMC. The map told me I was left of the localizer. The Loc display showed me to the right. For a minute I was completely confused. The problem turned out to be that after a capture, you cannot select a new ILS freq (automated design). My ILS was still on 25R. 4029

While cleared for a Quiet Bridge visual approach to 28R at SFO, the captain flew through the approach course. We entered the approach path for the parallel r/w 28L before he realized the error and corrected. We were on autopilot with F/D and heading select and altitude hold. If approach mode had been armed, we'd have remained on "our side." I was busy tuning and talking and didn't back up the captain. 4025

I flew through the localizer (toward a parallel runway) on a Loc back course because I was following the F/D (on heading select) with the Loc armed and the front course properly set in the window, but I had failed to arm the back course feature. The captain did not notice it because of heavy workload. 4035

I left the HSI in plan mode (oriented north) and took off on Rwy 36 at DCA. (Orientation was correct because of north departure). I think I would have caught it had we taken off on another runway. We turned up the river as cleared and entered low clouds and severe turbulence at 1500 feet. (Wind on ground was 360 at 65 kts). Continued left turn and my HSI still said 360 degrees. HSI mode should be on T/O checklist. I suggested this to company, but not adopted. Obviously I should have returned HSI to map. ATC was very unhappy with me. 4045

#### Workload management; distraction; time for scanning

ATC changes below 5000 feet, i.e. runway changes at LAX. Both pilots had head down and did not see light aircraft approximately 1500 feet away. 2010

I've had only one major problem and it could be dangerous. Going into LAX for the first time, getting all set up to land on 25L then at last minute they switch us to land 24R. We spent too much time trying to program the computer and came in too high and had to make a go-around. I believe that habit <excessive programming in terminal area> is an accident waiting to happen. It could have been avoided first of all by changing the ATC

procedure. Another way is to give us more training on these kinds of situations and learn to know exactly what buttons to push when it happens. 2017

I feel that the aircraft should be totally monitored through FL 180 during climbs so as not to miss the 29.92 alt. setting. While climbing out of SEA I began my company time report over radio out of 10,000, as per our SOPA <see Glossary, Appendix 3>. I was involved in this while passing through FL 180. The captain gave a short P.A. about the Cascade Mts. We both missed 29.92 at 180, creating a 400 foot deviation at level cruise. Since in contrast to our company SOPA, I wait until FL 180 before doing any company call business. The emphasis on these calls should be reduced. 2027

Nobody's looking out the window! The emphasis in all airline training is precise instrument flying, not scanning during VMC conditions. (Ever see anyone scan outside in the simulator during VMC?) and those magenta lines and symbols are just spellbinding to watch and everyone does. Visual scanning during VMC is not stressed in training or anywhere else. We missed one <other aircraft> by 500 feet going into LAX on the profile descent. I didn't see it until it was pointed out by ATC. We were in a high workload situation doing the "runway switch" in LAX. 2084

In APP mode landing at LAX after LOC and G/S capture. Runway was changed, new vector given by APC, new LOC frequency given. But when you change the LOC frequency you are still on <the old> frequency because you must come out of APP mode by turning A/Ps and F/Ds off. The LOC of the old freq. is a trap that many crews fall into at least once. It leads to approach plate confusion, lineups on the wrong runways. Parallel runway operation with frequent changes at LAX is a problem. At early stages, head tends to be in the cockpit much too much, concentrating on computers and not outside. After 100-200 hours the situation gets much better. Unfortunately, at my company pilots come on and off the 757 very quickly; seems there is always a "new" man in the cockpit. Setting up departure routes when it is airway-to-airway <see list of "dislikes", Question 1-1, Chapter IV> is time-consuming and can lead to mistakes. My first clearance from KEWR to KMCI was: SMST 9 SBJ SBJ265 J64 J78 J80 CAP LASS02 MCI. I said, "Wow, where is all my time-saving automation?" Our preflight time is now less than 40 minutes (45 minutes prior to departure -- more cost savings). Sure, it can be done, but it takes a lot of charts and time to punch it all into the FMC. 1064

While being vectored for a runway change I was building the approach backwards from the R/W to the MM, OM, IAF etc. Due to the "hurry up" environment, I misplaced one of the W/Ps. Doing a double check with the approach charts, I realized what I had done. 2033

While flying at 12,000 in the MSP terminal area, using weather

radar to vector around thunderstorm cells, which were particularly active, we entered an area of moderate precip, some 15 miles north of MSP. Almost immediately Mode 2A of the ground prox sounded "Whoop, whoop, pull up, pull up", and the weather radar went to solid red on all range scales. Coincidentally, the ACARS selcal aural sounded (indicating a message was waiting) and a flight attendant signaled from the aft section requesting the MSP arrival time. The cacophony of aural signals caused substantial distraction and confusion, and resulted in difficult communication with MSP APC. Our request for vectors was not heard by APC, and a MSP altitude and heading change was missed by us. After several minutes we were able to sort out the aural warnings and calls, and disable the Mode 2 Warning while re-establishing clear contact with MSP. When we emerged from the precip, the weather radar regained its usefulness and we resumed a more normal terminal arrival, using the radar to vector around cumulus build-ups. It is obvious that a third crew member would have been of substantial assistance here, however, a weather radar which is not useful in precip is useless 25% of the time.  
2044

Trying to copy takeoff load advice via company radio because ACARS was inop. As a result one pilot was talking to and receiving instructions from ground control while the other pilot was off the air. Consequently there was a mix-up and we missed a taxi clearance and taxied onto the wrong taxiway. Solution: the automated stuff has to work or you are worse off than the early two-pilot planes. 4054

See also No. 1026 above (wrong input) and No. 2067 below (altitude deviations).

Autothrottle setup errors: wrong mode, not armed or engaged etc.

Level off at low altitude (2000 feet) while still in throttle hold. Power not reduced until nearly 300 kts. We're conditioned to expect autothrottle to maintain speed. 2018

Took off with autothrottles ON/ARM. Is not on the "Before Start" checklist. Could have taken off with less than full T/O power if we had thought that the autothrottles were controlling T/O power.  
2042

During level flight at 5000 ft. (manual) the autothrottles were selected to climb EPR. Speed was 250 kts. We accelerated to 270 kts. before the pitch was changed enough to bring the speed back to 250 kts. Lack of experience with the system was the problem.  
2056

Landing was made at LGA with a short turn time. During descent into LGA the autothrottle was selected to "off" on the MCP. When the checklist was read subsequent to engine start at LGA the A/T switch was missed (checklist does not cover this). During takeoff roll the EPR was advanced to "near" T/O EPR. It was not

discovered that the A/Ts did not go into throttle hold mode until about 90 kts. At that time the mode control switch was placed to "on" and EPR mode engaged. The "throttle hold mode" was then observed but the crew was not aware that the engine power did not advance to proper T/O value, but stayed at "near" setting that was obtained by initial manual advancement. Extra crew member in cockpit alerted crew after T/O. 2094

On a simulator checkride with "hurry up and finish" on the mind, single engine hold and procedure turns, autothrottles off. We forgot the autothrottles were off and one of us setting up for approach and other into the single engine checklist for shutdown, we stalled and recovered OK. This could have been prevented by one of us only flying. 4036

LNAV set up errors, failure to engage system, mode errors

Was assigned a heading to intercept an airway; was distracted and forgot to put the A/P to LNAV from Hdg. Hold. Flew through the airway for a couple of minutes before realizing it. Was my fault -- I was becoming complacent. 2005

Selected an FMC route and then failed to select LNAV. There should be a better warning system if you haven't selected LNAV after programming the FMC. 2050

Vectors by ATC off airway. Re-intercept heading issued but LNAV not armed. I watched as the A/C approached original course and saw that it was not turning to intercept and advised the captain, who engaged LNAV, whereupon A/C immediately turned 25-degree bank at FL 410 to catch up on intercept. This situation was solely a matter of <lack of> crew awareness, and was cured by awareness of non-flying pilot. 2067

I have occasionally programmed something and not executed it and have frequently plotted a direct route and failed to engage LNAV. 1042

Executing new route and not engaging LNAV. Not monitoring the ADI properly. Cross-checking the HSI and ADI after every automated change is the answer. 1063

During departure from PIT the departure controller instructed us to hold 180 degree heading to intercept the AGC 221 degree radial. The first officer was flying, and he programmed the route expecting vectors to a down-line intersection. Upon receiving the vector to intercept the radial, he programmed direct to the intersection he had expected, which resulted in a track different from what the controller expected us to fly. I hadn't checked his preflight programming closely enough to recognize the error. I check every F/O's programming more carefully now. The complacency which led to this could have been a dangerous problem and was my fault, not the equipment. 3008

I made a programming error on an intersection of two airways which almost resulted in a violation. The captain did not check the entries that I made. The new airways maps are getting harder to read and the fact that you get to the point that you hardly refer to the maps leads to the possibility that unfamiliarity with the maps could lead to error. 3034

The most critical error I have seen related to automation was selecting standard arrivals procedures and linking them to a stored route and then finding out later that a fix was not stored in the memory, so that the arrival that I flew was not correct. (For example, I went from A to C, bypassing B because it was not in the stored arrival and I didn't add it as I should have. 4063

Vertical navigation - crossing restrictions and level offs, mode confusions

Forgot to delete an altitude Xing restriction on the SID. This resulted in the VNAV (no matter what altitude) seeking this altitude. After 10 minutes of vertical speed/alt. hold, we realized the problem and deleted the altitude. 2022

After takeoff and selecting climb EPR, the autothrottles were left in EPR mode. VNAV was not selected. During climb at 250 kts. an intermediate level off was needed at 8000 ft. Speed mode was not selected and airspeed started to build rapidly. Autothrottles were disengaged and power pulled back to regain 250 kts. I think training is at fault because this capt. said he had been taught this technique of selecting EPR instead of VNAV with the F/D off. Many people I have flown with do not like to have the F/D on in order to hand fly more. It would be desirable to be able to engage VNAV with the A/P and F/D off, synch the salmon bug <command speed> on the airspeed indicator and the FMC gives the commanded VNAV speed and would still provide protection against going too fast below 10,000. 2024

Called for climb power on climb out (with autothrottles on) without selecting VNAV. Leveled off at assigned altitude (below 10,000) and A/C continued to accelerate to about 280 kts. before I disconnected everything. It seems like equipment could have been designed to never let you exceed 250 kts. when below 10,000 (unless manually overridden). 2034

One of the biggest problems has been the VNAV system. In the climb I have had restrictions on the departure (data base) and not seen them. Subsequently the F/D levels off for no reason seemingly. Also, in descent I get a crossing restriction late and by the time it is entered and processed, no way can the A/C make it. I believe most of this can be avoided by having faster calculation time for T/D points and maybe a visual presentation automatically displayed for any data base restriction without having to select WPT DATA. 1050

Vertical navigation - FLCH mode, speed deviations, etc. (Note: this category not clearly distinct from the one above.)

Was in descent using VNAV with speed intervention of 330 kts. as requested by ATC. Traffic call diverted attention and at 9700 feet realized speed was still 330 kts. (MCP altitude window was set at assigned descent altitude of 6000). Now I avoid this problem by writing down altitude clearance and setting MCP altitude to 10,000. 2031

FLCHed down through 10,000 above 250 knots - more training <needed>. 2062

Program in FMC indicating intermediate altitude level off on some profile descents with a final altitude that is lower. If lower altitude is set in mode panel and you use VNAV, all OK, but if you select FLCH which is more realistic in ATC environment, you lose the intermediate altitude protection. Avoid by selecting limit altitude till past point, then select next lower. Crew coordination -- both crew should know the mode and limits. 2066

The combination of excess speed, the improper setting of ALT SEL, and the use of FLCH all resulted in A/C descending to an altitude below FAF. Pilots need to pay close attention to speed control. No A/C below FAF altitude should ever be set on ALT SEL until FAF has been passed. FLCH should never be used to descend when inside FAF (FLCH could fly A/C to ground prior to RWY if ALT SEL improperly set -- i.e. 00000). 1033

On a flight from SAN to LAX the copilot was flying, using LNAV and VNAV. We were at 10,000 feet and cleared to 7000, 10 miles south of SLI. To speed our arrival, the copilot speed intervened to 300 knots. Around this time I was off the frequency getting the ATIS and calling company radio. He was talking to Approach Control and looking for traffic that was pointed out to us. As we approached SLI 10 DME the A/C started down out of 10,000 still at 300 kts. due to the speed intervention. I caught the error about 150 below 10,000 and returned to 10,000 to slow before continuing descent. 4008

See also 3032 under situational awareness below.

#### Radio communication error

I was making a cabin P.A. announcement while listening to ATC. The controller gave us an altitude change that the first officer misheard, read back the wrong altitude, and the controller missed it! I cut the P.A. talk short and established the correct "new" altitude. Cure? Another pair of ears. 2054

The type of incident or potential violation that comes to mind is descending to cross a specific fix at an assigned altitude and/or speed. On one occasion I heard the wrong distance (10 DME instead of 20) and programmed the system for the wrong fix. The

error was not noticed by my copilot who heard the clearance correctly. 1060

Presumed equipment failures or unexpected actions of automated equipment; need to monitor

Departure from Central American airport which is located in mountainous area, during marginal VFR conditions, resulted in both pilots being head out of the cockpit (nose to windshield) at lift off and initial turns to avoid terrain. "T/O power" had been set using EPR mode and insufficient engine instrument monitoring had allowed autothrottle to "lock in" EPR only. Reliance on engine limiter to protect against engine overspeed and EGT overtemp was a big mistake, since both were exceeded. Discussion of event with maintenance, pilot/supervisor, and a captain from Rolls Royce has convinced me that the engine limiter doesn't <limit> when in T/O mode with A/T on. Ambient temp, field elev., density alt. are all locked in when "T/O power" is selected. During climb from airport, lockout or lockup of fuel control could cause serious damage to engine unless EICAS is carefully monitored and power reduced in timely manner. 1001

We become so accustomed to all systems working correctly that when one fails we don't always catch it immediately. Yesterday, A/Ts failed -- situation: descending to a given altitude. I was reviewing the STAR when ATC asked if we were slowing. I checked the airspeed and sure enough, we had slowed. I manually pushed the throttles up and got speed back to normal cruise. The A/C had descended on VNAV and leveled off at correct altitude, but A/Ts did not keep A/C at cruise speed. I probably could have avoided this by not being distracted by my review of the STAR. 1009

Two times departing EWR west-bound on climb up to 6000 the autothrottles did not retard for level off with a high rate of climb and had to be manually pulled to idle as aircraft dumped over to avoid altitude bust. Aircraft still busted altitude by 400 or 600 feet, even with rapid control forces. 1012  
During departure from EWR the airplane would not level off at any intermediate altitude or at cruise altitude in either VNAV or FLCH. All level offs had to be done manually. After the first altitude bust, we were alert and didn't significantly bust any others; but that first one could have been dangerous as we soared through 6000 at about 2000 ft/min. During descent and on subsequent flights, everything worked perfectly and the only annunciation or alert was the altitude alert as we busted our selected altitude. 1035 (See also No. 1037 under altitude deviations.)

During my IOE I made an approach to runway 33L at Boston. Because of heavy rain and low visibility and my low time in the aircraft, and because I still had eyes as big as dinner plates when flying the 757, I decided to make an autoland. I had made one other autoland at a Cat II runway at LAX and the aircraft had performed exactly as advertised. Therefore I felt that the

autoland capability of the 757 was pretty good. The aircraft tracked the localizer and glide slope right down to flair, when all of a sudden she pitched up and started to roll but immediately settled down and landed on the runway "with a crash". Unfortunately the autopilot landed the aircraft on the left side of the runway and continued to track down the left side of the runway with the left main wheels uncomfortably close to the runway lights/edge. I thought she was headed for the ditch any second. Training <department> seems to have the impression that the 757 will do a perfect autoland every time on every runway due to the "demanding certification" of the aircraft. I have heard of other pilots having similar experiences with the 757, but what I am doing to avoid a repeat experience is that I will not autoland unless the runway is certified to be Cat II <BOS 33L is Cat I> or better or it is a VFR practice autoland, visibility 10 miles or better. 2028

Loss of situational awareness, over-reliance on automation, lack of understanding of systems, failure to monitor

When using FLCH on non-precision approaches it sometimes comes as a shock to the person flying to see the airspeed go below the bug <since he is> thinking that the autothrottle will hold the speed. 3026

Relying on VNAV to bug back the speed at 10,000 feet automatically leads to complacency. When FLCH is used for descent, I have been substantially below 10,000 before realizing that I am still at 300 knots. 3032

1) Autothrottle was inoperative - I was given holding prior to a fix, one pilot programming, the other pilot watching the programming operation instead of the airplane. Airplane slowed to 30 knots below pattern speed. Cause: lack of monitoring properly by pilot flying the plane. 2) On ILS approach, intercepting the glide slope at level flight from below, was fast so bugged back to Vref + 5, airspeed decayed to limit on ADI (no flaps). Cause: misuse of airspeed bug and lack of monitoring. In both cases airspeed problems probably the result of depending too much on autothrottles in past experience. 3039

Captain flying late at night, FL 410 on top of severe weather. EPR malfunction on right engine caused A/T to very slowly retard throttle. Left engine very slowly went to max continuous, but speed dropped off. I noticed speed 20-25 knots below bug speed and advised captain. Too much dependence on automation negated scan. Came very close to a stick shaker/stall over a thunderstorm. Need to maintain scan even at cruise. 3042

My F/O was going to land threshold minus 10 kts. decreasing, nose up 12 degrees increasing -- because it was a practice autoland. We would not only have gotten the tail, but probably would have wiped out. When I told him to take it around he said it was an autoland. I took over and made it from about five feet. An EEC

on the right had screwed up, which we found out at the gate. The big factor was his attitude that some computer would do it all and he didn't have to watch the company seven degree nose up and threshold speed. The autosystem is great, but we <pilots> are the "break glass" if all else fails and we must put out the fire. I don't think his blistered ear made much difference. 4015

I have seen a recurring problem on approaches to airports with multiple parallel runways, especially when the runway is changed at the last minute by ATC, the prime example being LAX. The normal approach is CIVIT profile descent to Runway 25L, which usually changes to an ILS to 24R, then visual to 24L. Well, you can only use RTE 2 for one additional approach (see Figure IV-1). The possibility exists that 1) the wrong approach will be selected; 2) using LNAV the A/C would approach the wrong runway; 3) the automation leads the pilots to follow the magenta line under heavy workloads without manually monitoring the ILS course using raw data. Without the automation the pilot has no choice but to use the manual LOC course. 4040

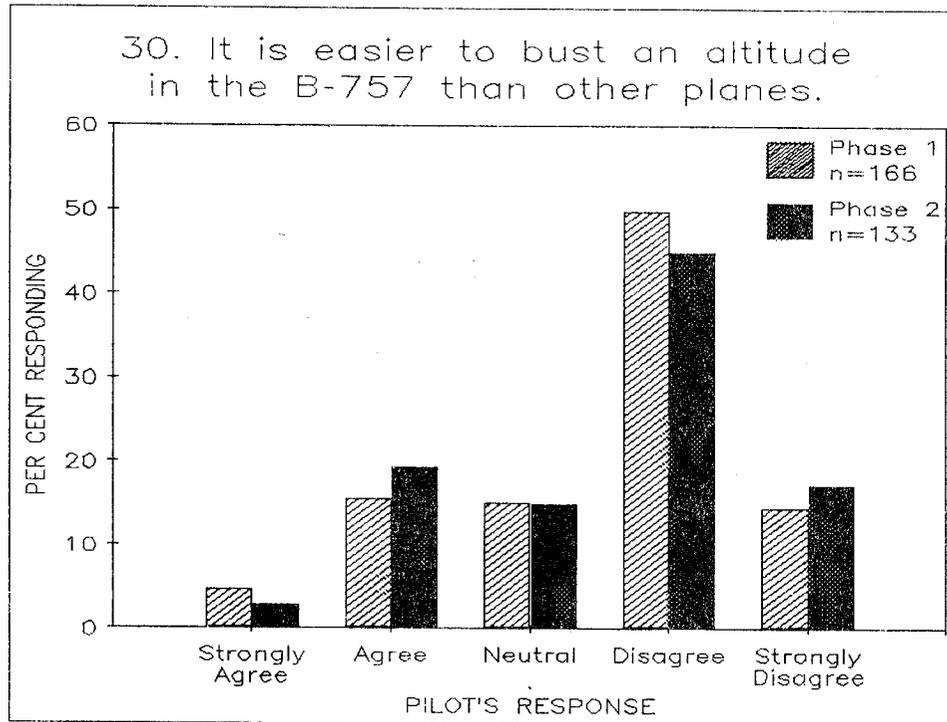
### C. ALTITUDE DEVIATIONS ("BUSTS")

Altitude deviations are a major source of errors in flying in the ATC system in the U.S. About one-third of all incidents reported to the Aviation Safety Reporting System are altitude deviations, and in recent years there has been a rapid increase in reports from the high technology aircraft. The reason for this is not clear. Some pilots have report that the aircraft simply did not execute its auto level off function even though programmed correctly. But most deviations can be attributed to programming errors, or a rather common error of "killing the capture" by inadvertently actuating something, usually vertical speed intervention, during capture mode, causing the aircraft to continue climbing or diving at whatever vertical speed is set.

There are occasional errors reported where the incorrect altitude was set into the window, but these are relatively rare. Most of the deviations in advanced aircraft result from setup errors when in automatic mode, or failing to level off when in manual modes.

Crews are particularly sensitive about altitude deviations since the implementation of the Quality Assurance Program (QAP) by the FAA in 1984. This program automatically detects altitude deviations of 300 feet or more in the presence of another aircraft within five miles, resulting in an increased rate of enforcement actions against crews. One airline captain has conducted his own analysis of altitude deviations (Noblitt, 1987), and ASRS has instituted a special call-back program for altitude deviations in high technology aircraft (Orlady, 1989b).

As the figure below shows, the crews disagree far more than they agree with the probe that states that automation enhances altitude deviations. About 65% disagree with the statement, and about 20% agree.



Marked disagreement as to the effect of hand-flying versus autoflight can be seen in the reports below. Some respondents argue that the bust occurred because they were distracted during hand flying and simply failed to level off; others argue that the bust occurred due to their lack of situational awareness during autoflight, and would not have happened if they had been hand flying. This is a difficult question, that could only be answered by extensive simulator experimentation comparing errors in manual versus auto flight modes. It is entirely possible that both are correct. Clearly altitude deviations, in traditional or modern cockpits, represent a serious safety problem, and need to be examined further by the research, design, and training communities.

## Incidents Reported

Only errors of a critical nature I have seen were two busted altitudes, both by captain flying manually! (3024)

Going to climb power after noise-abatement procedures when there is a low-level clearance - i.e. 5000 feet. A new pilot isn't ready for the climb rate <of the 757> and can bust an altitude. 2014

We had an autopilot which allowed the airplane to descend through a required altitude on VNAV, even with the proper altitude selected. There was no violation because I disconnected the autopilot 100 feet below the required altitude. 2026

On departure when flying a SID which is in the data base and also has a hold-down altitude, several times I have been unable to get rid of the altitude constraint with "climb direct" and VNAV mode. It becomes necessary to go to FLCH. This creates problems at low altitude in a busy area. The programming should be changed or all pilots should be trained to put an "A" <cross at or above> after climb constraints on the LEGS page. 1032

The Oakwood Two departure from JFK contains a 5000 restriction at HUU. ATC always issues a higher altitude before HUU so the restriction must be deleted to climb above 5000. Neither the captain nor I were able to figure out why the F/Ds weren't working correctly until about FL 250. In the meantime I did a bit of flailing around. We both spent too much time "heads down" trying to fix the problem. About the only thing I did right was the turn off the F/Ds and fly it. There was still not enough attention paid to everything else happening outside the aircraft. I believe that problems like this one represent a real hazard. A minor oversight effectively stopped both pilots from performing all of their job for a short time. I'm a little embarrassed because I had heard of this particular problem happening to others. I also felt that I had mentally prepared myself to hand-fly the aircraft when "it" decided to do something strange. In spite of this, I still fell into the trap. 2052

Altitude bust while hand flying in a terminal area. Captain was talking to company about a maintenance problem. I was flying and watching for traffic and talking with ATC. I think an alerting tone when approaching a selected altitude would be beneficial. 2058

Observed a few altitude busts while being hand flown due to distraction with company paperwork and radio calls, ATC radio calls and routing, and A/C abnormalities. This aircraft needs an altitude alerting system that signals the approach of an altitude, not after you bust it. I realize that this is contrary to the "quiet cockpit" philosophy touted by Boeing, but the standard altitude alerting system in other aircraft is distinct enough and recognized by all pilots to be immediately identified and not confused as an EICAS alert message. The one extra

cockpit sound is well worth the compromise of that philosophy. No extra training or crew coordination would be the cure. 2067

The problem was busting an altitude due to a programming error and ATC not realizing it either until we both suspected something was wrong at the same time. We were given an altitude crossing restriction and the other pilot entered it in the FMC prior to the wrong point. This resulted in us flying over the point too high and flying to another point prior to reversing course to comply with the entered restriction. The entry was made when I was off frequency talking to company and I was not in a position to update the entry made. Sometimes workload does not permit the "two person rule" to be exercised. No violation was generated because ATC did not catch the error either because the controller admitted that he was overloaded himself. 2077

After departure from LAX r/w 24L, ATC assigned 5000. Since we were climbing over water, we elected to skip quiet EPR and reduced to climb power. ATC assigned a left turn to hdg. 180. During the turn (hand flying) I went through 5000 to 5300, then returned to 5000. After analyzing the interrelationships of the flight guidance systems, I realized that if I had turned on my F/D and selected VNAV immediately after selecting climb EPR, the ADI would have announced ALT CAP, the F/D would have commanded a level off, and the autothrottles would have observed the 250 kt. limit. This is now my habit. 2083

My flight was planned at 37,000 feet and this was entered into the FMC. During climb, a clearance to 41,000 was received but not programmed into the FMC. The aircraft leveled at 37,000 and I was unaware of this not being the proper level off altitude for several minutes. Proper crew coordination probably would solve this, but system could have mode warning built in (EICAS if FMC ALT and MCP ALT are different.) 2094

Some time ago on a flight from PDX-ATL we were cleared to climb to FL 410 by ATC and the A/P failed to capture the altitude even though the lower portion of the ADI showed that the A/P had capture the altitude. The alt alert flashed but by the time we could correct the error, the A/C had gone up to FL 420. ATC picked up our error and called. This incident was written up in the maintenance log, but I was never informed what caused it. 1037

Busted altitude twice. It is easy to rely too much on auto level-off feature and autopilot. 1038

On other aircraft I took pride in hand flying the complete trip. One instrument scan exercise I used was to fly the last 1000 feet at 500 fpm, to a smooth level off, practicing the techniques of attitude instrument flying. I bused an altitude in the 757 while hand flying and avoiding a thunderstorm. The vertical performance and my lack of preparation for the level off caused me to pass my assigned altitude. That would never had occurred to me in a DC-9, using my old techniques. 1047

Once during climb out of DCA we were level at say 12000. Advised of reported moderate to severe turbulence between 17000 and 19000 and cleared to climb and maintain FL 230. I selected FL 230, FLCH, and set the A/S to 270 kts, along with climb power. My objective was to climb quickly through the turbulence. Approximately 300 feet below FL 230 with the A/P engaged, it was obvious that we would overshoot the assigned altitude. We were still climbing at some 1500 fpm. I disengaged the auto systems and level the aircraft with an overshoot of 200-250 feet above the assigned altitude. I don't know if this was a glitch or a design limitation. 1055

On several occasions have had the VNAV break altitudes, but have always caught it immediately. Like everyone else, you need to make sure that A/C does what you have told it to do, whether you tell it to do something by pushing a button, or by whatever means. A specific problem I have seen is the disregard of minimum en route altitudes on low altitude charts because altitudes are on the approaches. A specific example is the airport at St. Johns, Antigua. The airport has only ADF approaches. The pilots have requested VFR approaches to be included in the airport arrival program. In this case, one was set up for RWY 7. It would show a fix so many miles out, say 7 or 10 miles, at 1500 feet and straight in to RWY 7. When the weather is VFR at Antigua, usually 2000 scattered clouds, the control will clear you to descend to 2500 and clear you for an ADF approach or visual if R/W is sighted. To me this means maintain 2500 until you see the field and surrounding area. I've had a number of first officers select the VFR approach and start to descend to the 1500 feet depicted on the (approach) LEGS page, which would get them below the scattered clouds and view of the runway. Only problem with this is that about 10 miles out just to the right of runway center line is a 1450 foot hill. My only statement is they should also consult maps and area and approach charts as well as definition of visual approach and procedures. Seeing it on the computer doesn't make it correct. 1056

We once busted an altitude because the F/O was hand flying the aircraft. He was looking out the window and not cross-checking his altimeter. I was preoccupied with paperwork. I think you can become very complacent on the 757 because of all the automation. I think the only way you can overcome complacency on this aircraft is to be alert always. When automation is turned off, be doubly alert. 3007

We busted an altitude when the altitude alerter system was inoperative and carried as a C.I. <"carried item" - maintenance deferred> to be corrected at a future time. We are all much more dependent on this system than we realize. Flying without it really requires retraining and the aircraft should not be allowed to fly without it. 3013

Note: many of the reports in the previous section on general errors involve altitude deviations. See the following:

<u>Error category</u>	<u>Report No.</u>
Vertical navigation - crossing restrictions	1050
Vertical navigation - FLCH mode	2066, 1033
Presumed equipment failure	1012, 1035
Programming - failure to remove data	2011, 2051
MCP, autopilot, flight director etc.	2029

TABLE VI-1

Intercorrelation matrix for attitude probes in this chapter.  
HIT refers to hours-in-type (B-757).

PHASE 1

	HIT	p13	p30
HIT	1.00	-.23	-.14
p13		1.00	-.35
p30			1.00

For n=166,  $|r| > .15$  necessary for significance at the 0.05 level.

PHASE 2

	HIT	p13	p30
HIT	1.00	-.22	-.01
p13		1.00	-.25
p30			1.00

For n=133,  $|r| > .17$  necessary for significance at the 0.05 level.

## VII. COCKPIT RESOURCE MANAGEMENT, CREW COORDINATION AND COMMUNICATION

### A. INTRODUCTION

In recent years the airline industry, NASA, FAA, and NTSB has placed a growing emphasis on crew coordination, intra-cockpit communication, and in general the social process among the crew members. Generically the term "cockpit resource management" (CRM) refers to the manner in which the crew conducts a flight, not as two or three highly trained individuals, but as one team. Further definition and discussion of CRM and social processes in the cockpit can be found in the review by Foushee and Helmreich, 1988.

CRM refers to the manner in which the individual crew members support each other, the roles played by the captain as pilot in command, and the role of the first officer, and flight engineer if a three-pilot crew. It is an encompassing term which includes crew coordination, communication, the use of human and inanimate resources both within and without the cockpit (e.g. company radio, ATC), role definition, the exercise of authority by the captain, and assertiveness by the other crew member(s).

The interest in CRM grew out of a number of accidents and incidents in which the investigations revealed that the crews had failed to function as a crew. In most of these there was a breakdown in role definition: either 1) the captain had failed to seek or to heed the advice of junior crew members, or had created a social atmosphere that discouraged their participation; or 2) the junior crew members failed to assert themselves in pointing out deviations to the captain. These findings were confirmed in an extensive simulator experiment by Ruffell Smith (1979). In these experiments, an over-water LOFT mission was run in a B-747 simulator, and a critical in-flight mechanical problem was inserted. Ruffell Smith's results showed that the crews often failed to work together as a team, or to take advantage of resources, human and inanimate, readily available to them, often resulting in a failure to solve the problem.

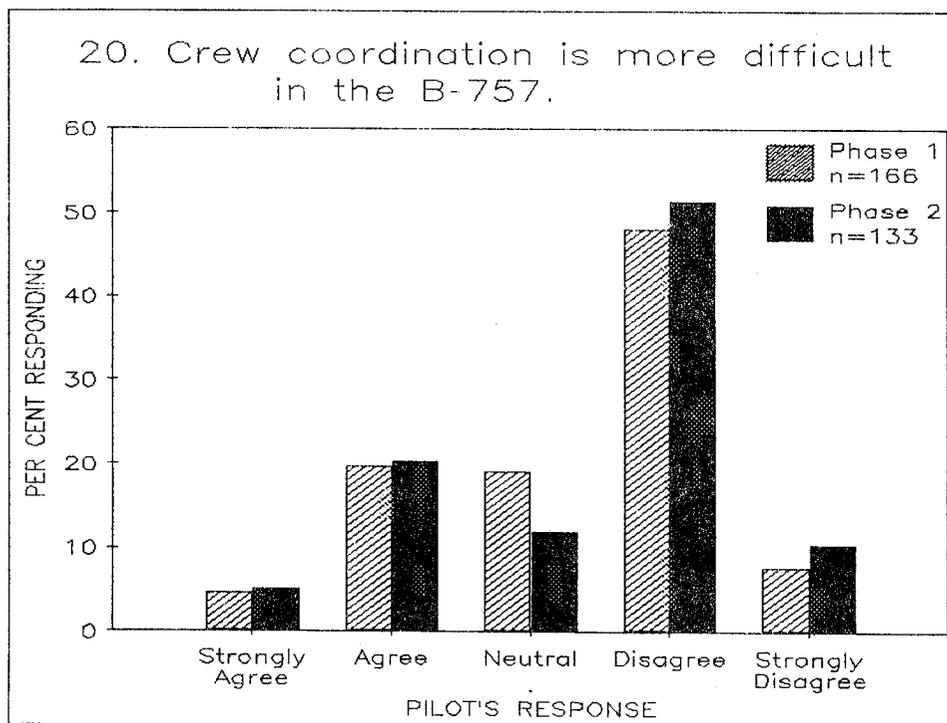
In response to these incidents and accidents, as well as Ruffell Smith's experimental results (1979), and further research at NASA-Ames Research Center, air carriers became interested in training for effective CRM. As a result, a number of U.S. and foreign carriers now have CRM instruction as part of recurrent training, or as one-time courses. Often CRM is combined with LOFT; situations are introduced into LOFT mission that require a high degree of team effort, and at some carriers, videotapes are made during the flight for later viewing by the crews. CRM is not presently required by the FAA, but an Advisory Circular is now in preparation, and many view this as the prelude to an FAR.

Two concurrent trends may combine to bring added importance to crew coordination and teamwork:

1. The movement toward exclusively two-pilot crews as carriers modernize their fleets with two-pilot aircraft and eventually retire their three-pilot aircraft.
2. The introduction of advanced cockpit automation.

While the benefits of CRM are yet to be demonstrated or even examined experimentally, there is good reason to believe that in the two pilot crew, effective teamwork is particularly critical. It can further be argued that cockpit automation exerts an influence on crew coordination and CRM. First, it may be that crew coordination is more critical in the advanced technology aircraft, since it is essential that both pilots maintain "situational awareness" at all times, especially when one crew member is "programming" either the CDU or the MCP. Also, there seems to be some tendency toward a breakdown of the traditional clear demarcation of "who does what." Although certain duties are clearly assigned to the PF and PNF, there can be a relaxation of this discipline: often one pilot will take over programming duties from the other, particularly at times of high workload.

This flexibility to deviate from procedures, and to reallocate duties as the situation dictates is not necessarily a bad thing, as it is an adaptation to high peaks of workload. But it is



clearly a departure from the principles of standardization, which is the foundation of flying safety. In short, it appears that advanced cockpit technology tempts departures from standard practices. At the same time, it seems equally clear that a well-standardized, well-managed crew has little trouble in working together as a team in the automated environment. From the comments that follow one sees a great diversity of opinion.

#### B. COCKPIT RESOURCE MANAGEMENT, SUPERVISION, AND COORDINATION

Item No 20 on the previous page indicates that the crews generally disagree with the negatively stated probe, with only about 25 per cent agreeing that crew coordination is more difficult in the 757. Most of those interviewed expressed the view that crew coordination was no more difficult, but was more essential in the automated cockpit. They often spoke of not understanding what the other pilot was doing; of the problems of two pilots entering data into their CDUs at the same time, with neither looking out of the window. Captains complained of first officers taking too many liberties by actually making decisions that were the responsibility of the captain, by programming their CDU (e.g. points at which to slow the aircraft during descent).

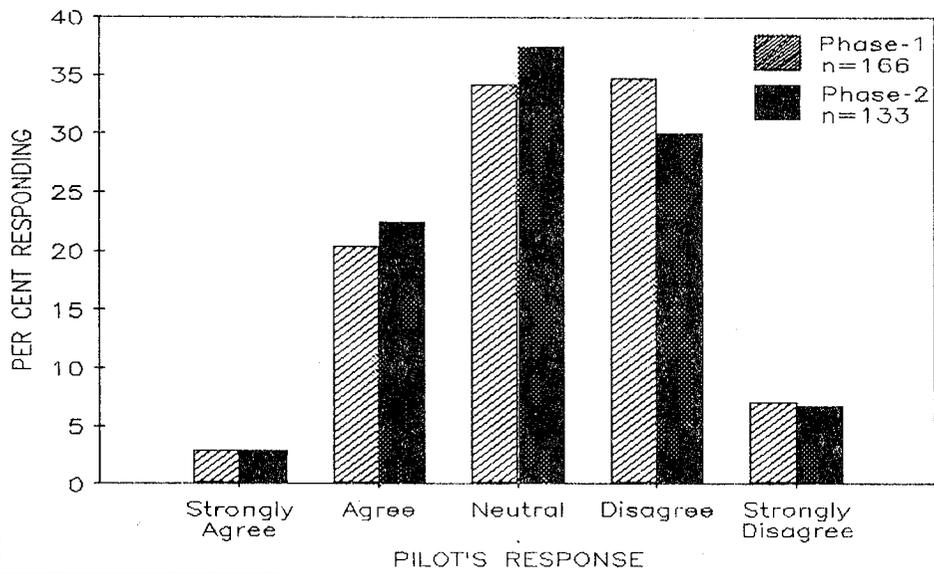
Numerous captains stated that it is somewhat more difficult to supervise the work of the first officer in the automated cockpit. This may be due to the fact that the CDU gives the first officer more opportunities to make decisions than he had on traditional aircraft. Some captains complained of usurpation of authority by the F/Os ("he who controls the CDU controls the airplane"). This is probably unintended, and due primarily to the fact that often the first officers were faster on the CDU than the captains, giving them an apparent "advantage".

Some mentioned that it was difficult for the captain to see what the F/O was doing, and that it took time to digest what had been entered in the CDU, whereas in the DC-9 or 727 one quick scan of the panel revealed what modes had been selected, and hence what one could expect. Although some airlines' procedures call for the captain to approve changes put into the CDU before they are executed, this supervisory step is often omitted.

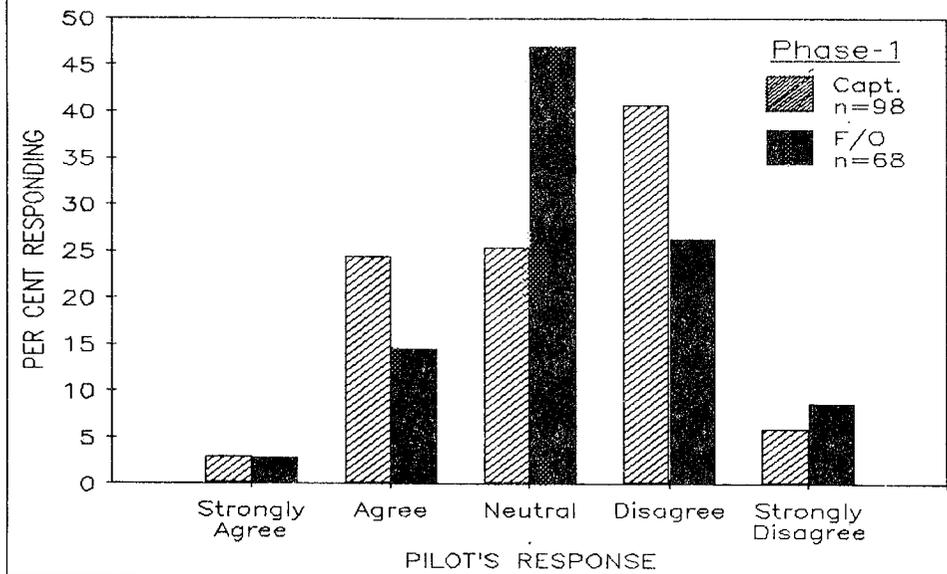
The data presented in P36 shows a clearly divided group on the question of the ease of supervision in the 757 compared to older aircraft. The data contain more than the usual number of "neutral" or "undecided" responses in the center of the scale, and slightly more disagreement than agreement with the probe.

It would appear that if crew coordination and captains' supervision in the advanced aircraft can be identified as a problem, it could be attacked through CRM training and LOFT exercises. It may be that CRM programs, which have always been taught as if they were aircraft model-independent, should be tailored somewhat for the advanced technology aircraft.

36. In the B-757, it is easier for the captain to supervise the first officer than in other planes.



36A. In the B-757, it is easier for the captain to supervise the first officer than in other planes.



P36 was one that produced a statistically significant difference in Phase 1 between captains and first officers, but the interpretation of the results is not clear, particularly since so many F/Os responded "neutral" on this question. The results are displayed in P36A on the previous page.

In spite of the preoccupation with workload and crew size, many respondents provided valuable insights into crew coordination per se. One can see from the comments that follow a rather divided opinion on the question of two versus three pilots, with strong advocates of each position.

### Crew Comments

#### **1-4. What would you say about crew coordination on the 757 (compared to other aircraft)?**

There was a tendency of the respondents to view this question in terms of workload; many wrote only on the workload issue, and particularly on the two versus three pilot cockpit. For reasons discussed previously, crews from Airline-2 tended to focus on the crew size issue, comparing the 757 to 3-pilot aircraft (particularly the 727). Airline-1 pilots, many of whom had experienced two-pilot operations in the DC-9, tended to focus on the automation and the differences between the 757 and the DC-9.

TABLE VII-1

This table displays the frequency of responses to Question 1-4 by general categories. The reader is again cautioned regarding the arbitrariness of categories in the tables. The first part of the table regards the crews' overall evaluation, where they used such words as "excellent", "good", "poor", "less difficult" etc. The author has combined seemingly similar answers such as "good" and "better" into a single category. Comparative adjectives such as "better" or "worse" can be interpreted as comparisons to other aircraft, as suggested in the question.

<u>Response</u>	<u>Number Responding</u>
<u>Overall Evaluation</u>	
Excellent, much better	16
Good, better, easier	55
Same, adequate, OK	17
Fair, more difficult	13
Poor, much more difficult	4
<u>Specific Comments</u>	
Workload excessive in non-normal conditions	10
Workload excessive, requires 3-pilot crew	7
2-pilot operation superior to 3-pilots	8
Workload lower than other aircraft	3
Workload high unless proficient; takes time to acquire skill to manage workload	3
ACARS needed to reduce workload	2
Requires more crew coordination	28
Uncertainty about "who does what"; need for improved procedures and crew duty delineation	10
More training for coordination needed; CRM needed	3
Proficiency critical; weak pilot critical	7
Over-utilization; enter too much data	9
"Do it yourself" tendencies, not coordination	3
"No problems" (so stated) [1]	8

[1] This could probably be interpreted as a "Good" response in terms of the first part of the table.

## Crew Comments

(The following representative comments cover most of what was written about crew coordination. Again, it should be noted that the comments quoted here often involve not only crew coordination, but related issues such as workload, checklists, distractions, procedures, and crew complement).

When hand flying, the PNF must do all programming on FMCs and F/Ds, and both pilots agree on what is selected. During autoflight, PF should program or ask PNF to do it. This airplane requires constant awareness as to who is doing what and this is easily broken down. The 757 requires as much, if not more, crew coordination than other aircraft. 2001

I feel that crew coordination for the most part is good. The company has divided the duties so that neither pilot is overburdened. 2006

Crew coordination is easier on a 2-man aircraft, as both pilots are in the loop and aware of the environment the aircraft is in. This was sometimes not the case in the 727, as captains were drawn occasionally into matters regarding passengers, connections, etc. with the S/O. Having said that crew coordination is better, the ability of two pilots is less apt to take place. While management of two is easier than management of three, the 757 makes it imperative that both pilots be knowledgeable and ahead of the aircraft, as often the PF is a solo act. The workload on a pilot when the other pilot is under the weather or double qualified on other equipment and not recently experienced in the 757 is considerable. 2013

Things work very smoothly if both pilots are sharp. Workload can be very heavy down low in bad weather at a busy terminal. I love this airplane and am proud of my ability to fly it well; but all things considered, a three-person crew is far better. We have lost 90% of the cross monitoring in abnormal situations. 2018

My background is two-man crew. I prefer the two-man crew (smaller loop of communication). I feel that there are times when the captain does not have the time to verify what the F/O is doing (i.e. programming new runways or approaches in the FMC). The F/O must be as qualified as the captain. Therefore I feel that IOE experience is extremely important for F/Os. 2022

The coordination (crew) has to be fully understood, precise, and diligent for the roles of the PNF and PF. This may be attributed more to the fact that the 757 is a two-man A/C than to automation. However, automation does play a large role if both PF and PNF are trying to do the same job. Also there is the need for more verbal communication, i.e. one pilot is on one frequency

and one is on another. Each needs to know what was said and fully understand the intent of the communication. There needs to be trust in your fellow pilot. 2023

There is certainly more trust and reliability on the pilot. When both are sharp, this works fine, but if either pilot is weak, the other pilot is one tired person by the end of the day. This is especially true when something goes wrong, because you very quickly get out of the loop of either managing the system that has failed, or flying the aircraft, whichever your job. 2027

Compared with the 727, the extra pair of eyes is indeed missed. I find on short legs that the PNF is very busy, but not to the point that safety is compromised. SOPA has specifically assigned crew duties and I have yet to see any deviations. There is an atmosphere in this carrier that in our first two-man aircraft, there has got to be a lot of cooperation among crews while adhering to SOPA. 2031

Vastly inferior to a three-man crew. Both crewmen have to be at peak efficiency to begin to operate the B757 at a safety level compared to 3-man. Any deterioration of performance due to time zones, lack of rest, hunger, etc. must be avoided. Automation, at any level, will simply not replace alert pilots. Major efforts should be made to ensure proper meals, rest, and avoid scheduling pilots to fly vastly different times in successive duty periods. The tradeoff of two-man crew with high automation has thus far ignored the human factors involved with long duty periods involving high-altitude, long-range flights. This must no longer be ignored. 2038

Two problem areas I see with respect to crew coordination on the 757 are (1) short en route time operation, and (2) malfunction analysis and handling. An insight into problem (1) can best be gained by recounting the 28 minutes, off-to-on, of a flight between LAX and SAN. The following scenario, while typical, is not exact, and is for illustrative purposes. Times are given in minutes after takeoff in the first column:

01	Flight	Establish contact with LAX departure
01	LAX CTR	Take heading ---, expect climb in 5 miles
03	LAX CTR	Take heading ---, climb to 11,000 feet
03	LAX CTR	Traffic 2 o'clock, 10 miles
04	LAX CTR	Contact LAX CTR, frequency ---
04	Flight	Establish contact with LAX CTR
05	Flight	Climb check
05-06	Flight	Contact company LAX gate radio, give departure report
07	Flt Att	Coffee?
08-09	Flight	Contact MSP company radio, give dep. report
09-11	Flight	Give P.A. announcement to passengers
12	LAX CTR	Proceed direct ---, contact Center freq. ---
13	LAX CTR	Take heading ---, descend to 5,000 feet
14-15	Flight	Tune SAN ATIS, copy SAN weather and runway
16	Flight	Descent check

16-17	Flight	Select arrival page of CDU. Program SAN arrival
17-19	Flight	Check landing weights, select LOC freq. and course. Select minimum altitude bug and set airspeed bugs. Readjust altimeters, announce flight attendants, approach check
20	LAX CTR	Contact SAN APC, frequency ---
20	Flight	Establish contact SAN APC
21	SAN APC	Take heading ---, descend to and maintain 3000
22	Flight	Approach check, challenge and response
23	Flight	Contact SAN gate radio for arrival gate, give inbound time
24	SAN APC	Descend to 2000 feet, direct REEBO, maintain 2000 feet until intercepting LOC, cleared for localizer 27 approach, maintain 170 kts. to REEBO
24	SAN APC	Contact SAN tower 118.3
24	Flight	Establish contact with SAN tower
25	SAN TWR	You are high. Can you make the runway from your present position?
25	Flight	Request 360 degree turn
26	Flight	Landing check
27	SAN TWR	Cleared to land
28	Flight	Touchdown

2044

Crew coordination is easier than on a three-person aircraft during normal operations. When traffic gets heavy, the weather bad, or there's a mechanical problem, you miss that third person. Two people then have to do the work of three when you feel like you need four to get everything done. There are many possible errors with only two: missed altitude, missed or improperly performed checklist, no one to look outside long enough, only one other set of ideas. With two pilots it's so easy for one to get involved in his own work that there is reduced or no backup for each other. There is a potential for disaster with one pilot out of the loop. 2052

I give my F/O a briefing before each trip begins on what I expect. My biggest concern is the F/O being in too big a hurry to push buttons, especially when in autopilot mode. A major problem is close to the ground, especially on T/O with an engine failure or fire. I'm a strong believer in "sit on the problem." In this case, more harm can be done with a wrong decision than no decision. I wait till both pilots know the problem and agree on the solution. The FAA wants you pulling and pushing switches if a fire light comes on, instead of waiting. Aircraft control is what you want and what needs to be maintained. Slow and careful is the choice. 2066

I think this question is an easy target for almost everyone to say that it is harder. But I think it is only a matter of different considerations that come into play, not an increase in difficulty of task. Greater awareness must be had of your own

actions and their effect on the other pilot. I feel that the extra burden <two-man crew> is something that all 757 pilots are aware of, and are tuned in to, expecting and accepting. It is very much within the abilities of a well trained and professional pilot for normal operations and minor abnormalities. Major emergencies and failures or compounded problems are another story, and a major shortcoming of two-man crews. 2067

Crew coordination is everything on the 757. Personality differences, effective communication skills, resources management, setting priorities, proper habit patterns, and clear delineation of duties are immensely magnified in importance on this aircraft. It does not overload you as long as you plan, coordinate, communicate, and execute according to precise operating habit patterns. 2076

The atmosphere I have found to be the most democratic of any airline cockpit. Both individuals inherently know they need one another due to the lack of the "luxury of a third person". Individually each pilot places more faith in the other due to having to work alone on something due to the workload requirements. In addition, I do not think the S/O has been eliminated per se. What has happened is the captain and the F/O have split the S/O's responsibilities and carried them out. 2077

(1) Some captains are reluctant to engage in activities previously handled by S/Os and the F/Os on a three-man aircraft (company reports, maintenance write-ups, etc.). Thus coordination suffers. (2) During emergencies, there is much less coordination in the two-man vs. the three-man crew. (3) I know of one captain who does not allow his copilots to even touch their CDU! 2088

Not as good sometimes. We spend time figuring out or monitoring the A/P and not really announcing our intentions to the other pilot. Sometimes we get out of the loop. Complacency and lack of discipline seem to be common problems when the automation is used. 2090

The cockpit can be the most boring with the least to do, or the most hectic and overworked. 2096

It is generally good and the automation makes the reduced checklists work nicely. But the bottom line is a third crew member in an aircraft without the advanced automation is a far safer system. The extra eyes and mind is a better deal, especially in terminal areas, than all the automation I've seen on the 757. The automation doesn't see other A/C or provide backup for ATC instructions. 1027

Being requested by ATC to descend at a faster rate, I used speed intervention to make a more rapid descent, got distracted, and almost went through 10,000 feet at 330 kts. Crew coordination <was the problem> -- I should have let the F/O handle the problem until back to normal descent. Crew coordination can be a little

more difficult, due to the need to monitor what F/O is putting into the computer, especially airway intersections. 1030

I think this area needs more emphasis. Many times while hand flying, I am expecting the captain to perform some duty for me such as a change in the heading bug and altitude selector as changes are received from ATC. When he doesn't do it, I have to take time to decide whether to ask for it or just do it myself. This is sometimes, but not always, related to the fact that in the terminal area, the PNF can be very busy with ATC, company communications, FMS programming, MCP programming, etc. 1032

Crew coordination is perhaps the most difficult thing to attain. Most pilots come to A/C from first generation A/C where the one-man act could be accomplished. The 757 requires more discipline on the part of the pilot. He must read and evaluate information and proposed changes to the flight path. A pilot gets a "free look" at a change if he will only look. 1033

Crew coordination is really not necessary. One person could fly this A/C safely. I have seen either crew member sort of "take over" the operation of the 757. The only problem I see is boredom, especially on long flights! There is not enough to keep busy. I have seen crew members compete for the few duties. 1038

If both pilots understand the automation functions, it's great! If one or both pilots do not, then it is bad - very bad. 1046

Crew coordination is excellent. However, the "over-enthusiastic" pilot can often get carried away trying to do too much, too fast, too soon. That can jam up the CDU, confuse the other pilot etc. It's usually good to verify at the start of the trip how inputs of data and ATC changes will be made. 1052

Crew coordination is basically the same as the DC-9 until it comes to the computer. On our airline we alternate actually flying the A/C. On the 757, we have said the PNF will operate the computer as far as route changes are concerned. With the advent of the full-up VNAV, I have found it necessary to say that the VNAV portion must be left to the PF. Why? Because I find that so many pilots want to put in too much information in the computer, such as airspeeds and altitudes. I know what's in the computer as to altitudes and airspeeds, so when I push VNAV I know what airspeed the computer will go to. Yet when some one else changes these to 130 kts. over threshold 50 feet, I find I have to not only fly the plane when it is my turn, and also look out the window for aircraft, but I also have to watch him (F/O) to see what he's putting in the computer. 1056

Crew coordination is excellent! A bit better than the DC-9. Since both pilots have to be familiar with the computer, the F/O is more a part of what is going on than in the DC-9. I think the higher level of training produces a first officer who is really a part of the crew as opposed to feeling like excess baggage in some three-man crews. 1066

Crew coordination? It's very difficult for a pilot to ask the F/O or captain to push all the buttons when called for. The tendency is to do this by yourself. Programming in the terminal area is a problem. Most pilots do not have their terminal charts readily accessible. The aircraft capabilities make us lazy. The tendency is to get complacent, although one scare as a result of being unprepared is usually enough to make you less unprepared.  
1067

(Note: other comments on crew coordination and communication can be found in the chapters on workload, and cockpit errors.)

TABLE VII-1

Intercorrelation matrix for attitude probes in this chapter.  
HIT refers to hours-in-type (B-757).

PHASE 1

	HIT	P20	P36
HIT	1.00	.20	-.17
p20		1.00	-.35
p36			1.00

For n=166,  $|r| > .15$  necessary for significance at the 0.05 level.

PHASE 2

	HIT	p20	p36
HIT	1.00	.02	-.21
p20		1.00	-.33
p36			1.00

For n=133,  $|r| > .17$  necessary for significance at the 0.05 level.

## VIII. WORKLOAD

### A. INTRODUCTION

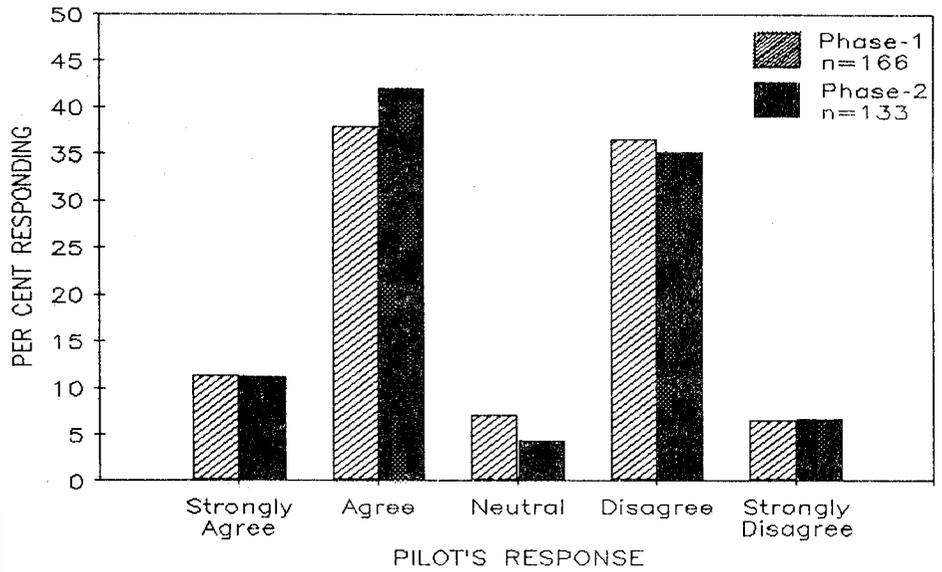
Cockpit workload is central to the question of automation, as the rationale and justification for automatic devices has always been that they would effect a reduction in pilot workload. The ability of automation to reduce workload was largely the basis for the decision of the President's Task Force on Aircraft Crew Complement (1981) to support the development of two-pilot cockpits for future transports. Finally, workload is a subject evoking strong opinions on the part of most pilots.

The very definition of pilot workload is troublesome, and its measurement has occupied human factors engineers and design engineers for several decades. Much has been written on the subject, and periodically a new workload measure is proposed, experimentally tested and debated, but the search goes on. Designers and FAA certification personnel inevitably fall back on subjective measures, such as the time-honored Cooper-Harper scale. For a recent review of pilot workload and workload measurement, see Kantowitz and Casper, 1988.

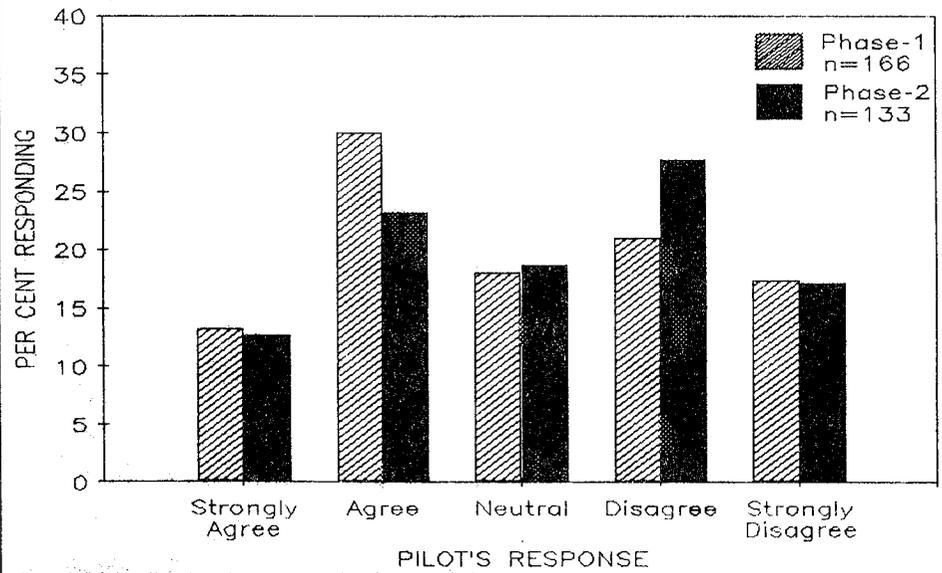
One feature of workload measurement that is particularly vexing, and especially important in the advanced technology cockpits, is mental workload. Mental workload defies measurement, possibly even definition, because it is largely unobservable. But there is no denying that mental or cognitive activity is a large and important component of total workload, and further that it becomes a larger and more significant component as automatic features are added to the cockpit. To some degree, manual workload is replaced by mental workload in the advanced aircraft. On the other hand, it may be argued that automation can reduce mental workload, as for example, in computing top of descent (TOD) points, and computing VNAV paths to make good on a crossing restriction, a maneuver which creates high cognitive demands in traditional cockpits.

The advanced displays present in the 757 are very effective in reducing mental workload. The two features of the EFIS cockpit most frequently and favorably mentioned are the HSI map display in general, and in particular its green altitude predictor arc. Both are clearly instrumental in reducing mental workload. Likewise the EICAS displays reduce much of the requirement for systems monitoring. The author heard only favorable comments about the EICAS, and most pilots spoke favorably about the automation of the general airplane systems and their ease of operation. Automation is usually discussed in connection with flight path control, but in a pilot's mind, systems operation and monitoring looms large as a workload issue. They view most favorably functional system automation, which seldom fails and generally is not vulnerable to crew error.

18. Automation does not reduce total workload, since there is more to monitor now.



26. With the automation available today I prefer the two-pilot cockpit to the three-pilot cockpit.



One cannot discuss cockpit workload with pilots without confronting the question of the two-versus-three pilot cockpit. This is seen by crews as part and parcel of the workload picture, and for good reason. There are a large number of pilots who have spent most of their career in three-crew aircraft, and who feel strongly that for a variety of reasons, most but not all related to cockpit workload, and that the reduction to two pilots is a compromise with safety. Others feel equally strongly that two pilots can do the job, and that crew coordination and CRM works better in this environment. As mentioned previously, most of the Airline-2 pilots in the study had never flown two-pilot airliners, and they were particularly resistant to concept of the two-pilot cockpit. This opinion was shared by some of the Airline-1 pilots, but in general those with DC-9 experience seemed to favor the two-pilot design.

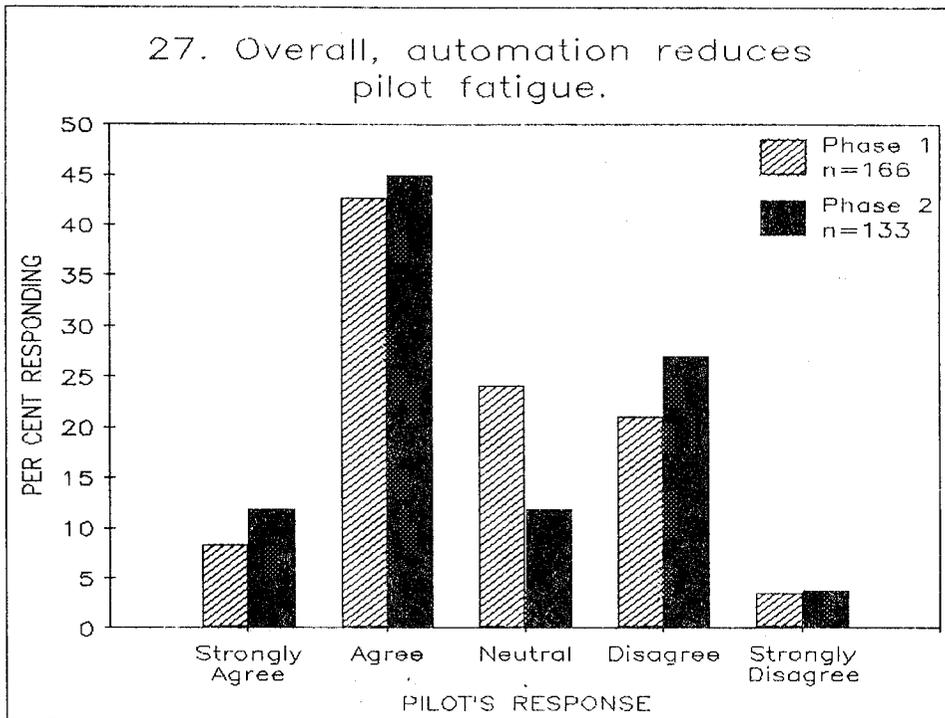
The data displayed on the previous page in P18 and P26 reflect two rather fundamental questions, and they could hardly be more symmetrical, indicating a deep division on the question of workload in the 757, and the importance of the flight engineer. The data in probe No. 18 indicates that the 757 pilots were about evenly divided on whether or not this increases the totality of workload.

Those who still advocate the three-pilot cockpit advance not only workload as their argument, but several other factors as well. They speak frequently of the "third pair of eyes" for collision avoidance (which also may be regarded as a workload question), the role of the S/O in monitoring and backing up the pilots, and the frequent use of the S/O as the interface between cockpit and cabin. With no S/O to perform these functions, they fall on the two-pilot crew. Many state that if the a problem requires a pilot entering the cabin, "we are left with a one-pilot crew." It is often stated that the S/O may not be essential during normal flight, but is essential when mechanical problems occur. Numerous responses mentioned the role of the S/O in handling company radio communications, which is frequently mentioned as a burdensome demand in 757 operations.

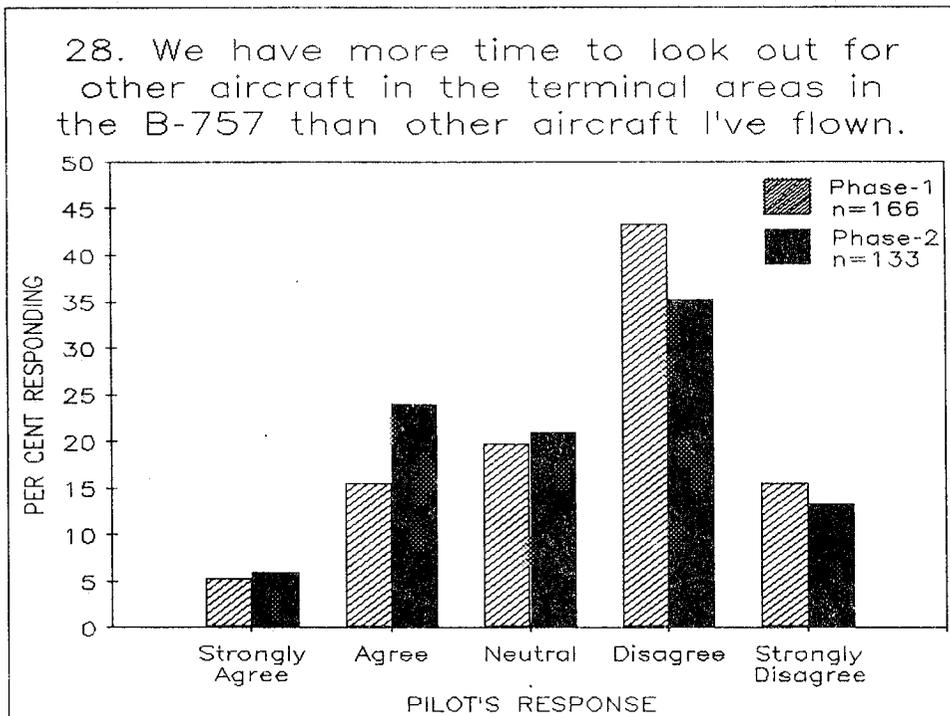
The most frequent arguments in favor of the two-pilot crew state that two pilots plus an EICAS can do a better job of monitoring than three pilots; that it is easier for the captain to perform his supervisory function with two pilots (the S/O being seen as beyond his effect range of supervision); and the generally better coordination with two pilots being able to monitor each other. Even the advocates of the two-pilot crew mentioned the "third pair of eyes," but recognized the coming of TCAS, which they felt will be more effective than an S/O for collision avoidance.

The most frequent comments in both the questionnaires and the interviews dealt with the demands for programming the CDU, especially in the terminal areas, and the effect on "heads up" time. For further information on this subject, see also Chapter IV (Equipment, especially the section on the CDU), Chapter VII (Crew Coordination) and Chapter IX (ATC).

27. Overall, automation reduces pilot fatigue.



28. We have more time to look out for other aircraft in the terminal areas in the B-757 than other aircraft I've flown.



The comments that follow reflect pilots' concern over the lack of time for head-up scanning, and the concern over the amount of time that both pilots are head-down, due largely to the demands of the CDU. Part of this problem is due to frequent ATC changes. As many pilots complain, if they could only count on flying the course and vertical path that they program, their task would be simpler, there would be less CDU demand, and more head-up operation. This problem is clearly most critical below 10,000 feet, particularly on arrivals, when ATC demands route changes, off-course vectors, and speed and crossing restrictions, making LNAV and VNAV utilization difficult if not impossible, and requires speed changes, and frequently runway changes. More will be said of this in the next chapter (IX) on the influence of ATC in advanced cockpit operations. It is noteworthy that about 25 per cent of the pilots responded with agreement to Item No. 28 (next page), indicating that they felt that the 757 allowed more time to look out compared to other models.

The subject of fatigue has not been explored in this study, and was seldom mentioned by the crews in interviews, questionnaires, or during jumpseat observations. Where it was mentioned, most commented favorably on what they perceived as a reduction in fatigue attributable to automation. See Item No. 27, previous page.

## B. COPING STRATEGIES

Frequent comments were made in both the questionnaires and interviews about the management of the automation, and means of avoiding or coping with high levels of workload. Some of these are discussed below.

### Workload Management and Advanced Planning

Numerous pilots stressed the importance of management of workload, and of planning ahead. They recognized the importance of management by doing as much planning and data entry as possible during phases of lower demand. Many stressed pre-flight programming at the gate whenever possible, and likewise for planning and programming during cruise in preparation for descent. For example, during cruise would seem the time to enter winds on the LEGS page; this is routine data entry which could affect the VNAV path, and can easily be done in non-critical phases of flight, before TOD.

A good case for the workload-reducing capability of this aircraft is flying a complex SID, for example the San Francisco PORTE SEVEN depicted on the next page. In a traditional aircraft, where reference must be made to VOR radials and DME distances and frequent tuning of VORs is required, this is an extremely high workload procedure, even for a three-pilot crew. In the 757,

BAY Departure (R) 135.1

**PORTE SEVEN DEPARTURE (PORTE7.WAGES) (PILOT NAV)**

MT SAN BRUNO WEATHER INFORMATION AVAILABLE ON 118.05  
(RADAR REQUIRED FOR RWYS 1 L/R DEPARTURES) (DME REQUIRED)

For obstacle clearance this SID requires the following minimum climb gradients:  
Rwy 19L: 480' per nm to 1400'.  
Rwy 19R: CAT A & B, 480' per nm to 1400'.  
CAT C & D, 530' per nm to 1800'.  
Rwy 28L/R: 300' per nm to 2000'.

Gnd speed-Kts	75	100	150	200	250	300
300' per nm	375	500	750	1000	1250	1500
480' per nm	600	800	1200	1600	2000	2400
530' per nm	663	883	1325	1767	2208	2650

**TAKE-OFF**

**Rwys 1L/R:** Intercept and proceed via San Francisco R-350, cross the 4 DME fix at or above 1600', then turn LEFT to a 200° heading to intercept and proceed via Point Reyes R-135 to cross Porte Int at or above 9000' and Pesca Int at or above 13000'. Then turn LEFT to a 090° heading to intercept and proceed via Woodside R-116 to cross Wages Int at or above FL 200 or at assigned LOWER altitude/flight level. Thence via (transition) or (assigned route).

**Rwys 10L/R and 19L/R:** (Rwys 19L/R departures, turn LEFT as soon as practicable due to steeply rising terrain to 2000' immediately south of airport).

rising terrain to 2000' immediately south of airport). Intercept and proceed via San Francisco R-095 to intercept Oakland R-135 at or above 5000'. Proceed via Oakland R-135 to cross Oakland 25 DME fix at or above 9000'. Cross Wages Int at or above FL 200 or at assigned LOWER altitude/flight level. Thence via (transition) or (assigned route).

**Rwys 28L/R:** Intercept and proceed via San Francisco R-281, cross the 6 DME fix at or above 2500' then turn LEFT to a 180° heading to intercept and proceed via Point Reyes R-135 to cross Porte Int at or above 9000' and Pesca Int at or above 13000'. Then turn LEFT to a 090° heading to intercept and proceed via Woodside R-116 to cross Wages Int at or above FL 200 or at assigned LOWER altitude/flight level. Thence via (transition) or (assigned route). When San Francisco VORDME is inoperative, Rwy 28 departures EXPECT radar vectors to Point Reyes R-135 then resume SID.

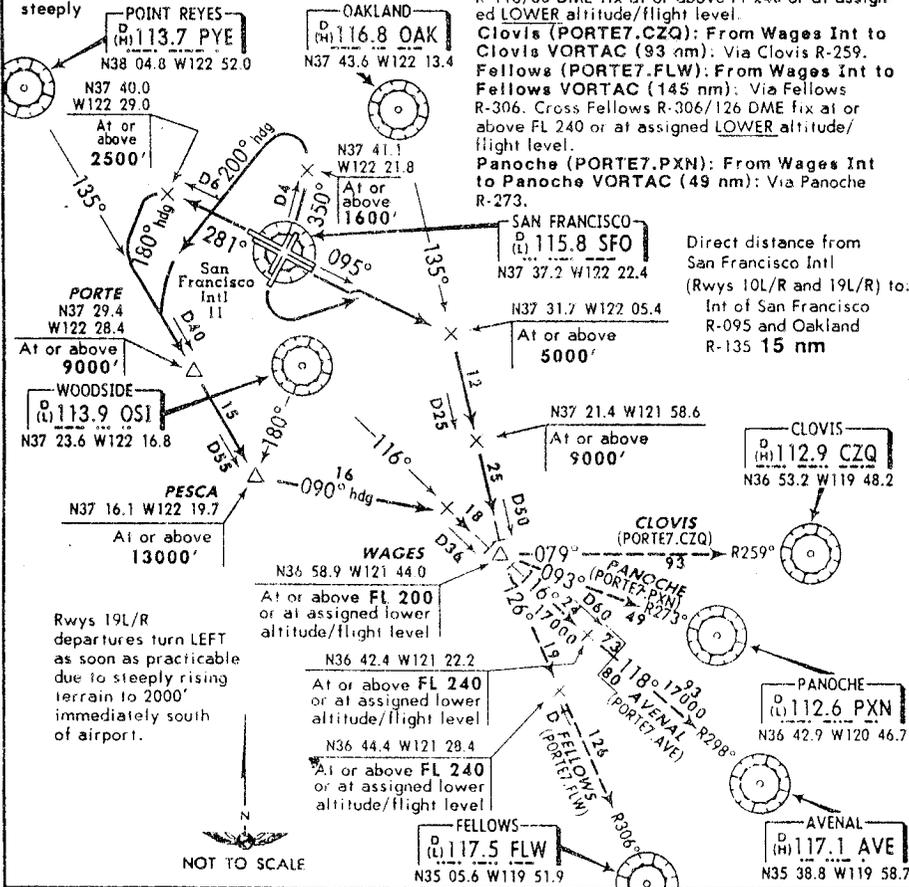
**TRANSITIONS**

**Avenal (PORTE7.AVE):** From Wages Int to Avenal VORTAC (117 nm): Via Woodside R-116 and Avenal R-298. Cross Woodside R-116/60 DME fix at or above FL 240 or at assigned LOWER altitude/flight level.

**Clovis (PORTE7.CZQ):** From Wages Int to Clovis VORTAC (93 nm): Via Clovis R-259.

**Fellows (PORTE7.FLW):** From Wages Int to Fellows VORTAC (145 nm): Via Fellows R-306. Cross Fellows R-306/126 DME fix at or above FL 240 or at assigned LOWER altitude/flight level.

**Panoche (PORTE7.PXN):** From Wages Int to Panoche VORTAC (49 nm): Via Panoche R-273.



CHANGES: Communications.

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Figure VIII-1. PORTE SEVEN departure from KSFO

where manual tuning of VORs is usually not required, flying a SID is quite simple if the fixes and altitudes are preprogrammed, providing that Departure Control allows the crew to fly it as published. Departing KSFO via the PORTE SEVEN SID would be LNAV, VNAV, and autopilot/autothrottle operation at its best. The reader may find it instructive to step through the SID and calculate the number of times a VOR must be tuned and a course selected in this departure.

### Route-2 Capability.

Only a few pilots mentioned the use of the Route 2 capability as a means of anticipating changes and avoiding programming during critical phases. Most frequently this was employed in anticipation of landing runway changes, although some expressed the frustration that even two-route CDU capability was not enough to prepare for "musical runways" at LAX (see next chapter).

### Experience

There was general agreement that as one becomes more experienced in the 757, the workload appears to diminish. Several adaptive mechanisms were attributed to experience: 1) the ability to quickly enter changes into the CDU; 2) the ability to plan ahead and anticipate the need for CDU or MCP interventions; 3) a change in tactics, namely using the automation less, particularly below 10,000 feet. Many captains expressed the feeling that the more they flew, the more they tended to "click it off" [1] when workload increased, especially when encountering rapid ATC route changes, crossing restrictions, and runway changes. Captains frequently mentioned the need to restrain F/Os from excessive programming, and to intervene when inexperienced F/Os spent excessive time trying to solve problems with CDU programming rather than "flying the plane." It is something of a paradox that about half of pilots reported that when workload increased, they turned the automatic features off. (See footnote below). One is mindful of the suggestion of Curry (1985) that pilots of advanced technology aircraft be given what he called "turn it off training." This view was voiced by numerous crews in discussing training. They stated that ground school and simulator instructors should "teach us how not to use automation."

### High Altitudes and Direct Routing

Pilots were unanimous in their praise of two features of the 757 which allowed ATC to give them more favorable treatment, and therefore workload reduction: high altitude capability, and

-----  
[1] The term "click it off" is frequently used pilot slang for turning off or deselecting one or more automatic devices, reverting to more manual modes of operation, particularly during times of heavy workload. It usually refers to deselecting the LNAV, VNAV, or autothrottle and autopilot modes.

long-distance direct routing due to the inertial capability of the FGS. High altitudes allows requests for direct routings to be granted, and also reduces radio communications with ATC. IRS navigation allow long-range navigation to a VOR location as a fix with no need to receive a signal from the VOR.

Crew Comments

2-4. What can you say about overall workload of the 757 compared to the other aircraft you have flown? Include mental workload, monitoring etc. What about outside scan?

Tabled below are the responses where a clear cut answer of relative workload was discernible. The symmetry of responses in this table is consistent with the data displayed in response to Item No. 18 earlier in this chapter.

TABLE VIII-1

<u>Response</u>	<u>Number</u>
Much more workload	1
More	20
Same or more	7
About the same	8
Same or less	2
Less	24
Much less	8

Note: many of the responses tabled above were somewhat qualified. Some of those responding in the "more" categories qualified their answer by saying that the excessive workload was only below 10,000 feet (see Table VIII-2). A large number also cited the two-pilot cockpit, not automation per se, as the source of the workload problem.

There was general agreement that workload was higher below 10,000 feet either departing or arriving, and was less above those altitudes, and much less at cruise. Several commented that a considerable amount of workload was relocated from flight phases to pre-start and pre-takeoff phases of flight. This point was also made by MD-80 pilots in a previous study (Wiener, 1985b).

Some of those responding in the "less" categories qualified their answer by stating that the workload was less "as long as everything is working."

TABLE VIII-2

Specific comments made in response to question 2-4.

<u>Comment</u>	<u>Number</u>
Excessive workload below 10,000 feet [1]	18
Increased workload due to only two pilots	11
Workload increased by ATC changes and uncertainty [2]	16
Increased mental workload [3]	8
Must resist excessive programming below 10,000 feet	14
Workload increased by company procedures	4
Difficult for new pilot, but improves with experience	11
Excessive workload during abnormal conditions	4
Importance of pre-planning in workload reduction	4
Crew coordination critical to workload	4
Complacency arises due to low workload	3
Less workload as long as everything normal	2
Excessive workload on short legs	2
You should "click it off" below 10,000 feet	2
Workload high if one of the pilots not proficient	2
Preflight activities more demanding	2
Automation allows better management of flight	1
Crew can spend less time monitoring non-essential systems	1
Excessive workload in bad weather	1
Complacency due to high reliability of systems	1
ACARS very helpful in reducing workload	2

-----  
 [1] Many respondents reported that workload was manageable or light in phases of flight above 10,000 feet.

[2] Runway changes particularly; LAX mentioned in most cases.

[3] Several respondents remarked that high mental workload is not necessarily bad, in that it keeps them active and alert. This point has not been examined in workload research.

TABLE VIII-3

Intercorrelation matrix for attitude probes in this chapter.  
HIT refers to hours-in-type (B-757).

## PHASE 1

	HIT	p18	p26	p27	p28
HIT	1.00	.15	-.22	-.14	-.31
p18		1.00	-.31	-.36	-.55
p26			1.00	.43	.41
p27				1.00	.37
p28					1.00

For  $n=166$ ,  $|r| > .15$  necessary for significance  
at the 0.05 level

## PHASE 2

	HIT	p18	p26	p27	p28
HIT	1.00	.13	-.30	-.11	-.28
p18		1.00	-.29	-.36	-.50
p26			1.00	.35	.29
p27				1.00	.48
p28					1.00

For  $n=133$ ,  $|r| > .17$  necessary for significance  
at the 0.05 level

## Crew Comments

Workload is about the same or even less than A/C with three-man crew, provided checklists are completed far enough ahead so that they do not interfere with flying the A/C or receiving instructions from ATC. There are no operational procedures that need interfere with outside scan below 10,000 feet, except in an emergency. Good flight management is the key. 4001

The 757 is a mental cockpit. It does leave more time for managing. 4002

Workload is the same or heavier due to the two-man cockpit. Part of the load is mental. Time after time an approach has to be changed below 5000 feet. Also any time the aircraft is in a transitory condition, you have to monitor everything because you might get a surprise. A lot of times we would just click it off and go back to manual if the load became heavy. 4003

Workload below 10,000 is higher than other A/C. This is a perfect plane for a mid-air collision. 4004

It is easy to get pushed and make minor errors on the ground before takeoff if you try to move at the pace that external pressure required (making schedule, radio communication, FMC programming etc.). Planning ahead is definitely required for approaches. All the A/C I have flown have peaks and valleys of workload. However, the peaks and valleys are more accentuated on the 757. 4007

Overall workload is greater on the 757. Mental workload is higher because you have one less person to help you remember to do things. The automation is nice, but the environment is not ready for it, and it will never replace the three-man crew. 4008

The cockpit is busy for a new pilot (3-4 months). If the pilot keeps in mind that he can still fly the airplane like very other aircraft he's flown, and not become fixated with the computer, he will not experience excessive workloads. Once I became comfortable and adept with the system, I found workloads lower than other aircraft. 4009

Below 18,000 the workload is greater. When one pilot is programming or talking to the company, he is completely out of the loop for helping the other pilot. 4014

It is the most fun fixed-wing aircraft I've flown (old helicopter pilot). I have a bid in for the DC-10, but I don't look forward to going back to needle, ball and airspeed. From the cockpit door forward, there's nothing I would be happy to leave behind. I love the airplane. 4015

If the flight profile were known before departure, the workload

in the 757 would be considerably less than other A/C. However, with today's ATC system and constant rerouting and vectoring below 10,000, I would say the workload is as great or greater than other A/C. 4018

During short legs, the workload is excessive. Coordination with flight attendants, ATC, and company radio puts a substantial stress on both pilots during outside scan and programming. Any malfunctions during these short legs exceeds the capability of both pilots to perform safely. Communications with the flight attendants and the company cannot be ignored. 4019

I must deliberately refrain from extensive programming below 10,000. This is something that was not emphasized enough in training. If you fight the urge to program, there is adequate time for outside scan. 4021

Keeping busy and more mentally alert because of a two-man environment is not necessarily a detriment. I feel that I was more "in tune" with the entire flight management program in the 757 than other aircraft. Bottom line: there's no substitute for another pair of eyes. 4027

The ease of navigating with an FMC vs. an INS is a tremendous boost, i.e. going some place in the 757 uses a three-letter identifier, instead of coordinates. Less chance for error. 4030.

Workload is increased during a systems problem. One pilot works the checklist while the other is "minding the store." At this point no one is really backing up the checklist procedure, and no one is backing up the flying operation. For the PF during such a situation, there's a tendency to watch the other guy, so there's a distraction from flying the airplane. I would feel more comfortable with someone else <flight engineer> following the operation. 4031

The overall workload is higher due to mental workload, but I think this causes a more disciplined cockpit because you don't want to "look away" and end up missing something that happened. 4033

In the new, deregulated environment, I miss the S/O to take care of passenger requests, comforts, and other demands as we continue a delayed operation. Since he isn't there, you or the other pilot have to take the time. Since you want to please as many passengers as possible, the workload is higher, which can take time away from monitoring or scanning. 4043

Normally the workload is about the same or a little less. In a busy terminal area such as DCA or LAX, it is much greater and can be very dangerous, esp. in VMC conditions. The runway changes at LAX and speeds that are not compatible (e.g. 210 to the OM) make things very busy at times. It is hard for me to understand why there are not many mid-air and near-misses in the LAX area. The

757 definitely requires a conscious effort to look outside, because it can become a "heads down" operation if you let it.  
4045

Some times the monitoring can be hard because the systems are so reliable, and there is a tendency for complacency. 4047

I had two occasions when a S/O would have been useful when systems failed. On one occasion, the F/O was out of his seat pulling circuit breakers to reset a system. ATC called with a new frequency, the flight attendants called to say it was hot in the cabin, and company dispatch called to get a position report, and I was trying to make a PA <announcement> to tell the passengers why it was so hot. Then the F/O asked me to repeat the C/B numbers. My "fun meter" almost pegged out. This kind of thing could have been very hazardous at 3000 feet. Overall I feel that the 757 is 99.5% as safe as a three-pilot operation. The 0.5% loss is probably a reasonable tradeoff in today's airline environment. 4048

As for mental workload, the 757 generally causes an increase, especially in terms FMC programming. Airplane systems are well designed and do not add to workload. Monitoring is increased somewhat. Outside scan suffers tremendously. There is such a tendency to use full navigational capabilities of the FMC that a great deal of programming occurs at critical times, when all eyes should be outside. Often there are no eyes outside. There is time for outside scan, but it is easy to get distracted. 4057

Total workload appears to be reduced, but monitoring of systems is increased, making long trips more tedious. Outside scan time definitely reduced. 4058

Overall workload is less, but workload in terminal areas where runway changes are common (esp. LAX) is increased to the point of jeopardizing safety. Even one head in the cockpit is too many.  
4059

The 757 is wonderful unless you are recleared in a terminal area, or something malfunctions. Then you are overloaded. There is no middle ground. Automation becomes a tyrant in any kind of anomalous operation. Outside scan suffers all the time. 4061

No workload at cruise, double workload below 10,000. Flying the old airplanes was much easier and safer in the rapid-fire environment. 4062

The success of this aircraft is based on all the automatic stuff, so it pains me to see the MEL <minimum equipment list> keep growing. We fly without an APU. A couple of months ago we sheared a generator shaft and had no APU backup. If we fly these aircraft (and bigger ones) with two-man crew, they must be meticulously maintained. 4070

Generally speaking, VNAV is useless in today's ATC environment.

Too many changes to be made in terminal areas. I have made fewer than ten VNAV descents that were not modified by ATC. Constant reprogramming. 3001

Workload diminishes greatly with familiarity. Thus does outside scan improve. However, one must scan more in visual conditions at the expenses of serving the FMC which is (now) less important. 3006

Workload on 757 is about half of what it was on DC-9. Also, because the 757 is such a nice A/C to fly, the mental workload is also less, due to automation. I think outside scan is also improved. 3007

Workload is about the same, just timed differently. Simplified checklist and automated systems aid in reducing "before engine start" activity, but LNAV and VNAV programming requires attention and rechecking at a time earlier than is necessary with antique instruments. This earlier planning allows greater opportunity to scan outside the cockpit en route. Some pilots have a tendency to program VNAV by going head down into the cockpit and reprogramming, rather than using basic autopilot functions. I feel safety would be enhanced by using FLCH, Heading Sel., and altitude sel. window during descent and approach. 3008

Every jet should have three-man crews. The company is always increasing workload. The <ATC> system now has one continual stream of radio communications which we can no longer absorb and act on. We have lost an important factor in the safety equation because we don't pick up the errors made by others. Bring back the third man. 3013

Better, quicker, safer than any other aircraft with the exception of terminal areas. If weather is good, ATC vectors, altitude changes etc. are too fast to program and keep an eye outside. 3018

757 does not provide enough time for scanning in the terminal area. This is the only two-man aircraft I've flown, and I believe the automation vs. third crew member is a poor tradeoff. The economics only make sense as long as nothing goes wrong. A third set of eyes, both inside and outside the cockpit, is far more valuable than the 757's automation. 3021

A properly trained crew, using state-of-the-art automation correctly will have a much lighter workload (monitoring only, vs. monitoring plus physically doing). Because of this fact, it is obvious to me that with this lighter workload the crew has much more time to be outside. I, as captain, have only to glance at the mode and request settings to know the F/O was on the ball, and we are both back outside. How easy and simple and safe it was -- the good people and the B-757 -- these I miss <respondent recently retired>. 3025

The B-757 automation is so interesting and fascinating -- there

doesn't seem to be a heavy workload. The outside scan is affected at first, but as experience increases, so does time for scan and monitoring. 3037

Of all the airplanes I've flown, the 757 is the easiest, and this is good. Much said these days about complacency, meaning carelessness, but this is not a necessary result. Relaxed does not equal sloppy. Being relaxed plus alert are what the cockpit needs and the 757 permits, but ever-present judgment. 3038

All two-man planes should have ACARS or a similar reporting system. Generally 757 workload is excellent and allows time for outside scan, but communication with ramp and station for in-range items and flight attendant requests negates this. 3045

The automation of the A/C systems (fuel, elect., hyd.) make the machine easier to operate, but the demands of the autoflight systems take up much more time, and leave little or no time for outside scan in terminal areas. 3049

The workload is nearly identical <to earlier models>. The 757 has the advantage of shifting a significant portion of the workload to before engine start. 3053

Depends on phases of flight. Before departure: workload higher due to two-man crew, computer programming, preflight, understanding EICAS messages and their affect on mechanical reliability of your aircraft. Climb: workload reduced due to autopilot and LNAV, VNAV climb, and performance of A/C which allows direct routing. Cruise: Workload definitely reduced due to direct routing and higher cruise altitude. Terminal arrival: high workload due to programming. 3055

## IX. AIR TRAFFIC CONTROL AND COCKPIT AUTOMATION

### A. INTRODUCTION

In this chapter we shall consider briefly the influence of the air traffic control (ATC) environment on the task of flying advanced technology aircraft. This matter has been discussed previously, in Chapter IV on cockpit equipment and Chapter VIII on workload, and many of the comments of the crew members in these chapters overlap. The purpose of this chapter is not to critique the ATC system, but to assess the extent to which it impacts in a special way on high technology cockpits.

One cannot help but be impressed when first encountering the flight guidance systems and displays of the modern aircraft. The VNAV and LNAV capability, the advanced autothrottle, IRS navigation, and the navigational displays seem to be ideal for operating in a complex environment. Furthermore, some of the advanced displays, such as the HSI map mode, the green altitude predictor arc, and the flight path predictor display, represent a giant leap beyond the displays available in traditional cockpits. One captain remarked, "you can take all of this other stuff away, but just leave me with the map and the green arc."

#### ATC Capabilities

While the cockpit equipment is intended to assist crews in conforming with ATC clearances, there are problems, not with the cockpit equipment per se, but with the ability of ATC to allow the crews to exploit it. The basis of the problem is that the ATC system must be able to accommodate all types of aircraft, with extreme variations in on-board equipment, mission profile, flight characteristics, and pilot proficiency, so today's system is a by necessity compromise. As a number of the crews put it, "if we (757-generation aircraft) were the only ones up there, the system would work great."

The ATC system of today has not kept pace with advances in cockpit capability, and is badly in need of modernization. This is under way presently, but will probably not produce a noticeable effect until the end of the century. The system simply is not cordial to the advanced capabilities of the new aircraft; it is essentially geared to 727-era cockpits and capabilities.

#### Controller Familiarity

Many of the crews discussed also the lack of understanding of the ATC personnel of the capabilities of the aircraft. This may or may not be the case, as the pilots may be interpreting the clearances they receive as reflecting lack of understanding when the problem is actually a lack of ground-based system capability. Many of the crews, while critical of the system, had praise for the controllers and their efforts to cooperate, and there were

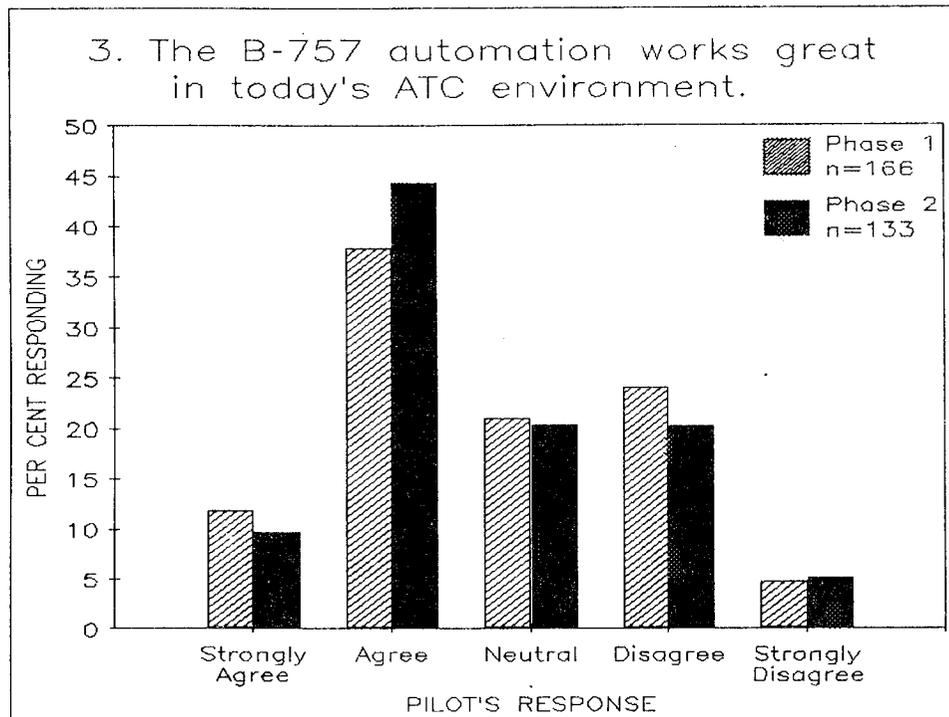
frequent comments that their service was improving as ATC became more accustomed to the 757-generation capabilities. (See crew comments that follow). Numerous crew members mentioned that they had never had a controller on the jumpseat of a 757 on a "fam trip" (familiarization), and they thought that this was a missed opportunity to instruct ATC personnel in the capabilities of the modern cockpits. A few mentioned that they felt that pilots should also visit ATC facilities for their familiarization.

## B. ATC INFLUENCES

### Workload Induced by ATC

The most frequent complaint was changes in clearance resulting in the following effects:

1. Pre-planning and programming went for naught.
2. VNAV and LNAV capabilities could not be exploited.
3. Workload increased in order to cope with the changes, especially changes below 10,000 feet, including runway reassignments, departures from STARS and SIDs, speed changes, and crossing restrictions.



ATC changes would exert similar effects (Item No. 3 above) on the crew of any type of aircraft. The question here is whether the instructions are particularly difficult for advanced cockpit operation, and this is presently impossible to say. There is serious concern on the part of crews with respect to Item No. 3, and the feeling that ATC changes can induce a high level of workload if the crews attempt to program the changes during critical periods of flight. Many pilots are reporting that they tend to abandon FMC programming and revert to basic autopilot/flight director modes during critical times, including runway changes close to the airport (see previous chapter on workload).

More and more the author has heard from captains that they felt they had to restrain the first officers from attempting to program every change, to the detriment of extra-cockpit scanning, and many were critical of their training programs for not placing more emphasis on this, as well as programming solutions. In a previous field study, Curry (1985) had recommended that crews be given what he termed "turn-it-off training."

Despite some of the criticisms, Item No. 3 on the previous page reflects a generally favorable view of the management of flight in the ATC environment.

There was considerable difference of opinion on this topic, as numerous pilots reported that they had no trouble reprogramming when necessary, and they praised the ability of the automation to reduce their workload in performing complex procedures, including runway changes and unexpected crossing restrictions (see Table IX-1 which follows).

#### Altitude and Performance Capabilities

It was felt by all that the high altitude capabilities of the 757, coupled with the long-range navigational capabilities of the IRS/FMC were a definite asset in flying the ATC system. The ability of the 757 to fly above FL 370, which in turn allowed the crews to request and obtain long-range direct clearances, was highly valued. Some mentioned that many controllers did not understand that the 757 did not have to receive a VOR, and could navigate to a VOR location even if it were off the air. It was not unusual during the first year of this study to hear a controller clear a 757 on an assigned heading to a distant VOR, "cleared direct when receiving."

The climb and descent capabilities reflect another interface problem with ATC. Due to the limitations of today's systems in dealing with aircraft of widely differing performance capabilities, the rapid climb of the 757 cannot be exploited. Pilots complained of the fact that since the 757 tended to descend slowly, ATC was keeping them too high, too long, often necessitating the use of drag devices in order to make good a crossing restriction on descent, or remain on their VNAV path. Some crews have shown considerably ingenuity in "fooling the

computer" to achieve their purposes. For example, they discovered that they could manipulate the TOD point so as to start down earlier than the correct VNAV calculation by either scheduling thermal anti-ice (TAI) in the CDU (but not actually using it), or by inserting fictitious tail winds.

The following incident was submitted to the regional chief pilot of a carrier not associated with this study. Shortly after this another pilot reported an identical incident. It was the feeling of the reporting pilots, as well as the chief pilot, that this could have happened in any aircraft, but that the glass cockpit aircraft are particularly vulnerable due to the tendency to follow the magenta line once displayed on the HSI. This was brought to the attention of ATC, who took remedial action.

On XXXX, 1987 I was the captain of flight XXX. We received a clearance to depart KSEA via the SUMMA TWO departure with a Pendleton transition. At about the 5 DME we were instructed to turn to a 130 degree heading and intercept the departure. The only part of the SUMMA TWO that shows on the <HSI> map of 757 type equipment is the assigned route (see attached Jeppesen plate, Figure IX-1). This turn to 130 degrees appears to be a good heading to intercept the Pendleton transition.

I did have a discussion with the first officer as to whether this was the controller's intention. About the time I was going to get a clarification we were turned over to another controller who gave us a turn to the right to intercept the 143 degree radial. He stated that we were heading for Mt. Ranier. During a discussion with the controller, he stated he had observed other 757 aircraft heading for Mt. Ranier.

I feel that a human factors type of situation exists that causes 757 type aircraft pilots to feel that the 130 degree heading short of the 11 DME is a heading to the Pendleton transition. It could be eliminated with a clearance to intercept the 143 radial, or a clearance to SUMMA.

In summary, a mismatch exists between the capabilities of the modern aircraft and today's ATC system. It bears repeating that the pilots in this study generally recognized this and while critical of the system, expressed gratitude for the quality of service the controllers were attempting to render. It is difficult to predict what will lie ahead. There will be some short-term gains as an increasing number of advanced technology aircraft enter airline fleets, and controllers become more familiar with their capabilities, but these gains may not be sufficient to offset the effects of forecast increases in traffic into the next century. Real relief may have to await the installation in the late 1990s of the National Air Space Plan (NASP), whose automatic systems should allow more pre-planning and adherence to lateral and vertical routes which will be in harmony with the capability of the advanced cockpit technology.

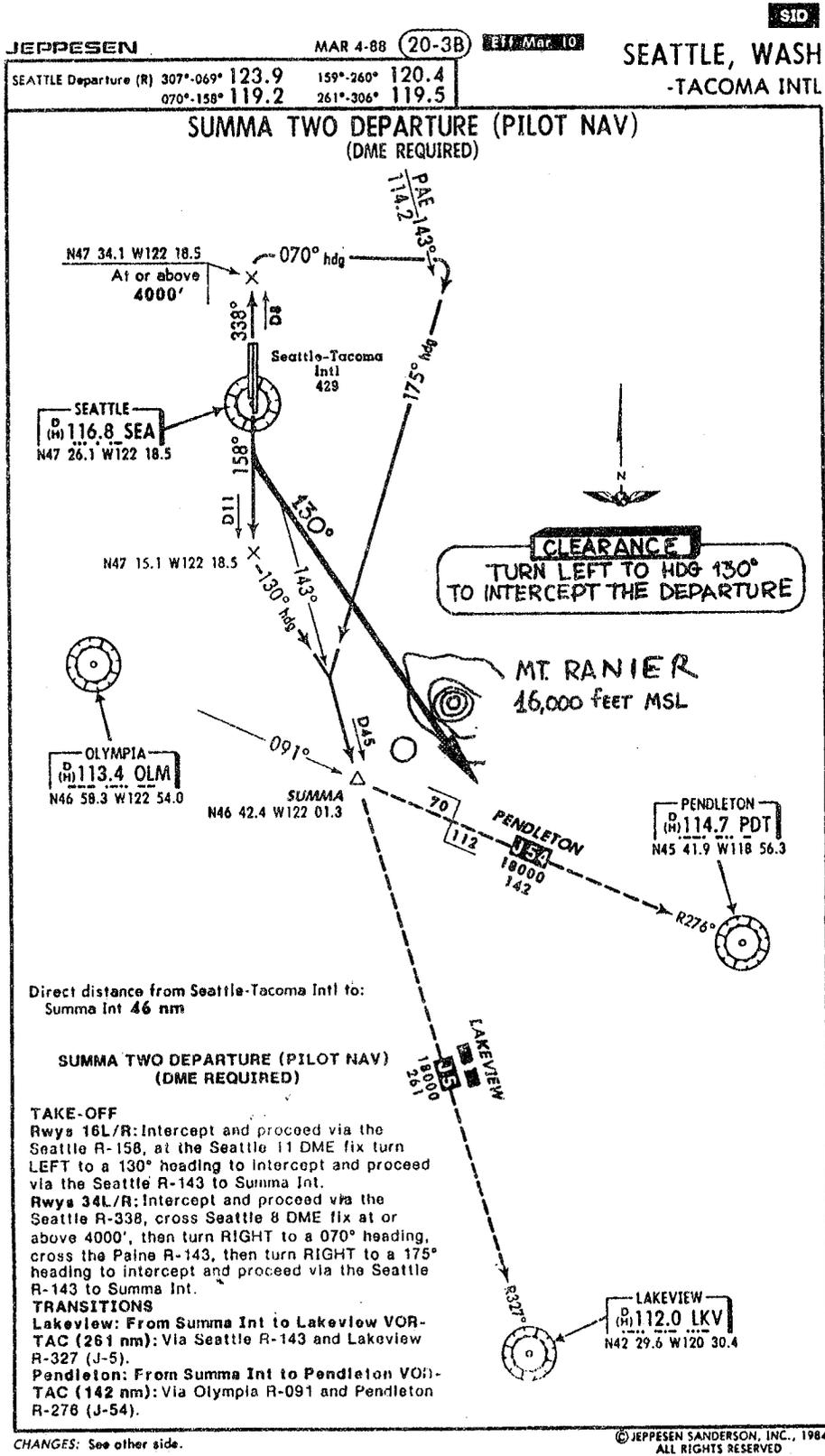


Figure IX-1. SUMMA TWO departure from KSEA. Note that the clearance, the intercept vector, and Mt. Ranier are not on the original approach plate, but were added by the reporting pilot.

1-6. Do you like the way the 757 automation interfaces to the ATC environment? Please mention things you have trouble with, and things that work well, in working with ATC.

TABLE IX-1

<u>Response</u>	<u>Number Responding</u>
NEGATIVE	
Works poorly; overall negative view	26
Too much programming; too much head down time; too many vectors in terminal area	37
Too much runway switching	12
ATC doesn't understand our capabilities; tries to control 757 like a 727; can't interface to 757 automation	35
Problems in terminal areas; VNAV ineffective;	16
Descent problems; keep us high too long; don't allow for longer glide; too many "drag required" messages	27
POSITIVE	
Generally works well	60
High altitude and "direct to" capability an asset	8
Works well except on descent	20
ATC's understanding of 757 capabilities improving	8
HSI map big aid, esp. in "direct" clearances, avoidance of lateral errors	6

Note: other negative comments frequently given involve FMC being too slow in updating (see Chapter IV), ATC not adhering to STARs and SIDs, inability to capture glide slope from above, and ATC unaware of ability to navigate to out-of-service facilities. Other positive comments: ability to navigate to out-of-service facilities (e.g. VORs off the air), able to give ATC precise headings and speeds when requested, ETA computation, and green altitude arc eases work in making altitude restrictions.

## Crew Comments

No. The whole FMC program is set up for a letter-perfect ATC system with no other airplanes in the sky. 2004

Generally yes. ATC is reluctant to let us start down and stay on the optimum descent profile. ATC is getting better as more and more 757/767s arrive. 2011

When you get used to it, it's great. You can go direct after you get out of the Washington or S.E. Cleveland sectors. You can call up those holding fixes or odd items they drop on you that you've never heard of, and see them on the map <HSI map mode>. 2012

We seem to spend a lot of time programming the FMCs with forecast winds aloft, descent winds, pre-planned flight paths etc, so that the FMC can compute an accurate T/D point only to find that 95% of the time ATC modifies our descent path by causing us to level off or turn off our pre-planning route during descent. Maybe we're wasting our time programming final approach speeds down to 50 feet above touchdown zone on the LEGS page. Maybe much less programming would be appropriate. 2015

No! I get the impression that ATC has no idea how the 757 operates. They have no concept (or don't care) concerning our efforts to give the passengers a comfortable ride (steep descents, mandatory use of speed brakes, or excessive flaps to get down, etc.). They don't seem to consider fuel economy, scheduled arrivals etc. But they do an outstanding job in the most important area, safety. My hat is off to them, but improvements could be made. Controllers have to ride around in the planes more often, and we pilots have to get over to the ATC facilities more often. 2017

ATC seems to be "getting to know us." It seems that a year ago there were no problems with INS clearances and less understanding of our need to start down a little earlier. Also as our experience builds, we know what the plane will do, and I find the atmosphere is more relaxed as time goes on. 2035

It would seem that automatic flight guidance has attempted to replicate the instinctive reactions of the pilot, with more rapid and precise response to flight path error stimuli. It succeeds to the extent that preprogrammed criteria are followed, and fails where changing aircraft configurations, ATC requirements, weather conditions etc. require extensive readjustment of the flight path, at the very time when the pilot must examine approach guidelines, make visual observations of instruments inside, and obstruction related observations, participate in intra-cockpit coordination, and required check list items. The autopilot, flight director computer does not, and cannot, anticipate ATC vectors, speed changes, or altitude requirements, so that as the pilots' workload changes inversely to his distance from the ground, his opportunity to program changes proportionately. 2044

It interfaces well for the most part. Problems occur when extensive reprogramming is required at low altitude. Unfortunately, this always happens at busy airports when you can least afford the distraction. LAX is the best example. I think of LAX as "musical runways." The runways on the ATIS and the arrival you filed are the least likely ones you'll fly. Setting up for two runways usually avoids too many problems. While it's not an automation problem, ATC's tendency to keep aircraft high and slow until close to the airport causes difficulty in descents for landing. 2052

Generally speaking, we interface well with ATC. There are a few places they give clearances that are actually more difficult to set up in the 757 than in the 727. For example, in the 727 you can simply tune your VORs and check the DME to make a crossing restriction. In the 757, it takes a lot more entries to set up crossing restrictions. ATC is trying to help us save time and fuel, but in so doing they create more work for us to a certain degree. For example, they cut a corner on an airway with an altitude restriction later on, and a lot of pre-planned stuff we put in the FMC gets dumped and has to be reinserted. Mind you, I am not complaining, because it's a fun plane to fly, but the time spent programming could be spent looking for other traffic. Also, the reprogramming gives more room to insert an error. ATC folks mean well, but aren't familiar with our "magic." The 757 has fantastic climb performance and many of the ATC facilities have not learned to keep up with us and therefore we have to do a lot of leveling off every few thousand feet as we climb. This may lead to an altitude bust or speeding ticket some day. The FMC capabilities of going direct anyplace work very well with ATC. Also, the FIX page is very handy when working with ATC. 2053

I feel that the 757 automation is very helpful and reduces pilot workload in the takeoff, climb, cruise, and descent phases of flight. The 757 automation can increase pilot workload and become a liability below 10,000 feet on approach when (1) ATC changes runways, (2) the map shifts, or (3) the route or runway information dumps out of the FMC. These three conditions have happened to me, and I feel the programming required for automation is a liability during the approach phase of flight. 2055

No. At the present it is not uncommon to be caught high or really trapped in a very clean aircraft that is not allowed to descend because of lower traffic which is not yet to its optimum descent point. At lower altitudes, it is rare to be able to fly an arrival and an approach without vectors for spacing, which requires either reprogramming or flying heading and/or airspeed changes. I feel the loss of "another pair of eyes" when engaged in these activities with an already high cockpit workload with checklists, frequency changes etc. For example, a short segment (TPA-ORL - 35 minutes) can be a wonder of efficiency or a complete disaster, with continuous high workload, start to stop.

I would expect, with the arrival of more efficient aircraft, that the ATC itself will change. Perhaps the computer-capable and efficient aircraft will be allowed to utilize their capabilities and the older, less efficient aircraft will be made to conform, perhaps by having to make power-on descents, and by flying published arrivals and approaches. 2062.

No! No! No! ATC can't seem to understand that this airplane does not want to come down! They treat us like older A/C with a 3:1 glide <3 miles longitudinally for 1000 feet vertically>, and this thing with its 4:1 is very difficult to get down without "cheating" all the automation. This just negates the fuel efficiency advantages of the aircraft and its automation. The 757 is also much slower on approach, which causes all kinds of problems with automation. 2064

VNAV descent is not realistic unless you are going into Great Falls, Montana at 3:00 a.m. I have seen improvements with ATC -- they realize what we can do with a 757. They could eliminate a lot of vectors and speed control if they'd tell you when to be over a point. 2066

It isn't going to interface well until there are more 757s than 727s. 2074

Generally the automation interface works well with ATC. There are times, however, in heavy traffic or weather where, unless you are completely up to speed with all the auto functions, it could become burdensome. I feel comfortable with my knowledge of the use of the auto functions. I can input whatever ATC gives me with little distraction from the overall flight. 2078

The 757 descent doesn't fit in with ATC. It has to start down much earlier than other aircraft. Also, when we have a crossing restriction off a certain navaid (e.g. cross 20 west of MKE at 240), we sometimes get radar vectors and then recleared to our original nav aid (MKE). The only way we can do it without losing our waypoint (20 west of MKE) and computer descent is to use heading select and put the track line over MKE. If we plug in direct MKE in the CDU we lose our descent path. 2082

I believe that the 757 automation in the terminal area/approach phase is somewhat unrealistic, due to the extensive vectoring and runway or specific approach changes required by the density of today's traffic. Some pilots seem to be reluctant to fly without a magenta line <executed programmed course> even though establishing one requires heads-down programming below 10,000 feet. This reluctance seems more prevalent in pilots new to the aircraft. All in all, the interface is satisfactory. My biggest concern is a runway or approach change close to the airport which requires one pilot to get "out of the loop" as he reprograms the computer. 2088

I think it's a great system. As my familiarity and competency with the system increases, I appreciate more and more the

automation and its usefulness with the ATC system. 2089

The 757 automation is nice. It is the ATC system that needs to catch up with technology. Much of the advantage of our automation is lost because ATC is 20 years behind. The 747-400 will have an even greater problem with an inflexible international airspace system. 2095

I don't feel there is much of an interface. We still must come out of LNAV for vectors for traffic frequently, and there are frequent altitude restrictions or changes in altitude for traffic. We let our VNAV figure out a good top of descent point for us, and then after our descent is begun, we receive crossing restrictions, speed changes, vectors, etc. that completely alter the path that our FMC had calculated. Until such time that the ATC computer and the FMC are connected through a data link system and we humans just monitor at both ends, there is no true interface. I don't particularly look forward to that day, but I guess it's got to come. 1001

The only thing that gets me is the high frequency of ATC changes in the approach plan. A place like ATL is extremely vulnerable. Last year I flew one trip where we scheduled to land on no less than four different runways before we got on the ground. Each change entails researching the new approach, feeding data into the avionics and correcting flight path when we should be looking out the window. Four runway assignments is unusual, but two is quite common in ATL. I prefer not to reprogram each change other than to tune in frequency and go manually. I say that ATL is vulnerable because I've gotten the impression over the years that ATC operates the system so as to accommodate the system rather than the traffic. ATC flexibility to pilot requests for closer runways is almost nil, but on the other hand A/C operating into ATL must be completely flexible to ATC instructions. And to what end? They have about four times the runway capability as a place like LGA, but the delays at ATL are more often and longer than LGA, not to mention the 20 mile finals ATC prefers. 1002

The automated navigation makes cross reference between map and instrument much quicker and error free. The autopilot requires very close scrutiny, especially on localizer capture. Autopilot has failed to capture localizer on many occasions. The VNAV is not very well utilized when ATC dominates the descent. This happens when centers refuse to coordinate and arbitrary descents are required. 1007

Unfortunately new controllers don't understand the capability of this A/C. When given a descent for traffic, give us a point to cross and an altitude. We'll do it! "Cruise descent" or "Descend now" may not meet their criteria. They should tell us what they need. Same on climb restrictions -- tell us what you need. We get needless reroutings when VORs are out of service. We navigate from position to position, not by radio. When they do know, it's beautiful. I have once, working with a knowledgeable controller, slowed down, crossed a fix at his

assigned time, did not have to hold, saved fuel, and was less of a problem to him! 1010

Works very well outside of heavy traffic areas such as ATL, DCA, New York, ORD, etc. Not infrequently, last minute changes in clearances/routing make for scrambling to reprogram the computer, particularly when "cleared for takeoff." Some areas of ATC seem to be unaware of the capabilities of the B-757, i.e. "receiving YYY VOR, go direct...", not realizing that we can navigate to that VOR immediately whether or not it's on the air. 1029

In general, yes. Rarely have I had the opportunity to fly a SID or STAR as published (or in the FMC). Trying to program ATC changes in routes/altitudes is a distraction. I like the green arc on the HSI -- easy to advise ATC of ability to make a crossing restriction. Also like ability to go-direct-to. 1045

If the clearance were adhered to it would be nice. The emphasis is on a proper T/D point for fuel conservation, however when ATC constantly changes it, it increases workload. The problem seems to be with vertical and not with lateral. Of course the many changes at low altitude in the terminal area create a problem, particularly with traffic watch. 1047

Yes. In general I see no significant problems in working within the ATC environment, other than remaining alert at 3:30 a.m. on a six-hour leg. 1051

(1) The 757 is way ahead of ATC's capabilities. Last minute runway changes -- not only do you have to change the ILS freq, but you also need to reselect the runway on the computer. This all usually at 1500 feet altitude, five miles from runway, with VFR traffic. (2) I believe that if one tries not to put everything into the computer, including his grandmother's telephone number, the system is excellent for looking out the window for other traffic, and still change altitudes and airspeeds as needed. If I am told to descend to 5000, and/or slow to 200 kts., I can accomplish this immediately on the MCP and push FLCH, and then be back looking out the window. Yet when you have someone in the other seat who puts the information in the window first, not only do you have another head-down in the cockpit for a considerably longer time, but this doesn't consider the additional time it takes the aircraft to react to computer information after you have entered it. 2056

It works OK, but I don't think we need any more automation at this time. Changes in the approach or departure take too much time below 10,000. 1059

In a see-and-be-seen visual approach, I feel it is best to make limited use of the automated systems unless they can be set up ahead of time. The automated systems do not interface with ATC very well because of the unpredictable changes during descents and approaches. 1063

## X. OVERALL ATTITUDE TOWARD AUTOMATION

### A. INTRODUCTION

In this chapter we shall attempt to examine the overall attitude of the crews toward cockpit automation and its influence on their perceptions of their jobs.

It must be recognized that the pilot's view of automation was inseparable from other factors, including among others: performance of the aircraft itself, the two vs. three pilot issue, and the environment in which they fly. It was very clear in the face-to-face interviews with the pilots that it was not always possible for them to deal with what were intended to be abstract questions about automation independently of the aircraft itself. That is, abstract questions about automation were asked, but they were often answered in very concrete terms, with references to various aspects of the cockpit equipment, flying tasks, training programs, ATC environment, regulations, and company policies, etc.

### B. SPECIFIC ISSUES

#### The 757 Aircraft Itself

The flight crews were universal in their praise of the aircraft per se. They felt most favorably toward the power and performance of the 757, its ability to climb rapidly and to fly at and above FL 390 which in turn made it easier to obtain direct clearances, and the general layout of the cockpit. Many favorable statements were made about the ease of operating the basic airplane systems: part of this could be attributed to automation of the systems, but much was due to fundamentally good design which simplified learning and operating the systems. In the second questionnaire the pilots were asked to specify the aircraft in their company's fleet which they would prefer to fly. The results, displayed in Figure X-1 (next page), are quite clear. The only generally negative comments came from a significant number of pilots who felt strongly that it was "too much airplane for a two-pilot crew."

Many expressed a sense of pride in being able to fly a state-of-the-art aircraft, although nearly half of the responses to P4 on this subject were neutral, and a considerable number were negative. At the same time, there were almost no "agree" responses to P22, regarding missing the "good old days" of simpler aircraft.

### Attitudes Toward Automation in General

As the earlier sections of this report indicate, the views toward automation were generally positive, but mixed. Again, it was impossible to treat this as a totally abstract question about automation as a concept. One's answer might be driven by his views of specific equipment, and certain experiences. Those who were positive toward automation most often spoke of its workload reduction potential, the reliability of the systems, the ease of navigation, the advanced displays, and the EICAS system.

Those who were generally negative toward automation based their views on perceived increases in workload at critical times, the difficulty of programming the CDU, and two fears: making a gross error, and loss of manual flying skills. Many of those who expressed negative views were probably not negative toward automation in any abstract sense, but were expressing a frustration over the difficulty of operation of the present generation of systems in the present ATC environment. Improvements in the human-machine interfaces would probably reduce some of this feeling, as would improvements in the aircraft-ATC interface.

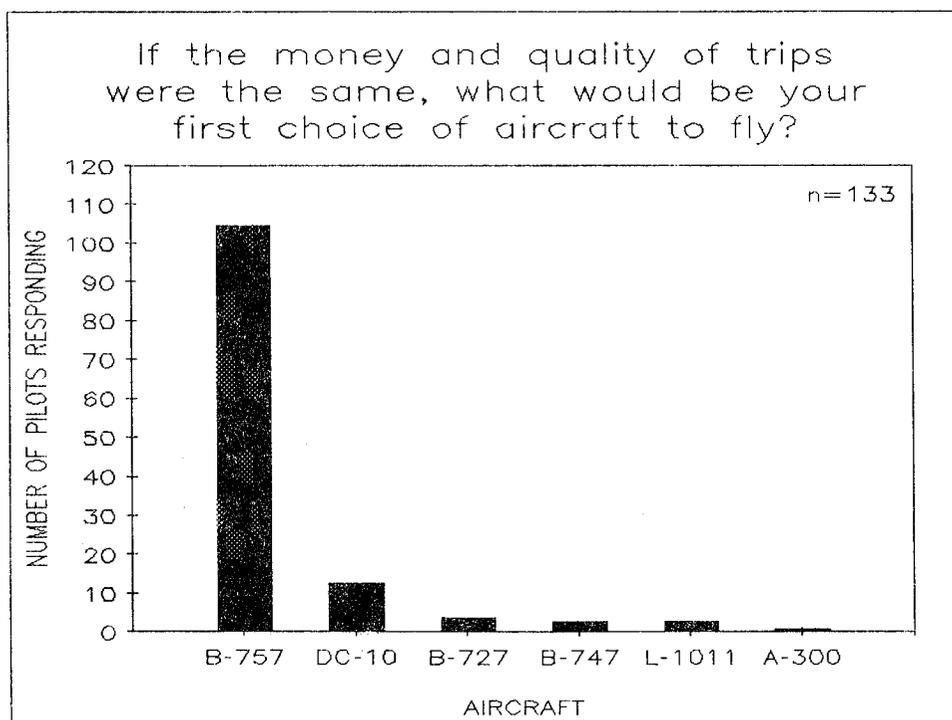


Figure X-1. Aircraft preferences in company's fleet.

## Safety

Many of the flight crews, even those with generally positive attitudes toward automation, were dubious as to whether automation represented a step forward in flight safety. This view was consistent with attitudes expressed in a previous study of DC-9 to MD-80 transition (Wiener, 1985b). One of the conclusions in that report stated:

In general cockpit automation was not viewed, even by its strongest supporters, as a boon to safety. Their attitude toward the safety aspect of automation was essentially neutral. (p. 94).

## Experience with the Aircraft

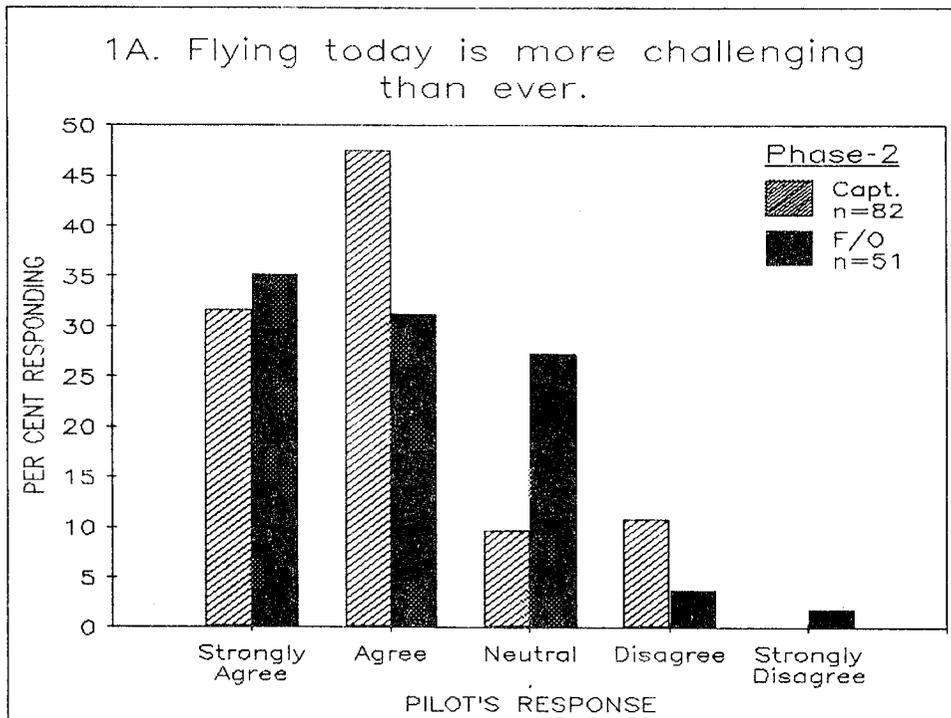
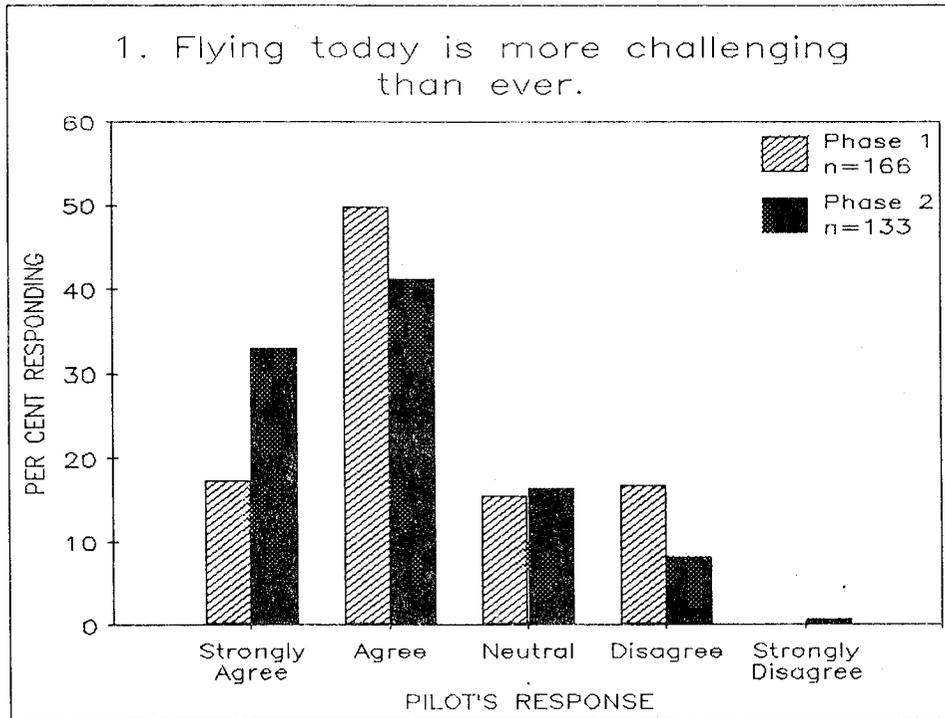
Both the open-ended questionnaire items and the interviews revealed that many crew members expressed the belief that as one's experience with the aircraft increased, many of the perceived problems vanished. However, the author's hypothesis that there would be a general shift toward more favorable views of automation from the first phase questionnaire to the second (over a year later) on the appropriate attitude probes was not supported. Based on quantitative data, we cannot report any shift in attitude from the first to the second questionnaire (mid-1986 to mid-1987). In fact the distribution of responses in the two phases are strikingly similar. Statistical tests were performed on the Phase-1 vs. Phase-2 responses to the 36 attitude items. Only two of the 36 tests performed (Bowker test for symmetry of responses) were significant (P16 and P34). These two contrasts did show an increasingly favorable view of automation. See Appendix 5 for these data.

## Air Traffic Control and Automation

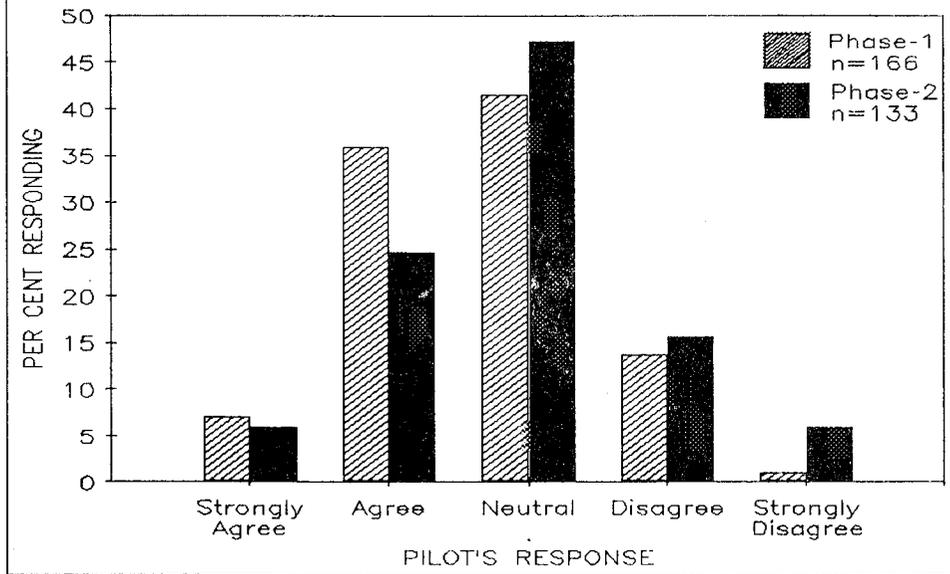
Although there were considerable complaints about the difficulty of operating the automatic features effectively, particularly LNAV and VNAV, due to ATC changes, item P3 (previous chapter) shows about 60% agreement with the probe "The B-757 automation works great in today's ATC environment", and almost as many neutral choices as disagreement. There is virtually no change in responses to this item from Phase 1 to Phase 2, and thus neither increased familiarity with the systems on the part of the pilots, nor of the presumed increase in awareness of 757 performance on the part of controllers, altered these views.

## Loss of Skills

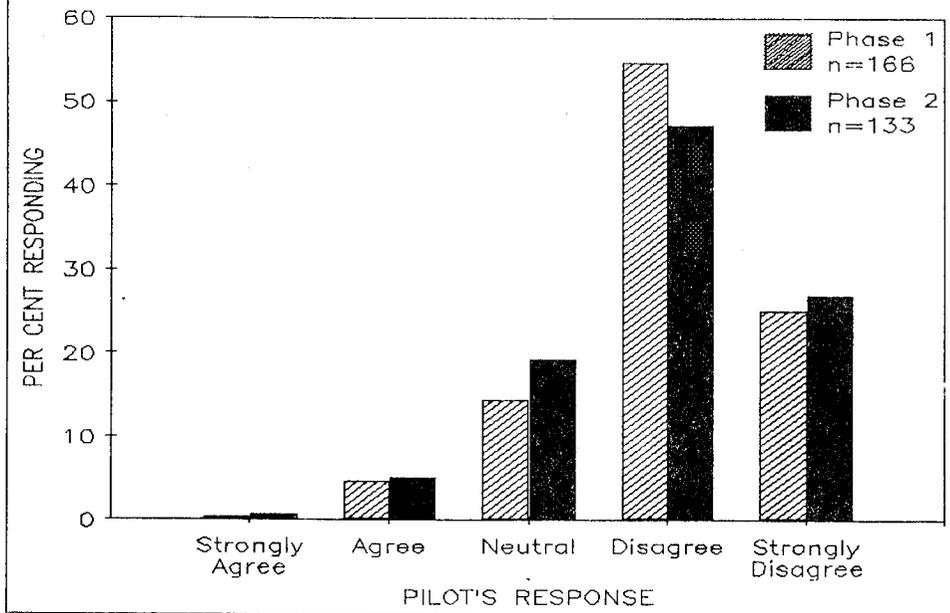
The fear of the loss of basic flying skills arose in nearly every interview. Most pilots expressed a concern about this, but many of those are quick to report the perception that they have not yet suffered any skill degradation, meaning that they felt that they had been able to combat this with self-imposed discipline



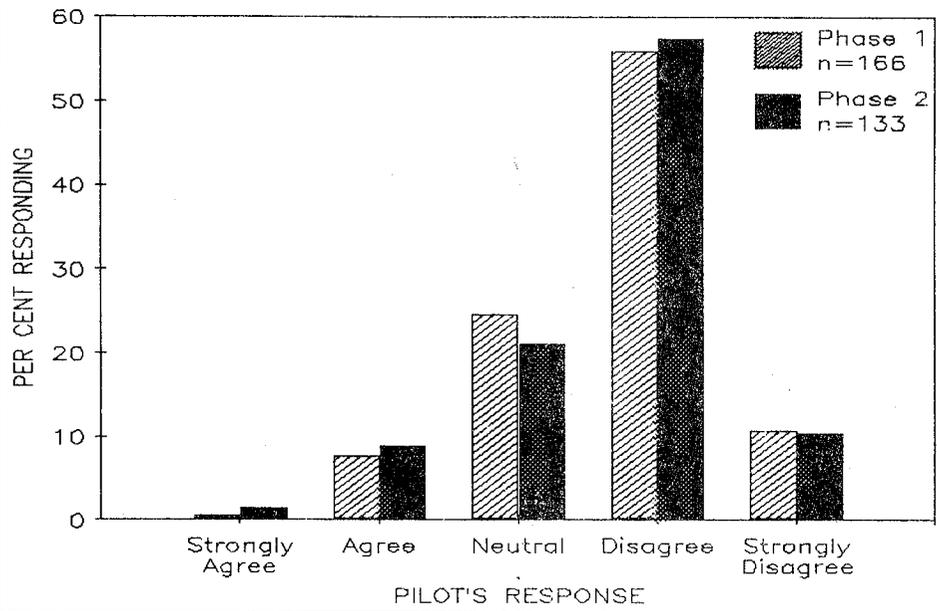
4. It is important for me to fly the most modern plane in my company's fleet.



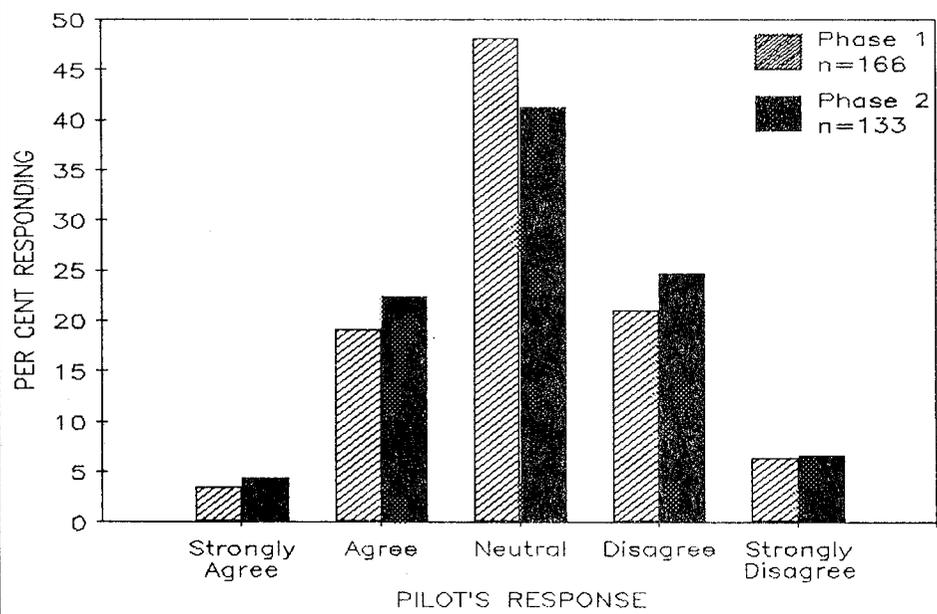
6. I think they've gone too far with automation.



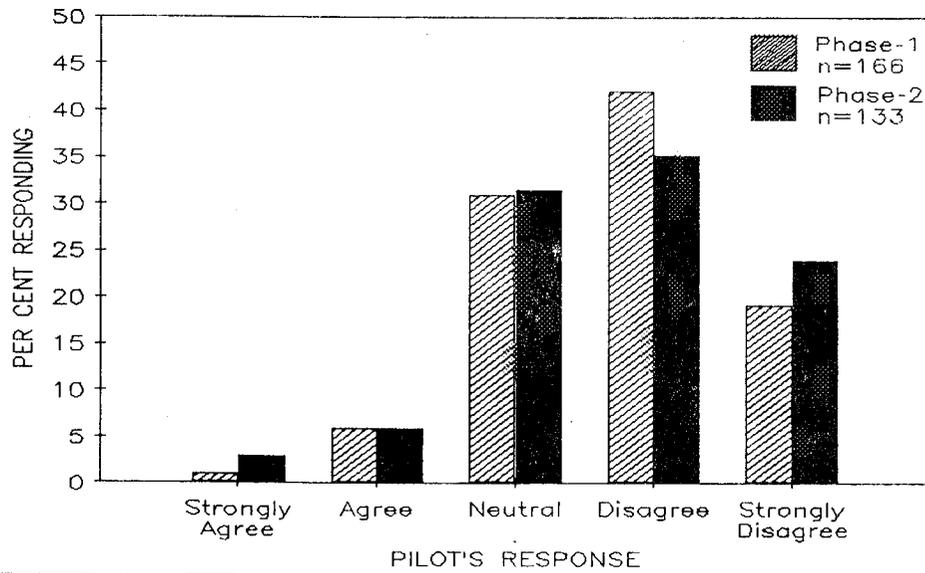
8. I use the automation mainly because my company wants me to.



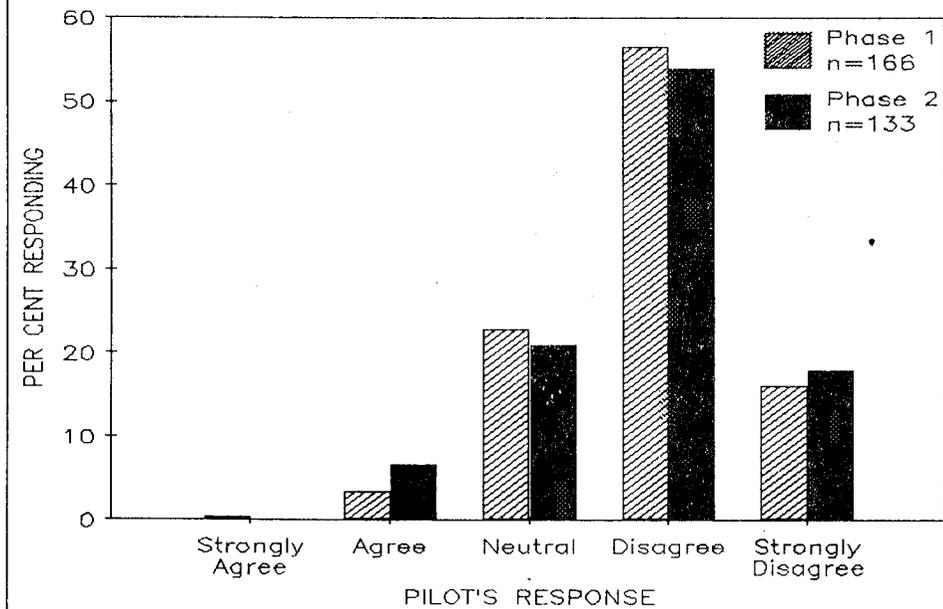
14. I look forward to more automation- the more the better.



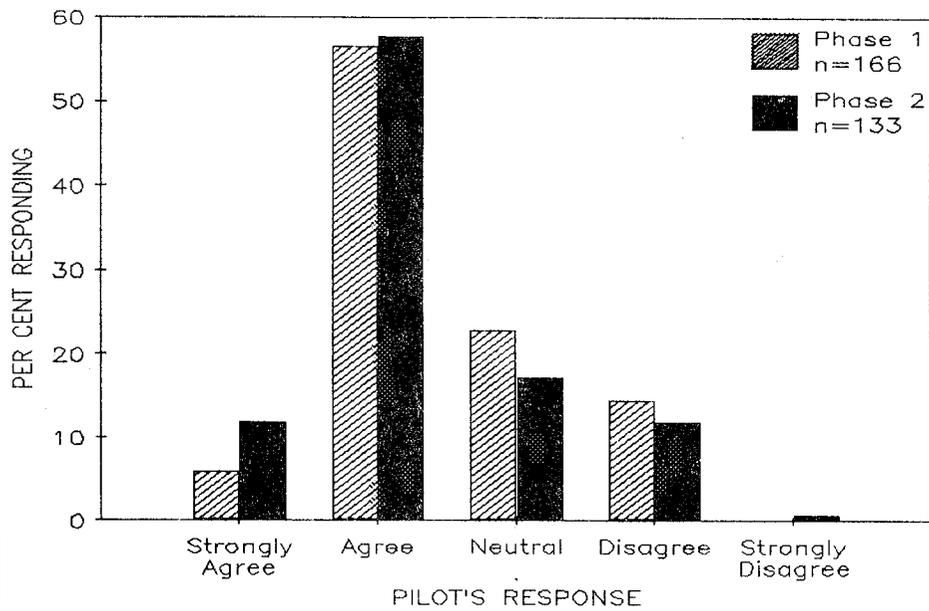
19. Automation is the thing that is going to turn this industry around and make it profitable again.



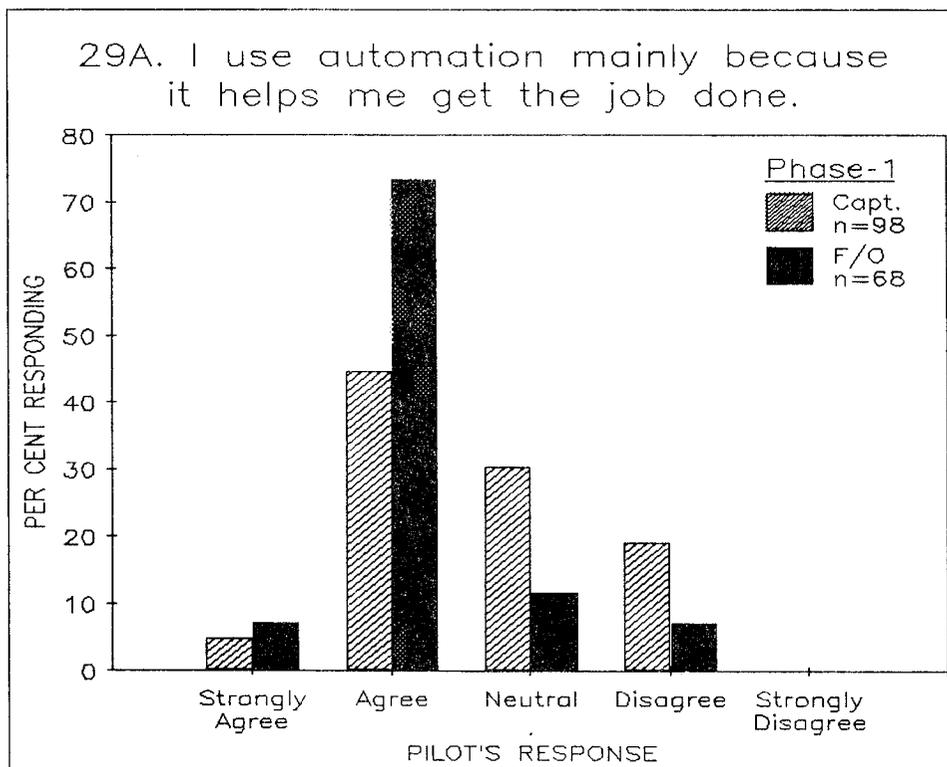
22. I miss the "good old days" of simpler aircraft.

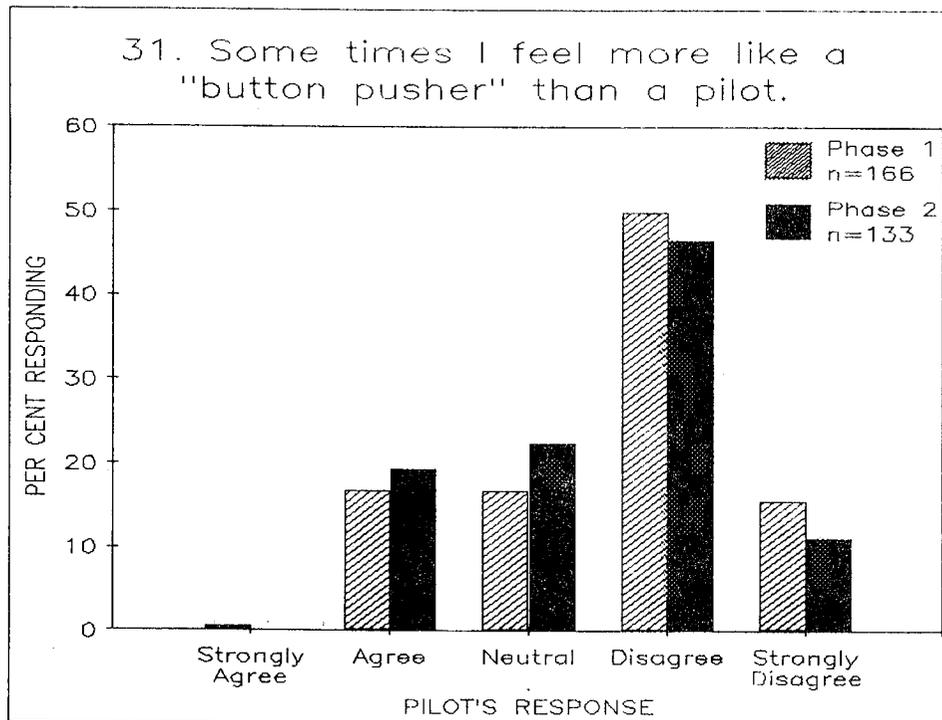


29. I use automation mainly because it helps me get the job done.



29A. I use automation mainly because it helps me get the job done.





such as voluntarily hand flying a portion of each trip. Most who had taken proficiency checks by the time of their interviews stated that they had experienced no problems. P2 expresses the concern of somewhat surprisingly, given the comments made during the interviews, of about half of the pilots. P9 (Chapter V) shows one of the most unanimous opinions, with about 90% of the respondents indicating their desire to hand fly a portion of every trip as a means of skill maintenance.

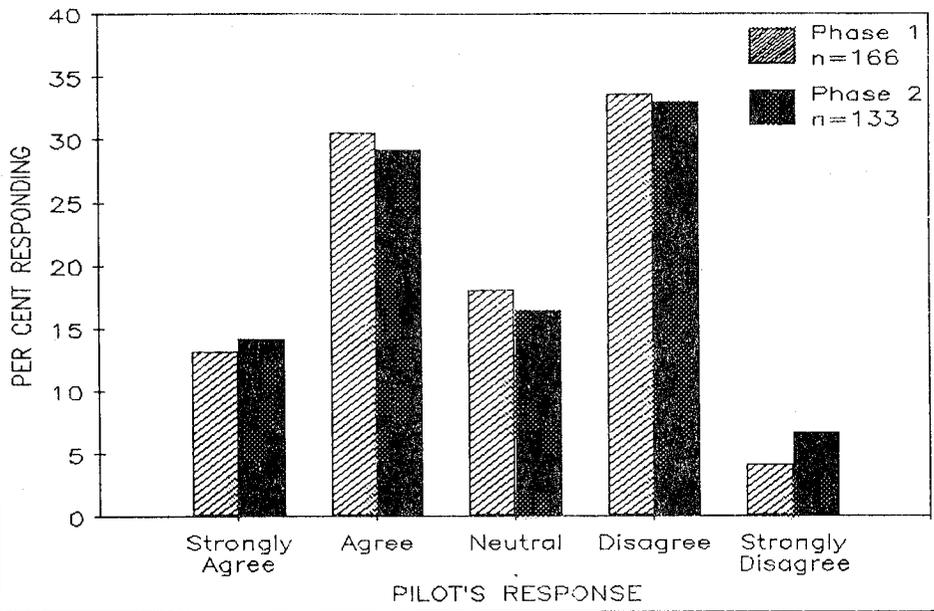
#### Usage of Automation

P8 and P29 were designed to look into the motivation to use automation, and should be examined jointly. Clearly these probes indicate that the crews turn to automation not because it is expected of them, but because they view it as positively as a means of getting their job done. These findings are consistent with the Wiener-Curry guidelines No. 4 and No. 5 (Appendix 1), and the general view that automation should be used as the crew sees fit, and not as an obligatory selection.

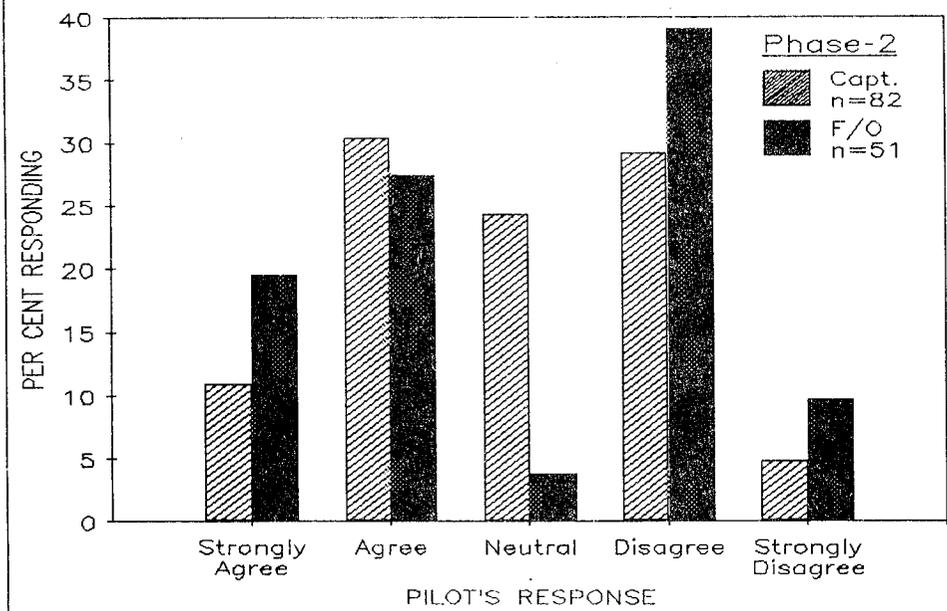
#### Future Designs

The generally positive view toward automation comes out in certain questions that deal with views of present and future aircraft and their equipment, for example P1, P6 and P14. P1

33. After flying the B-757, I would never want to go back to old types of planes.



33A. After flying the B-757, I would never want to go back to old types of planes.



shows general agreement with the probe that flying today is more challenging than ever, and P6 shows strong rejection of the probe that "they've gone too far with automation." In spite of this, only about a quarter of the crews agreed with probe in P14, "I look forward to automation - the more the better." Perhaps the second part of the probe was ill-conceived -- pilots may have agreed with the first part, but rejected the notion of "the more the better". Only a small number of respondents agreed with the probe in P19 that automation would be the thing that turned the industry toward profitability.

To test the consistency of these responses, the inter-correlation between P1, P6, and P14 were examined for Phase 1 and Phase 2. In both phases, the only significant correlations were between the probes P6 and P14 ( $r = -.42$  in Phase 1;  $r = -.54$  in Phase 2). The negative sign of the correlation coefficients indicate what one might expect: those who agreed with P6 tended to disagree with P14 and vice-versa.

### Psychosocial Factors

Many who have written in the field of automation, in aviation and elsewhere, have predicted that as systems became more automatic, the workers in those systems would suffer a sense of detachment and lack of self-worth. These authors foresee the day when workers in these highly automated industries will perceive themselves alienated from the goals of the system, playing a minor or peripheral role, or becoming the servants of the machines, rather than the other way around (Wiener and Curry, 1980). So far we have seen no evidence in this study, or previous field studies that such a thing has taken place in cockpit automation. While there are undeniably some crew members who express some alienation, as seen by those agreeing with the probe in P31, this is probably the expression of a frustration over the difficulties of mastering the requirements of advanced flight guidance systems, and not a deep-seated psychosocial disturbance over automation.

As reported in the MD-80 study (Wiener, 1985b), the prevailing psychosocial sentiment would be pride in flying the most advanced aircraft in the company's fleet. Certainly the question is not closed, and future studies with ever-increasingly changing roles for the pilots will have to continue to investigate this sensitive issue.

TABLE X-1

Intercorrelation matrix for attitude probes in this chapter.  
HIT refers to hours-in-type (B-757).

## PHASE 1

	HIT	p1	p4	p6	p8	p14	p19	p22	p29	p31	p33
HIT	1.00	.03	-.18	-.01	-.01	-.04	-.15	.05	-.03	.09	-.20
p1		1.00	.02	.11	.02	.12	-.03	.03	.02	.10	-.01
p4			1.00	-.08	-.10	.17	.07	-.14	.04	-.07	.30
p6				1.00	.42	-.42	-.10	-.42	-.03	.47	-.14
p8					1.00	-.32	-.02	.28	-.05	.40	-.10
p14						1.00	.27	-.26	.03	-.23	.10
p19							1.00	-.02	-.11	.04	.28
p22								1.00	-.02	.43	-.35
p29									1.00	.05	.05
p31										1.00	-.18
p33											1.00

For n=166,  $|r| > .15$  necessary for significance  
at the 0.05 level

## PHASE 2

	HIT	p1	p4	p6	p8	p14	p19	p22	p29	p31	p33
HIT	1.00	.16	-.20	.09	.04	-.09	-.15	-.07	-.09	.06	-.30
p1		1.00	.10	.08	-.07	.10	-.17	.02	-.03	.17	.15
p4			1.00	.03	-.01	.22	.37	-.09	-.02	-.04	.46
p6				1.00	-.44	-.54	-.18	.41	.08	.35	-.19
p8					1.00	-.34	-.14	.27	-.09	.25	.01
p14						1.00	.29	-.36	.04	-.31	.31
p19							1.00	-.15	.12	-.18	.30
p22								1.00	-.02	.38	-.17
p29									1.00	-.01	.05
p31										1.00	-.06
p33											1.00

For n=133,  $|r| > .17$  necessary for significance  
at the 0.05 level

## XI. DISCUSSION AND CONCLUSIONS

The purpose of this study was to evaluate the human factors of the training for and operation of advanced technology transport aircraft. Although the Boeing 757 was used as the "laboratory" in this research, this report should not be regarded as a design review or critique of that particular aircraft. The B-757 for our purposes was merely an exemplar of the modern, "glass cockpit" technology. The author has no doubt that similar conclusions would have been reached had the study been performed with some other model employing the same technology and a two-pilot crew (e.g. A-310 or MD-88).

The conclusions in this study are largely based on pilot opinion, as well as the observations of the author. These are not experimental results based on comparing old and new technology aircraft either in line operations or simulation. Such studies have not been conducted as yet, and indeed much of what has been written about human factors in cockpit automation has been based on opinion surveys of one kind or another. The author is not aware of any comprehensive, experimental comparison of traditional versus modern technology aircraft that would meet the standards of "scientific proof." Hopefully such studies will be forthcoming, perhaps from LOFT exercises where such comparisons can be safely performed.

Nonetheless this study contains a vast amount of data based on the experience of 201 line pilots who have transitioned to the 757, and some who have since left for other aircraft, and can make a "post-glass-cockpit" comparison. In the preparation of this report emphasis has been placed on direct quotations from the participating crews, as they reflect opinions and incidents based on extensive line experience in the crews' own words.

### A. GENERAL FINDINGS

In general, the pilots in this study exhibited a high degree of enthusiasm for the aircraft, their training, and the opportunity to fly a state-of-the-art transport aircraft. Some of the enthusiasm for the aircraft was not based on its modern avionics and automated flight guidance, but on other features such as performance, engine power, simplicity of systems, overall reliability, cockpit comfort, and flight characteristics.

It is more difficult to summarize the pilots' attitudes toward automation in general. For purposes of this discussion, the term "automation" refers primarily to flight path guidance, including power plant control, and warning and alerting systems. Automation of what pilots call "basic systems" (e.g. environmental control, yaw dampers, fuel systems, etc.) were not in dispute, and were highly regarded by the crews. Indeed, the difficulty of summarizing attitudes toward flight-deck automation

can easily be appreciated by observing the results of the 36 attitude probes, most of which revealed "mixed feelings" and often almost symmetrical distributions of agreement or disagreement with the probe (e.g. No. 18, Chapter VIII).

Restricting the term "automation" as noted above, it became clear that many pilots, while reporting that they enjoyed flying a modern plane, also indicated strong reservations in two critical areas: 1) safety, and 2) workload reduction. The particular concerns over safety and workload overlap to a degree, and were strikingly similar to those voiced by crews who had recently transitioned from traditional DC-9s to the MD-80 (DC-9-80) in a previous field study by the author (Wiener, 1985b).

As for safety, many of the crews expressed the view that automation may have gone too far, that they felt they were often "out of the loop", probably meaning that they tended to lose situational awareness, and that they feared that automation led to complacency, a term used repeatedly in interviews and questionnaires in this study.

With respect to workload, there was strong disagreement, but at least half of the respondents reported concern that automation actually increased workload, that workload was increased during phases of flight already characterized by high workload, and decreased during periods of low workload. Even more serious, many, perhaps most, of the crews reported that in times of heavy workload, they tended to "click it off," that is, revert to manual modes of flight guidance because they did not have time to do the programming necessary to exploit the automation. One is reminded of the recommendation of Curry (1985) that crews be given what he called "turn-it-off training." Curry had noted that crews were generally trained to make full use of automation, but were not trained to make partial use, or to revert to more manual modes when they felt the need.

Certainly it is something of a paradox that in times of high workload, the crews felt that they needed to abandon, in favor of more manual modes, the very devices that had been placed in the cockpit in the hopes of reducing workload. Much of this difficulty can be attributed not to the basic premises of cockpit automation, but to the difficult human-interfaces, as the chapters on equipment, and particularly the subsection on the CDU reveal. The author's view is that the present generation of cockpit automation is going through an evolutionary phase that must for the time be tolerated, and that the designs of future generations will be more "user friendly", or as NASA scientists have described it, more "human centered."

Some of the responsibility can also be attributed to the fact that the ATC system has not kept pace with the capabilities of the advanced technology aircraft. This results in excessive workload due to frequent changes in clearances in busy terminal areas, and departures from preprogrammed flight profiles, depriving the crews of the opportunity to exploit some of the

most effective tools in the modern systems, mainly LNAV and VNAV. The portion of the problem that can be attributed to ATC will not improve until the modernization of the present ATC system goes on line, probably around the end of this century.

## B. SPECIFIC AREAS

### Equipment

In spite of the conclusions regarding the problems of the difficult interface, the crews reported satisfaction with the general layout of the cockpit, and few problems in the area of traditional human factors. The EICAS was well regarded, and generally seen as a workload reducing device, and a step forward in warning and alerting systems.

One of the carriers (Airline-2) was equipped with ACARS, Airline-1 was not. Airline-2 pilots were generally well disposed toward ACARS, but felt that its full potential was not being exploited, mainly the capability to interface the ACARS directly to the FMC so that flight plans displayed by ACARS would not then have to be typed into the CDU. The capability to transmit a clearance via ACARS from the company's computer directly into the FMC exists today and is implemented by some carriers. While this capability seems quite handy, and undoubtedly reduces workload at the gate, it does raise some difficult questions about potential hazards of computer-to-computer communication without human intervention (Wiener, 1988).

Many pilots expressed the desire for additional features, and many had learned ways to "trick the computer" to obtain desired results when no direct method was available. For example, crews who wished to start a VNAV descent earlier than their computed top of descent (TOD) point discovered at least two ways to cause the FMC to recompute the TOD. One was to enter a point for use of thermal anti-ice (TAI) on the DES page, even though there was no intention of using it. The other method was more precise, simply entering a fictitious tailwind. These methods of course would achieve the desired result, but would tend to defeat the purpose of VNAV in computing fuel-efficient descent profiles. Although pilots can be commended for their ingenuity, it would seem that if it is desirable for crews to be able to intervene in the selection of a TOD, they might be given a more direct way of achieving this. It does not speak well for automation that pilots of a modern airliner must deliberately enter incorrect data into a sophisticated computer to achieve a desired objective. (See Wiener-Curry guideline No. 2, Appendix 1.)

A major source of annoyance to the crews was the unavailability of information on the maintenance pages of the CDU. Many were quite vociferous in denouncing the policy that locked them out of the pages in flight, feeling that there was valuable systems information that could be used for decisions, particularly on

over-water flights. The recommendation by the manufacturer and the decision to make this information inaccessible was probably sound, but designers and operators should keep in mind that it is unacceptable to a pilot to be told, in effect, "there's information down there, but you can't have it."

### Training

Training for the 757 at both airlines in this study was generally considered to be well planned and well conducted. A large number of pilots reported on their questionnaires that 757 school was the best training program they had ever been through. The two carriers employed somewhat different approaches to staffing and conducting their programs. At one carrier, all instruction was performed by professional ground school instructors, mostly retired military personnel. They employed no "stand-up" instruction, but only a tutorial relationship between the instructor and two crews (one captain, one first officer each). At the other carrier, ground school included some stand-up instruction conducted by line-qualified first officers. At both carriers, direct instruction was supplemented by self-study employing auto-tutorials on computers and slide-tape devices.

It would be difficult to say which system of delivering instruction worked better. The professional ground school instructors were highly proficient and skilled at their work. Ground school instruction was their job and their only job; it was not a temporary assignment. On the other hand, there is always something to be said for the validity of instruction by line-qualified personnel, who make up in "credibility" what they may lack in instructional experience. Line-qualified instructors are immune from the familiar complaints of "that's fine for ground school, but that's not the way it is out on the line." In fact the young first officers who gave stand-up instruction were quite impressive in their knowledge, enthusiasm, and style of delivery.

The most commonly heard criticism of ground school was that their was an over-emphasis on "magic" (automation) to the exclusion of basic airplane knowledge and skills. The conduct of the first day of instruction both in ground school and simulator was particularly criticized on these grounds. In the ground school it was felt that the first day should have been devoted to "basic airplane" introduction in the classroom, and likewise basic handling characteristics in the first day CSS instruction. Obviously pilots feel the need to understand the basic characteristics of a new airplane before becoming immersed in the details of its advanced equipment. As many reported, "it's still just an airplane." Some improvement in this situation has already occurred in the 757 training at host airlines, where more emphasis on the "basic airplane" has been added to the first day of ground school.

Over-emphasis on automation on the first day of ground school appears to be a valid criticism, and other training departments,

faced with introducing crews to the advanced technology for the first time, might consider revising their syllabi to respond to this need. If nothing else, such a revision might give the crews more self-confidence before moving into the unfamiliar land of the details of programming the FMC. It might also be helpful in overcoming the computer resistance seen in some of the older captains.

The auto-tutorial devices employed in training for advanced technology aircraft have not kept pace with the technology. The slide-tape presentations are clumsy to operate, are difficult and costly to update and correct. Except for occasional questions interspersed in the instructional stream, they lacked the ability to demand responses from the student. Students often fall asleep at the instructional station. The computer-based devices with graphics displays and touch-screen response mechanisms offer more "hands-on" experience, but the present devices fall short of state-of-the-art computer graphics technology. Display generation is slow, and the touch screens are inadequate in that they often either ignore the manual input, or mislocate it. The older systems still in use are monochromatic, though color displays are now available.

Clearly computer color graphic devices requiring manual responses from the student will be the direction the industry must move. These devices will be expensive for the carriers, both in capital acquisition costs and in courseware development. But in the end they should more than pay for themselves, both in quality of training and in relief from under-utilization of the capabilities of expensive hardware such as the CSS.

One cannot view 757 training without being struck with the need for a computer-based, part-task simulation device for CDU operations. The CSS, which was developed and purchased to relieve the even more expensive simulators from being used for teaching routine cockpit operations such as scan patterns, checklist usage, and "knobology" are now themselves being misused. Much of the CSS time, particularly in the first week of ground school, is devoted to CDU programming while the rest of the CSS capabilities stand idle. Clearly an off-line CDU device would bring relief to this situation. CSSs now carry multi-million dollar price tags. The CSS is now where simulators were a decade ago, inefficiently utilized for training for routine operations that might easily be moved to far less expensive and virtually equally effective off-line devices.

The perceived problem of loss of manual flying proficiency inevitably arises in connection with automation, as it is one that concerns management, government, and individual pilots alike. There are two issues here: 1) manual reversion in the event of loss of automatic flight guidance features or enhanced displays on an advanced technology aircraft; and 2) transition of crew members from advanced to traditional aircraft ("backwards transition").

This question (sometimes over-dramatically referred to as "automation atrophy") has not been attacked experimentally, as it should be. Data from this study and other field studies can shed some light, but are no substitute for a properly designed and conducted experimental study. The data reported here concur with that of the author's previous field study on the MD-80 (Wiener, 1988b), in finding little evidence that crews of advanced technology aircraft have suffered significant skill loss. Crews report little trouble in the event of loss of automatic features, and little problem on the manually flown portion of their proficiency checks. Many have resorted to their own self-imposed regimens of hand-flying to cruise altitude, manually flying departures and approaches, making flight director only and occasionally raw data approaches, etc. The pilots tend to design these programs for themselves, and then stick to them so conscientiously that in his previous study the author referred to them as "personal FARs." In fact, some first officers have complained that some captains would not allow them hand-fly as much as they wanted to.

One captain who was interviewed made an interesting comment about proficiency checks. He said that throughout his career the FAA examiners had "turned things off." Now they insist that everything be turned on. The interviewee expressed the opinion that (even on proficiency checks) a pilot should be allowed the use or not use features and modes as he sees fit, a view consistent with the Wiener-Curry guidelines (Appendix 1).

A number of the crews stated the opinion that the greatest problem they anticipated, or had already experienced for those who had made the "backwards transition", was the loss of the HSI map display. Many, while feeling that the map mode was one of the most valuable features of the advanced technology aircraft, were apprehensive that not so much their manual skills as their cognitive skills had suffered due to the ease of navigation and maintenance of situational awareness using the electronic map.

Skill loss is a complex issue, and unfortunately this report does not offer a lot of guidance. The indications from this and other field studies is that the problem may be less severe than previously thought. However, we must emphasize that: 1) the proper experimental study not yet been done; and 2) due largely to rapid movement of crews up the seniority ladder in expanding airlines, to date there have not been pilots who have spent large amounts of time in the "glass cockpit" aircraft, so the problem, if there is one, may lurk out of sight for some time before surfacing in the operational world.

It is clear that airline training departments worldwide face the greatest peace-time pilot training challenge in history. The changing pilot market may exert some pressures on training departments heretofore unfelt. With the shrinking of the traditional pilot hiring pools, and the rapid expansion of the Part 121 and Part 135 airlines, the carriers have been forced to relax standards for new hires, and in some cases recruit very

low-time pilots trained ab initio for airline seats. While making no judgment on the proficiency of these less experienced pilots, let us combine this fact with the expectation that in the near future, at many carriers, highly advanced aircraft may be the junior assignments in the seniority ladder. For example, two U.S. carriers have recently ordered large fleets of A-320s, and in the years ahead these may be the junior aircraft in their fleet. Thus airlines can anticipate that in the decade of the 1990's very inexperienced pilots may be occupying the right seats of very sophisticated aircraft. This poses an unprecedented challenge to the training departments of the industry, and perhaps the suppliers of training devices and software, and to the human factors profession as well.

### Cockpit Errors

The question of automation-induced errors has concerned the industry for some time. Even before the introduction of the glass cockpit the problem was recognized in the so-called second generation aircraft (essentially those with mode control panels which allowed selection of fairly sophisticated autopilot/flight director and autothrottle modes, including nav modes in conjunction with area navigation systems). The problem was that the more sophisticated systems, while reducing or eliminating small errors, appear to invite gross errors, that could have serious consequences (Wiener and Curry, 1980; Wiener, 1988).

However, balancing this is the great degree to which automation may prevent errors either through not accepting erroneous input in the first place (e.g. appearance of the "fuel insufficient" message on the CDU) or making the errors more apparent if they are entered (e.g. plan mode on the HSI map display). Unfortunately the use of machine intelligence to check erroneous human behavior is in its infancy; at least the current generation glass cockpit aircraft have made a beginning. But it is still very easy for crews to make programming or mode selection errors which could have serious results, as the errors described in Chapter VI indicate.

We are not able at this time to assert whether high or low automation aircraft generate more crew errors. Recently the Aviation Safety Reporting System of NASA has been conducting studies of reports from crews of advanced technology aircraft (Orlady, 1989a,b), but their database does not permit a direct comparison of error rates of aircraft of differing equipment sophistication. In one area of great concern, altitude deviations ("busts"), which is the most frequent topic of ASRS reports, there is the appearance of an inordinately large number of reports from the advanced aircraft, including many which were being operated manually at the time of the deviation. These deviations, which often result from failure of the aircraft to perform automatic level-off at the correct altitude, are usually traceable to human error and almost never to equipment failure.

On one hand the ability to program automatic level-off maneuvers should prevent the altitude deviation typical of low technology aircraft, simply forgetting, usually due to distraction, to perform the maneuver. But likewise, the devices invite new errors of their own making such as failing to modify altitudes with ATC changes, or "killing the capture" once the level-off maneuver has begun. But pending further research, we cannot state whether the high or low sophistication cockpits produce greater liability to altitude deviations and other errors.

The warning and alerting systems of the 757 deserve high praise in the view of most pilots. The introduction of the EICAS halted and reversed the continual upward spiral of the number of warnings and alerts in the cockpit (Wiener and Curry, 1980). Future models will probably see improved formats, increased use of computer graphics, prioritizing of alerts, and increased use of diagnostic aids on the EICAS display. Already the A-320 offers color graphic systems schematics on their version (ECAM), as does the B-747-400 on its EICAS.

It would appear to be a simple matter to exploit the computational capability of the FMC even further, adding some features to the flight guidance systems to aid the crews in avoiding errors. For example, a check of altitude against altimeter setting could result in a message to reset altimeters approaching FL 180 appearing (on various displays) as a backup to human memory. Similarly, a check of airspeed against altitude (above/below 10,000 feet) could warn the crew if they were exceeding the 250 knot speed limits, or electronically prevent it through autothrottle control. In maneuvering offshore, the warning could be canceled, or ignored. Whether automation should be used to warn crews of a condition, or intervene to prevent it, is a basic philosophical design question.

As the field of artificial intelligence develops, we can look forward to ever more sophisticated warning and alerting systems, and error-prevention systems. However, each of these contains its inherent drawback, the possibility of false or erroneous alarms. It is inescapable that any device capable of sensing an alert condition with a given probability carries the risk of some non-zero probability of a false alarm. The two are inextricably bound. For a system of fixed detectability, as the designer increases the probability of a valid detection of an alert condition (makes the system more "sensitive"), the probability of a false alarm must inevitably increase. The designer strives to increase the detectability of the system, by improving sensors, filters, alarm logic, etc., but once these are set, he must decide where to balance the probability of valid and false alarms. The only relief is to provide the pilot with means of corroborating the alert (see Wiener-Curry guidelines, Appendix 1).

Systems designers and artificial intelligence researchers are currently speaking of "error-tolerant" systems, meaning that human errors which are not prevented in their inception are

prevented from affecting the system. Thus machine intelligence recognizes the input as erroneous, and "traps" the error, preventing it from affecting the system, and calling it to the attention of the crew. The "insufficient fuel" message on the CDU, mentioned previously, is an rudimentary example. This and other philosophies of how one might employ machine intelligence to prevent or trap errors is covered briefly in Wiener, 1988.

### Crew Coordination

Chapter VII pointed to certain issues and problems in crew coordination that might be seen as characteristic of working in the two-pilot, advanced technology aircraft. Unfortunately we have little guidance in this area, as NASA research in cockpit resource management (CRM) has not yet considered the effect of the nature of the cockpit equipment, and CRM training now offered by many U.S. carriers has also not confronted the issue. In short, research and training in CRM to date has viewed crew coordination and CRM training as if they were model independent, except for the consideration of two- versus three-pilot crews.

The data in Chapter VII, as well as interviews and jumpseat observations during this project have convinced the author that this may not be the case. Crew coordination for a fixed size crew may not be independent of the model, and automation probably exerts an influence on the way the task is managed by the two pilots. We are assuming in this discussion that all advanced technology aircraft are served by two pilots; there are a few exceptions, where labor contracts have led to three-pilot crews in the new generation aircraft, but not in the U.S. The matter is still in contention by at least one European carrier that has ordered the A-320. Because the advanced technology aircraft are crewed by two pilots, and no doubt all transport aircraft will be in the future, the subject of crew coordination is of tantamount importance.

Based on the information in this study, we can summarize the areas of concern in cockpit resource management of high technology aircraft:

1. Compared to traditional models, it is physically difficult for one pilot to see what the other is doing. In the first generation jet aircraft the setting of the autopilot and other modes could be easily observed by both pilots; likewise in the second generation where most of the selections were made on a mode control panel (e.g. DC-10). But on the glass cockpit models, the important selections are made in the CDU (as well as the MCP), and this is not visible to the other crew member unless he selects the proper CDU page. Though some carriers have a procedure that the captain must approve any changes entered into the CDU before they are executed, this is seldom done; often he is working on his CDU on another page at the same time.

2. It is more difficult for the captain to monitor the work of the first officer, and to understand what he is doing, and vice-versa.
3. Automation tends to induce a breakdown of the traditional (and stated) role of the pilot flying (PF) versus pilot not flying (PNF), and a less clear demarcation of "who does what" than in traditional cockpits. In aircraft in the past, the standardization of the allocation of duties and functions has been one of the foundations of cockpit safety.
4. The modern cockpit seems to produce a redistribution authority from the captain to the first officer. The first officers now are able to make decisions (e.g. when to slow the aircraft on descent into a terminal area) that previously were the prerogative of the captain. Largely this is unintended, and is a result of the fact that first officers are often more proficient than their captains in data entry into the CDU, so the captain, particularly in times of high workload, may surrender some authority to the first officer just to get the job done. Often the captain recognizes the superior CDU skills of his first officers, and utilizes them to his advantage.
5. There is a tendency of the crew to "help" each other with programming duties when workload increases. This may or may not be a good thing - it is difficult to say - but it clearly tends to dissolve the clear demarcation of duties when one pilot says "here, I'll do that for you" and rushes to the CDU or MCP. Computer-based systems seem to invite such behavior. The same pilot who gladly jumps in and takes duties away from the other pilot in a high technology plane would probably not be tempted to do the same in a traditional aircraft, for example controlling cabin pressurization.

In summary, the highly automated cockpit may require special scrutiny for crew coordination and cockpit resource management, both in the assignment of tasks, and standardization of their performance. This may prove to be particularly important in the likelihood that pilots with the least experience may soon be assigned to the most sophisticated cockpits, as previously discussed.

### Workload

Workload reduction has already been discussed in this chapter under "Equipment." It is a difficult area, characterized by strong pilot opinion and little objective data. The question of how to define, let alone measure, workload baffles the human factors profession. This is particularly true of the "mental" or ("cognitive") component of workload.

What has emerged from this study is that one cannot make a clear case for automation bringing an overall reduction in workload, especially during those times when the reduction is most needed. As noted previously, the paradox is that when circumstances of the flight add up to an very high workload, pilots often find the automatic features so difficult to manage that they abandon them in favor of more manual modes. Here we must be careful to make clear what is being abandoned. As stated previously, when a pilot speaks of "clicking it off" he is referring to flight guidance systems, possibly including speed control. Certain important automatic features which do contribute to workload reduction remain in use, e.g. basic systems, EICAS, and other warning and alerting systems.

Be this as it may, there is no escaping the conclusion that the same automatic features (e.g. LNAV and VNAV) that were placed in the aircraft in the hopes of reducing workload, particularly at low altitude in terminal areas, are perceived by the pilot as workload inducing. This is due largely to: 1) human-computer interfaces that are difficult to operate; and 2) an inflexible ATC system which does not allow the crews to exploit the advanced features of the aircraft due to frequent changes in flight plan, off-course vectors, unpublished crossing restrictions, speed reductions, etc. When these occur, the crews typically attempt to enter them in the CDU, and then if the clearances continue to change, give up and "fly it like a 727," as it is often stated.

Some relief could come from software changes. For example, many pilots have complained of the difficulty of loading a route involving the intersection of two "J" airways where the intersection has no name established in the database. In this case the pilot must construct a "man-made" waypoint, either by taking place-bearing-distance off of one of the VORs (if the distance from one of the VORs is shown), or place-bearing off of two of the VORs, a cumbersome procedure at best. Flying an assigned heading to intercept a radial outbound from a VOR is another difficult procedure, which could probably profit from redesign of the software. [1]

Certain other factors influence the cockpit workload. These are not necessarily a consequence of automation, but they do impact two-pilot crews, and hence loom large in the mind of pilots on the advanced aircraft. These include company calls (often required at very unwelcome times in the flight, such as passing through 10,000 feet), PA announcements, dealing with cabin problems, and cabin-generated radio calls such as requests for wheelchairs, galley supplies, and other passenger services.

-----  
[1] Engineers from Honeywell have recently informed the author that their advanced systems now have the capability of joining two jet airways on the Route page. One carrier not associated with this study has created its own intersection names, which a pilot must look up in a manual and enter into the CDU as a waypoint (e.g. J4/J86 is EWM 11).

It is not the author's intention to open up the two- versus three- pilot crew controversy, but only to note that many pilots have reported that some of what they perceive as non-essential duties which were manageable on the three-pilot crews have become burdensome and even possibly hazardous in two-pilot operations. Many have recommended particular solutions, such as no company calls during climb until above FL 180; no departure of a pilot from the cockpit for non-critical cabin items; and possibly providing a VHF communications or ACARS unit in the cabin for the flight attendants to use for passenger-related communications with the company.

Many pilots suggested that their company has not yet adjusted their thinking to a two-pilot crew, and still demand procedures that may have been appropriate when there was flight engineer backup. If this is true, there will be a severe test of it ahead in the two-pilot, long-range models, such as the MD-11 and the B-747-400.

We should also note that much of the printed information available to the pilot has not kept pace with the modern cockpit. Designers of such aids as manuals, takeoff charts, minimum equipment lists, and even navigation charts have not recognized the need to revise and simplify printed materials that were once appropriate for three-pilot crews, where flight engineers could do the bulk of the "book work."

Another problem leading to confusion and hence increased workload is that fact that the computer-produced flight plan provided to the crew may contain waypoints whose names are inconsistent with those in the FMC. This is particularly true of waypoints located at non-directional beacons (NDBs). An example is Carolina Beach. The computer-produced flight plan (KMIA to northeast airports) reads "...AR3 CLB..." and the crew quite naturally attempts to load "CLB" into the FMC, only to receive "not in database" error messages. The FMC stores this waypoint as "CLBNB", which is on neither the flight plan nor the chart.

The author has several times seen crews puzzling over their inability to load such a waypoint before discovering from their charts that the waypoint is an NDB, and recalling that the "NB" must be added. It would seem a small matter to program the computers that furnish the flight plans to be consistent with the FMC designators, and it would also probably aid crews of conventional aircraft. Such inconsistencies generate increased workload and frustration, often leading to abandonment of the automation, and what is worse, they harbor the potential for serious error.

We conclude that the present generation of advanced technology aircraft has failed to realize its potential for workload reduction for both internal reasons, and reasons external to the hardware and software design. Hardware changes are unlikely in the present models, but software changes could be considered where a potential for workload reduction exists. Efforts must

continue toward workload reduction and more effective utilization of the resources of two-pilot crews. It seems imperative, given the forecasts for increasing traffic in the decades ahead, that current automation philosophy be reevaluated and that every means of reducing workload in the high demand environments be pursued.

### Air Traffic Control

The impact of ATC on advanced technology aircraft has already been mentioned several times in this chapter, and it is unnecessary to belabor it further. We are hopeful that the changes that will take place in the coming decade with the implementation of the advanced ATC systems under the National Airspace Plan (NASP) will relieve some of the problems, and allow fuller exploitation of the remarkable flight guidance capabilities of the highly automated aircraft.

It is regrettable that from the beginning, aircraft and ground-based ATC systems were designed, developed, and manufactured almost as if they were unrelated and independent enterprises. Even the current developments in ATC and in flight guidance systems reflect this proclivity. The proper utilization of aircraft and airspace will only be achieved when aircraft designers and those who design and operate ground-based ATC work in closer harmony. It seems strange that in 1989 it is still necessary to say that.

## C. SUMMARY AND RECOMMENDATIONS

In summary, this field study has shown that the modern, advanced technology transport aircraft is being effectively and safely operated by two-pilot crews, but that numerous human factors problems, as well as some problems external to the cockpit, prevent the safest and most effective utilization of the aircraft. We find the concepts of the present generation of automation essentially sound, but lacking in proper user interface design, resulting in less than optimal working conditions and under-utilization of the equipment.

We offer the following recommendations:

1. Research should continue on human-automation interfaces.
2. Research into making the ATC system more receptive to the capabilities of advanced aircraft should be conducted on a priority basis before the new generation ATC systems are placed on line.
3. Training departments of airlines should reexamine their training programs, syllabi, training equipment, and support materials to be certain that they have been responsive to necessary changes in training brought by the new aircraft.

4. Operators of modern, two-pilot aircraft should reexamine their procedures, checklists, flight plans, weather information, fuel slips, manuals, and company demands on the flight crew for opportunities to reduce workload and operational errors by providing optimal support material, and eliminating unnecessary procedures.
5. Research should be launched into cockpit resource management as it may differ in advanced versus traditional cockpits.
6. FAA should reexamine its certification procedures with the goal of carefully evaluating the human factors aspects of new models. Human factors other than merely estimates of workload should be considered, making use of error-predictive techniques.
7. Government agencies should encourage research into error-tolerant systems and other methods of exploiting machine intelligence to prevent, trap, or make more apparent errors made by the crew.
8. Standardize terminology and designations of nav aids across the CDU, charts, and ground computer-produced flight plans.
9. In general, future cockpits should be designed to provide automation that is human centered rather than technology driven.

#### D. EPILOGUE

Aviation safety is a living, growing, constantly changing enterprise. Times change, new equipment appears, and a steady improvement in machines, materials, training, maintenance, information, procedures, and supervision is constantly being sought. Many of the problems pointed out in this report have already been considered and remedied.

Certain portions of this report, mainly Chapter VI, involve self-criticism. It is a testimonial to the dedication of the two host airlines and the professionalism of the volunteer pilots that they would share their experiences and opinions with the author, and hence the aviation community. The willingness to recognize, report, and examine conditions that require remedy is the foundation of flight safety.

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2. The units of measure in this report are in feet and miles, as appropriate to air navigation in the U.S. and most of the world. For those wishing to convert to metric units, 1000 feet equals approximately 300 meters, and one mile equals approximately 1600 meters.

3. A glossary of terms peculiar to the Boeing 757/767 flight guidance system is included in Appendix 3. It is otherwise assumed that the reader is familiar with aviation terminology and abbreviations.

4. The following commercial software packages were used in this project: ABstat by Anderson-Bell; dBASE III by Ashton-Tate; ShowText by TimeWare; and Chart-Master by Ashton-Tate.

5. Figures IV-1, VIII-1, and IX-1 are reproduced with kind permission of Jeppesen-Sanderson, Inc.

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8. Special thanks are due to the participating line pilots who volunteered for this study and gave of their time. They are listed on the next two pages.

9. The two 36 X 36 intercorrelation matrices from the Phase-1 and Phase-2 attitude scales have been omitted in the interest of economy, and only portions of intercorrelation matrices are shown in this report. Copies of the entire matrices are available on request to the author: Box 248237, University of Miami, Coral Gables, FL 33124.

10. The opinions expressed in this report are those of the author, and not of any institution, organization, or agency.

## PILOT VOLUNTEERS

Adams	Lynn	Floyd, Jr.	R.N.
Allen	J. Scott	Fouraker	Joe F.
Andersen	Kenneth R.	Frazier	D.L.
Anderson	Thomas H.	Fugate	E.L.
Anderson, Jr.	W. E.	Giefer	Thomas S.
Arner	Byron J.	Gimson	Frederick A.
Arnold	Hazen D.	Grafton Jr.	C.W.
Beeler	Craig	Gray II	Jack E.
Bendjebar	Ralph H.	Griffith	Harvey L.
Berg	Gary M.	Grimes	Drew S.
Beslin	W. H.	Hadden	Eddie R.
Bianchi	Louis J.	Haglund	Paul D.
Billings	Steven C.	Hall	Gary
Blair	D.E.	Halverson	Loren
Boone	Robin	Hamilton	Bill
Boyce	Richard	Hamlin	Jack F.
Britt III	Victor H.	Hancock	James
Brown	Nelson W.	Harrott	Jerry
Buckingham	William H.	Hertzberg	Gary
Bucklin	Charles	Hervert	George
Burke	Raymond T.	Hiers	Herbert C.
Burson	Dave	Hoffman	Leonard
Call	Kayland	Hoffman	Robert G.
Campbell	John M.	Holt	Dorsey W.
Carlson	Gerald L.	Howard	Chane C.
Case	Jeffery Ray	Hyde	James A.
Case	Douglas W.	Inghram	Robert H.
Chadwick	Donald	Ingoglia	Phil
Chaklos	Tom	Jacobson	L.R.
Clyne	Patrick W.	Johnson	Michael A.
Cook	Barbara	Johnson	M. J.
Cooney	Vince	Kaffee	Jeffrey
Dailey	Joe R.	Kahn	G.S.
Danfelt	Eric	Keating	Donald W.
Darnold	James P.	Keck	Harold W.
Davidson	Bret A.	Keith	Thomas P.
Deming	Maurice A.	Kelley	Gerald
Derby, Jr.	Jack A.	Kelm	Kenneth B.
Dickey	Douglas T.	Klein	Thomas H.
Diem	Gustav	Knobel	James D.
Donlan	Patrick T.	Kohler	Joseph G.
Dundas	Charles P.	Kulenkemp	Jerome D.
Dunlap	Edward R.	Land	Howard Wayne
Duplissey	G.	Lavarello	Eugene F.
Durante	John P.	Lawton, III	R.G.
Dye	Doug	Leslie	Gary A.
Eglit	Verner	Levy	Martin A.
Eisel	Griffith H.	Lillyblad	Stephen
Felton	Roger	Lindley	James
Ficklen III	John D.	Linke	Don
Fields	W. Grant	Long	Joel D.
Finley	Gary L.	Longson	Weston J.
Fisher	George A.	Loy	David A.
Fisher III	J. F.	Machauer	William A.

MacLennan	Rod C.	Roland	K. Phil
Magill	Lincoln	Rydell	Gene V.
Malchow	K. R.	Sadler	Terris M.
Manning	Alan	Schunemann	Paul F.
McAllister	Darl	Scotch	Robert E.
McCann	Joseph P.	Scott	Phillip C.
McDonald	Timothy B.	Searls	R.R.
McTaggart	Edward Lee	Sharp	Jack
Meisner	Kendall N.	Sigman	Paul J.
Meyer	Bruce	Simmons	Carl R.
Millar	Douglas P.	Siraco	Philip
Miller	J. Phillip	Skinner	Gary L.
Milon	Ronald C.	Smith	Steven
Monson III	Laurence C.	Smith	Andrew C.
Moore	Pete	Snipes	S. Gray
Moore	Richard L.	Sommerfeld	Eugene A.
Morgan	Frank G.	Soper	Rex C.
Odell	Roger A.	Spry	Robert R.
Osborn	Rich	Stack	Daniel T.
Ozawa	Leland K.	Stecher, Jr.	J.D.
Palmer	Joe	Stoddard	G. P.
Paschall	Robert L.	Stone	John S.
Pass	Brad	Strader	James R.
Patzke	Robert K.	Stratton	Douglas P.
Peasley	Robt	Sullivan	John T.
Perez Jr.	Efrain	Swan	Ted
Pero	Kyle F.	Sweeney	John J.
Petagna	Scott	Tarburton	James G.
Petron	Ken	Taylor	Al
Petryk	James D.	Tedder	Virgil R.
Piszczek	Walter J.	Thompson	Walt
Pitmon	Gerald R.	Tomelden	A. Patrick
Plitt	C. W.	Tyson	Howard J.
Porter	David R.	Upthegrove	John L.
Prewitt	Reg	Van De Walker	Bruce
Pritchett	Jerry D.	Vanderslois	J.P.
Pruyn	Murry J.	Vanvickle	Ralph
Ranke	Don	Waldrip	Ken
Rataczak	William J.	Welch Jr.	Harry G.
Reinhart	Howard	White	Steve S.
Reitan	Albert G.	Wiechmann	Walter
Richmond	Geo H.	Wilder	David S.
Richter	Joseph J.	Williams	Clois E.
Riley	William J.	Williford, Jr.	H.D.
Robertson	Stephen C.	Wotherspoon	Gordon
Rogers	George	Wright	Dean S.
Rohrborn	Robert C.	Young	T. V.

## APPENDIX 1

### Automation Guidelines from Wiener and Curry (1980)

#### Control Tasks

1. System operation should be easily interpretable or understandable by the operator, to facilitate the detection of improper operation and to facilitate the diagnosis of malfunctions.
2. Design the automatic system to perform the task the way the user wants it done (consistent with other constraints such as safety); this may require user control of certain parameters, such as system gains (see Principle No. 5). Many users of automated systems find that the systems do not perform the function in the manner desired by the operator. For example, autopilots, especially older designs, have too much "wing waggle" for passenger comfort when tracking ground based navigation stations. Thus, many airline pilots do not use this feature, even when traveling coast-to-coast on non-stop flights.
3. Design the automation to prevent peak levels of task demand from becoming excessive (this may vary from operator to operator). System monitoring is not only a legitimate, but a necessary activity of the human operator; however, it generally takes second priority to other, event-driven tasks. Keeping task demand at reasonable levels will ensure available time for monitoring.
4. For most complex systems, it is very difficult for the computer to sense when the task demands on the operator are too high. Thus the operator must be trained and motivated to use automation as an additional resource (i.e. as a helper).
5. Desires and needs for automation will vary with operators, and with time for any one operator. Allow for different operator "styles" (choice of automation) when feasible.
6. Ensure that overall system performance will be insensitive to different options, or styles of operation. For example, the pilot may choose to have the autopilot either fly pilot-selected headings or track ground-based navigation stations.
7. Provide a means for checking the set-up and information input to automatic systems. Many automatic system failures have been and will continue to be due to set-up error, rather than hardware failures. The automatic system itself can check some of the set-up, but independent error-checking equipment/procedures should be provided when appropriate.

8. Extensive training is required for operators working with automated equipment, not only to ensure proper operation and set-up, but to impart a knowledge of correct operation (for anomaly detection) and malfunction procedures (for diagnosis and treatment).

#### Monitoring Tasks

9. Operators should be trained, motivated, and evaluated to monitor effectively.

10. If automation reduces task demands to low levels, provide meaningful duties to maintain operator involvement and resistance to distraction. Many others have recommended adding tasks, but it is extremely important that any additional duties be meaningful (not "make-work") and directed toward the primary task itself.

11. Keep false alarm rates within acceptable limits (recognize the behavioral impact of excessive false alarms).

12. Alarms with more than one mode, or more than one condition that can trigger the alarm for a mode, must clearly indicate which condition is responsible for the alarm display.

13. When response time is not critical, most operators will attempt to check the validity of the alarm. Provide information in a proper format for that this validity check can be made quickly and accurately and not become a source of distraction. Also provide the operator with information and controls to diagnose the automatic system and warning system operation. Some of these should be easy, quick checks of sensors and indicators (such as the familiar "press to test" for light bulbs); larger systems may require logic tests.

14. The format of the alarm should indicate the degree of emergency. Multiple levels of urgency of the same condition may be beneficial.

15. Devise training techniques and possible training hardware (including part- and whole-task simulators) to ensure that flight-crews are exposed to all forms of alerts and to many of the possible conditions of alerts, and that they understand how to deal with them.

C-3

APPENDIX 2

QUESTIONNAIRE NO. 1 (1986)

ID Code: \_\_\_\_\_

I. AIRCRAFT EXPERIENCE

We would like to know your past experience in your company's present aircraft. Please place an "X" in the box for each seat on each aircraft that you have ever occupied.

	SEAT		
	Captain	F/O	S/O
DC-9	*	*	*
B-727	*	*	*
A-300	*	*	*
L-1011	*	*	*
DC-10	*	*	*
B-747	*	*	*

Which seat in which aircraft did you occupy immediately before going to 757 school?

Aircraft \_\_\_\_\_ Seat \_\_\_\_\_

Do you think this made a difference in your ease of transition?

(Yes/No) \_\_\_\_\_

If "yes", please explain:

Approximate total time in 757 \_\_\_\_\_ hours

## ATTITUDE-TOWARD-AUTOMATION SCALE

(Note: this section appears on both questionnaires)

This is a 36-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."

Place your responses on the colored sheets.

1. Flying today is more challenging than ever.
2. I am concerned about a possible loss of my flying skills with too much automation.
3. The 757 automation works great in today's ATC environment.
4. It is important to me to fly the most modern plane in my company's fleet.
5. Younger pilots catch on to the new systems (like the CDU) faster than older pilots.
6. I think they've gone too far with automation.
7. I always know what mode the autopilot/flight director is in.
8. I use the automation mainly because my company wants me to.
9. I prefer to hand-fly part of every trip to keep my skills up.
10. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "managing" the flight.
11. In the 757 automation, there are still things that happen that surprise me.
12. I can fly the plane as smoothly by hand as with the automation.
13. We make fewer errors in the 757 than we did in the older models.
14. I look forward to more automation - the more the better.
15. I feel that I am "ahead of the plane" more in the 757.
16. I spend more time setting up and managing the automation (CDU, FMS) than I would hand-flying or using a plain autopilot.

17. Autoland capability definitely enhances safety.
18. Automation does not reduce total workload, since there is more to monitor now.
19. Automation is the thing that is going to turn this industry around and make it profitable again.
20. Crew coordination is more difficult in the 757.
21. Flying the 757 in terminal areas such as Washington and New York is easier than it was with the older planes.
22. I miss the "good old days" of simpler aircraft.
23. The "glass cockpit" instruments and displays are a big step forward.
24. Training for the 757 was as adequate as any training that I have had.
25. I am concerned about the reliability of some of the modern equipment.
26. With the automation available today I prefer the two-pilot cockpit to the three-pilot operation.
27. Overall, automation reduces pilot fatigue.
28. We have more time to look out for other aircraft in the terminal areas in the 757 than other aircraft I've flown.
29. I use automation mainly because it helps me get the job done.
30. It is easier to bust an altitude in the 757 than other planes.
31. Some times I feel more like a "button pusher" than a pilot.
32. Planning and selecting alternatives are more important in the 757 than they were in other aircraft.
33. After flying the 757, I would never want to go back to old types of planes.
34. There are still modes and features of the 757 FMS that I don't understand.
35. In the 757 there is too much programming going on below 10,000 feet and in the terminal areas.
36. In the 757, it is easier for the captain to supervise the first officer than in other planes.

ATTITUDES-TOWARD-AUTOMATION

ANSWER FORM

(Note: second page, items 19-36, not shown in this report)

Referring to the 36 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 36 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*	*	*	*	*	*

## OPEN-ENDED QUESTIONS

Please answer the following questions in your own words. (Note: space for the responses was provided on the original forms; the questions are compacted for this report for brevity.)

1. List the features or mode of the 757 automation, instrumentation, or avionics that you like and dislike. Explain why if you wish.

Like

Dislike

2. Describe any problems that you had during your IOE and early months of flying the 757. Are there still areas you have trouble with, or don't understand?
3. Describe in detail a error which you made, or observed, in operating the automatic features of the 757 that could have led to an incident or violation. How could it have been avoided? (equipment design? training? crew coordination?) Please describe specifically what was done.
4. What would you say about crew coordination on the 757 (compared to other aircraft)?
5. What did you think of your training for the 757? What topics should receive more/less emphasis? Any comments on training aids and devices that were used, or needed?
6. Do you like the way the 757 automation interfaces to the ATC environment? Please mention things you have trouble with, and things that work well, in working with ATC.

QUESTIONNAIRE NO. 2 (1987)

ID Code: \_\_\_\_\_

I. AIRCRAFT EXPERIENCE

1. (Approximate) Total 757 flying time \_\_\_\_\_ hours
2. Are you still flying the 757?
  - a. If yes, which seat? Left \_\_\_\_\_ Right \_\_\_\_\_
  - b. If no, what aircraft and seat are you flying?  
Aircraft \_\_\_\_\_ Seat \_\_\_\_\_

If your answer to this question is no, please also fill out the yellow form.

If you have retired, please indicate approx. date \_\_\_\_\_

3. a. Are you presently an instructor? yes \_\_\_\_\_ no \_\_\_\_\_  
b. A check airman? yes \_\_\_\_\_ no \_\_\_\_\_
4. Please indicate the approximate number of 757 autolands you have made (either as PF or PNF).

No. \_\_\_\_\_

Approximately how many were actual Cat II or III?

Cat II \_\_\_\_\_ Cat III \_\_\_\_\_

5. Approximately how many 757 non-precision approaches (as PF or PNF) have you made?  
VOR \_\_\_\_\_ LOC \_\_\_\_\_ ADF \_\_\_\_\_
6. Approximately how many approaches have you made (as PF or PNF) that were not in the data base (had to be built)?  
Number: \_\_\_\_\_
7. If the money and quality of trips were all the same, what would be your first choice of plane to fly in your company's present fleet?  
Aircraft: \_\_\_\_\_

(Note: Section II, the attitude scales, was identical to that in Questionnaire No. 1, so it is not repeated in this report.)

#### OPEN-ENDED QUESTIONS

1. Do you feel that you have experienced any problem with loss of proficiency (skills loss, or "loss of scan") due to automation? Did you have any concern about this? If so, what can you do to prevent it?
2. If you were to leave the 757 for an older model aircraft, what features would you miss the most? What would you be happy to leave behind?
3. Describe in detail a critical error which you made, or saw someone make, which you think could be attributed to automation. How could the error have been prevented (equipment design? training? crew coordination?) Please try to describe specifically what happened, and what should have been done. (This question was also on the previous form)
4. What can you say about the overall workload of the 757 compared to other aircraft you have flown? Include mental workload, monitoring etc. What about time for outside scan?
5. Have you ever experienced an altitude deviation ("bust") in this aircraft? Was it due to crew error, equipment failure, ATC communication difficulty, crew coordination, or what? Please describe in detail.
6. What changes in the method of programming of the CDU or additional features, pages, prompts, etc. would you like to see? Do you feel that the programming tasks could or should be simplified? In what way?

SPECIAL FORM FOR THOSE WHO HAVE LEFT THE 757

1. Please list all aircraft and seats that you have flown since leaving the 757, and indicate which seat you occupy now. If you left the 757 and returned, please indicate.

2. What features of the 757 did you miss after you went to another plane?

3. Did you have any trouble adjusting to the older model aircraft? If so, please describe.

4. Based on your 757 experience, please describe your feelings about flying highly automated aircraft versus less automated aircraft.

### APPENDIX 3 - GLOSSARY OF TERMS

The following terms refer to the flight guidance system and other automated systems in the Boeing 757. General abbreviations from aviation and air navigation are not listed.

ACARS - ARINC communications addressing and reporting system  
AFDS - autopilot flight director system (sometimes A/P F/D)  
A/T - autothrottle (also ATS - autothrottle system)  
CO-RTE - company route  
CDU - control and display unit [1]  
CRS - course  
CRT - cathode ray tube  
CRZ - cruise  
CWS - control wheel steering  
D-TO EPR derated takeoff engine pressure ratio  
D-TO N1 derated takeoff engine fan speed  
DNTKFX down track fix  
DSPY - display annunciation on CDU  
E/D - end of descent  
E/O - engine out  
EADI - electronic attitude director indicator  
ECON - minimum cost speed schedule  
EEC - electronic engine control  
EFIS - electronic flight instrument system  
EHSI - electronic horizontal situation indicator  
EICAS - engine indication crew alerting system  
F/D (or FD) - flight director  
FLCH - flight level change  
FMC(S) - flight management computer (system) [1]  
HUD - head-up display  
INIT - initialization  
INS - inertial navigation system (see IRS, IRU)  
IRS - inertial reference system  
IRU - inertial reference unit  
LAT - latitude  
LNAV - lateral navigation guidance  
LON - longitude  
MAP CTR - HSI map centered on a waypoint  
MAX CLB - maximum engine thrust for two-engine climb  
MAX CRZ - maximum engine thrust for two-engine cruise  
MCP - mode control panel  
MSG - message annunciation on CDU  
MOD - modification

-----  
[1] The terms CDU and FMC are often used interchangeably by crews, though they actually refer to different hardware.

OFST - route offset annunciation on CDU  
PBD - place-bearing-distance waypoint  
PDB - performance data base  
POS INIT - position initialization  
POS REF - position reference  
PPOS - present position  
RTE - route  
SOPA - standard operating procedure amplified (Airline-2)  
SPD - speed  
SRP - selected reference point  
T/C - top of climb (also written TOC)  
T/D - top of descent (also written TOD)  
TAI - thermal anti-ice  
TMC - thrust management computer  
TO EPR - takeoff engine pressure ratio  
TO N1 - takeoff engine fan speed  
TRK - track to a navaid  
V/S - vertical speed  
V/TRK - vertical track  
VNAV - vertical navigation guidance  
W/MOD - with modification of vertical profile  
W/STEP - with step change in altitude  
WPT - waypoint  
XTK - cross track  
1L, 1R, 2L etc. - CDU left line select key 1, right 1, left 2 etc.

#### APPENDIX 4

The following question was included on the Phase-1 questionnaire. Its purpose was to determine what crew members might have thought of as important issues in cockpit automation.

**Can you suggest a question we should ask crew members in our interviews?**

Do you discipline yourself to maintain visual vigilance and look outside?

We don't have hand mikes at our airline. You might ask if pilots would like them installed.

Would you like to see a "descend direct" function? This would define a descent profile from present position/altitude to the next position/altitude constraint in the LEGS page. This would be especially useful on vectors to an outer marker or approach fix, when ATC hasn't allowed descent on the optimum profile.

Did you feel as prepared for your first or subsequent proficiency checks as you did in other aircraft?

What circumstances cause the DRAG REQUIRED message to appear during VNAV <descent>? Which has greater priority when descending in VNAV, VNAV path or selected MCP speed?

How do long hours and short layovers affect your performance on automated aircraft?

Has the company training department become complacent about this aircraft? Has the training system allowed weak pilots to be released to the line?

In the event that one crew member becomes incapacitated, how do you feel you would fare in the event of minimum weather condition or minor aircraft problems? And would you use automation?

Do you find yourself becoming complacent as you become more and more familiar with the aircraft and the automatics?

Ask about checklists and procedures.

You are in a descent into ORD and you have been given radar vectors off the magenta LNAV track <programmed course>. Does the DESCENT page continue to provide VNAV guidance? If so, to what point is the deviation from VNAV path computed? Is this information available elsewhere? Where?

Is the top of descent and subsequent VNAV path computer using the first waypoint altitude and/or speed restriction, or is it computed on an average of all the waypoint altitudes and/or speed restrictions entered on the LEGS page?

What would be a pilot's response to "full automation" which is data-linked to the ATC controllers console?

Ask how they use automation in good vs. bad weather. And how they keep both pilots fully informed about ATC clearances and progress of alternate procedures of aircraft systems when required.

Why isn't SOPA more fitted to new aircraft than extension of older aircraft existing SOPA? Do other pilots perceive this to be a problem?

Solicit comments on cockpit layout and physical position of controls.

Ask about crew coordination in emergencies.

Now that we have electronic fuel control and spoiler control, ask about fly-by-wire. (I do not approve of that concept without some manual backup.)

It would be nice to compile a list of two-man crew "techniques and courtesies" that various pilots use from different airlines that might help everyone. This should be part of SOPA published by the company.

If you were going to redesign any part of the 757, what would it be and how would you improve it?

What can your other pilot (Capt. or F/O) do to facilitate crew coordination?

If you were exposed to the 757 for the first time all over again, what would you do differently?

What is your impression of the safety of a two-pilot vs. three-pilot aircraft?

How do you like the altitude warning system, and how many altitude busts have you had?

I suggest you ask pilots their experience level not only in company equipment, but also what other planes they've flown in their total career. This would give you a more accurate picture of experience level and their aptitude to adapt to 757 automation.

What kind of system errors have you noticed with no reasonable explanation?

Do you feel that some automated communication system, with possibly a printed cockpit readout for such things as ATIS, weather, gate assignments, fuel requirements, maintenance items, cabin cleaning and catering etc. would be of value to a two-man crew?

Do you feel that a head-up display would improve CAT III assurance?

Can you suggest improvements to the training program?

Do the video readouts increase fatigue? Eye strain?

Do you feel that the yaw damper system is adequate?

Any comments on recirculated cabin air?

Do you feel that the lateral roll rate is adequate?

Would you like to have a Doppler microburst detector? Do you feel that the 757 is better than other aircraft at escaping low level wind shear?

Do flight attendants on the 757 complain more or less frequently of fatigue and dry skin?

How much do you use VNAV below 10,000 feet?

What is the worst C.I. <carried item> to have on a 757? APU?

What is your impression of the radar return?

Do the 757 computers make you feel like a more confident and competent pilot?

How much total time do you have in airplanes? Some crew members may have been an S/O for 10-15 years and just moved to F/O seat. I suggest that their viewpoint might be different from others.

Ask a question that would better quantify heads down time below 10,000 feet by one or both pilots.

How do you feel about the FMC in the first 100 hours and were you confident in the use of the MCP?

Ask questions about how much time spent with head in the cockpit.

How long did it take you to feel truly up-to-speed on the 757 FMC?

What would you like changed about the 757 or automation?

Ask about the radar. Also the in-flight display of the maintenance pages.

How much of the FMC capability do you use actively? How often does ATC allow you to use the programmed descent mode?

Don't 757 pilots feel that this is about the maximum amount of automation for a while?

Ask about a typical profile, from takeoff to landing, and the problems that exist.

Ask about ATC problems and changes below 10,000 feet.

APPENDIX 5

Results of statistical contrasts between attitude scale responses in Phase 1 and Phase 2 of the study

The following data matrices represent the two significant contrasts of the 36 attitude scales subjected to the Bowker test (also known as McNemar test) for symmetry. This test measures whether there was a change in responses from the first to the second phase of the study (1986 vs. 1987). For example, one can see from the row and column totals that in the first matrix below, there were 30 level 2 ("agree") responses in Phase 1, and 46 in Phase 2. However, examination of the cells shows that 21 persons changed from a 2 response to a 4 ("disagree") in Phase 2, and only four responses changed from a 4 to a 2. The extent to which these are different, (21 - 4) in this case represents asymmetric shift of opinion. If the sum of all differences squared is large enough, the null hypothesis of no change in opinion from Phase 1 to Phase 2 is rejected, as it was only in these two probes.

In the two matrices below, the movement is toward a more favorable view of automation (more disagreement with a negatively stated probe). However, because only two of the 36 items are significantly different, the author's general hypothesis of an increase in favorable views toward automation with an increase in experience is not supported.

**P16. I spend more time setting up and managing the automation (CDU, FMS) than I would hand-flying or using a plain autopilot.**

		Phase 2					
Response		1	2	3	4	5	Total
P h a s e 1	1	1	4	1	2	0	9
	2	1	19	4	21	1	46
	3	1	2	5	4	1	13
	4	0	4	5	24	2	35
	5	0	0	0	0	1	1
Total		3	30	15	51	5	104

Chi-square = 21, df = 9, p < .05

P34. There are still modes and features of the 757 FMS that I don't understand.

Phase 2

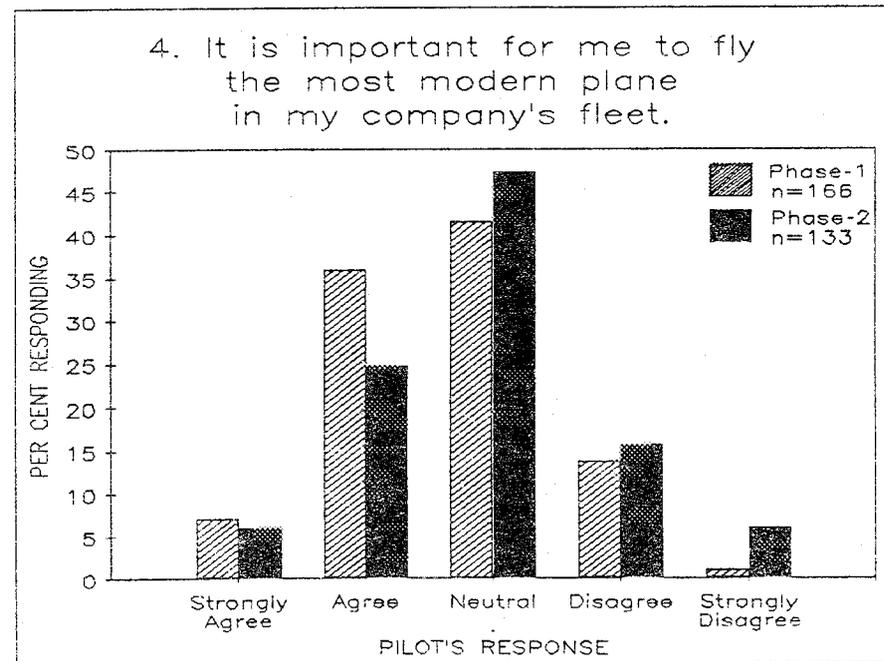
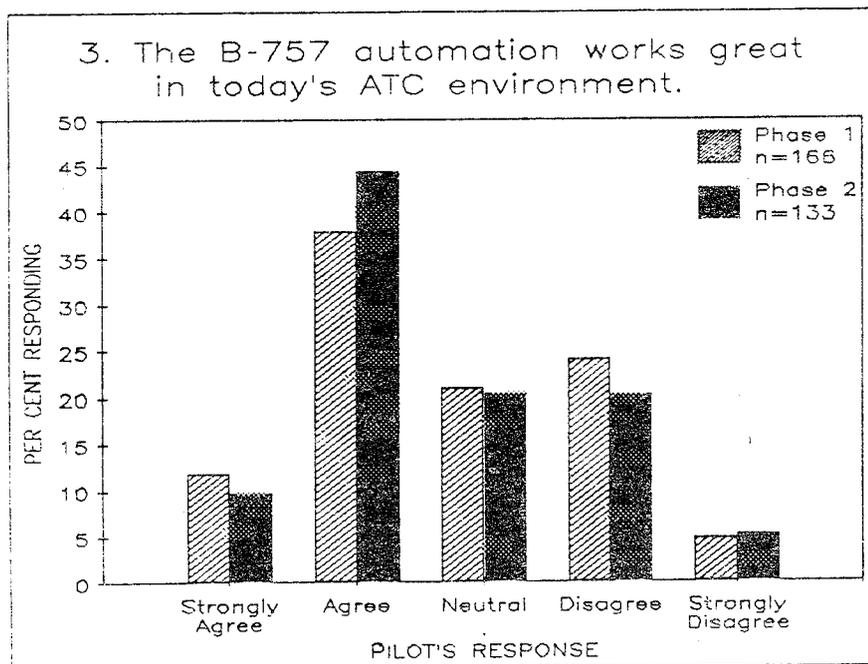
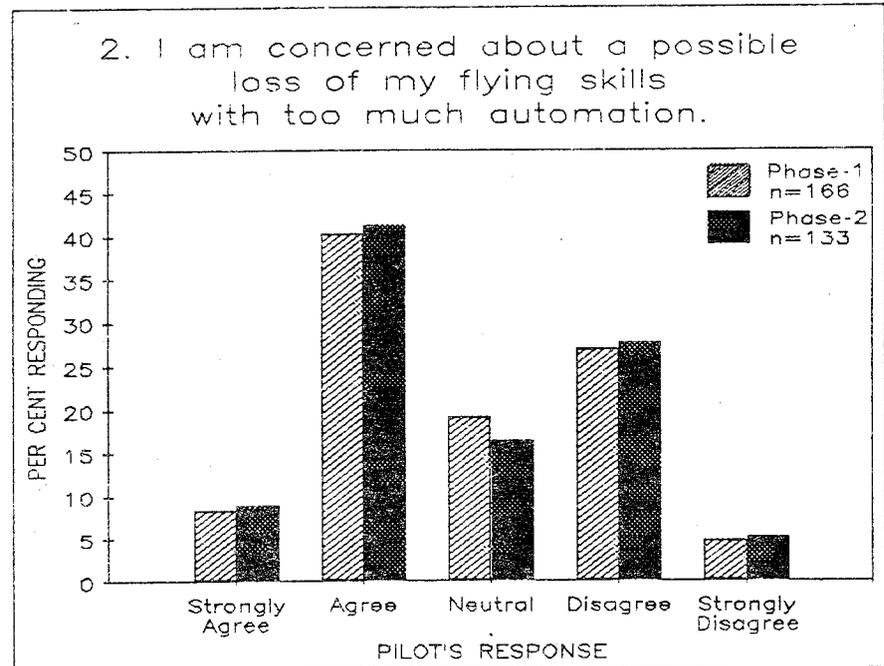
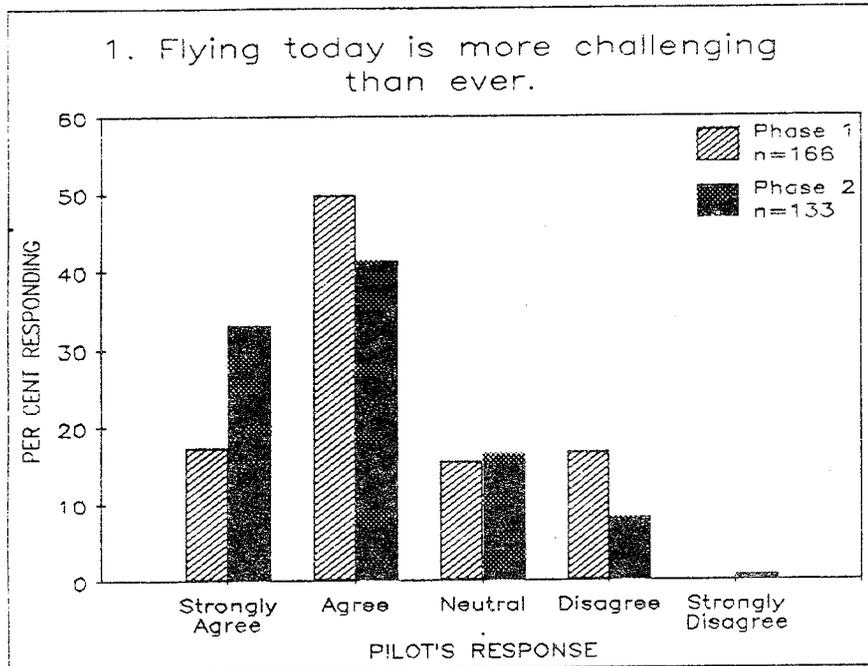
Response	1	2	3	4	5	Total
1	1	1	0	0	0	2
P						
h	0	12	8	11	3	34
a						
s	0	2	5	7	1	15
e						
1	0	6	1	31	4	42
5	0	0	0	6	5	11
Total	1	21	14	55	14	104

Chi-square = 15, df = 7, p < .05

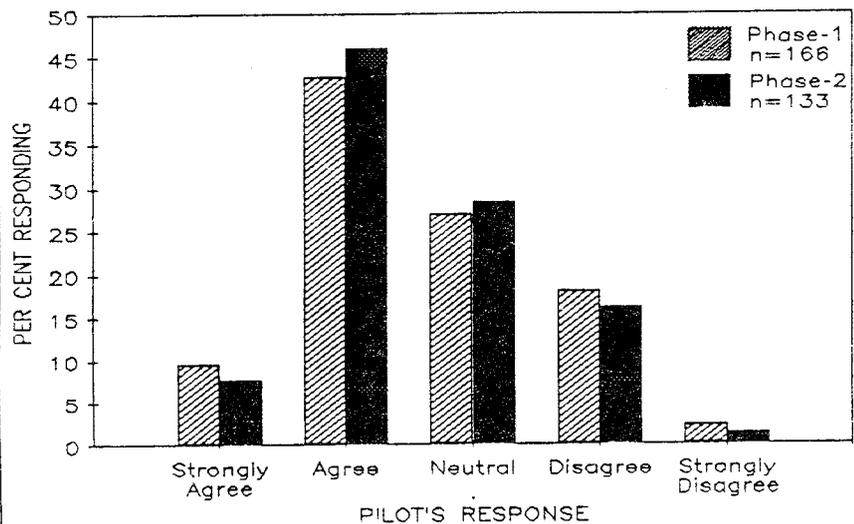
## APPENDIX 6

Graphic presentation of responses to attitude scales P1 through P36 in Phase 1 and Phase 2

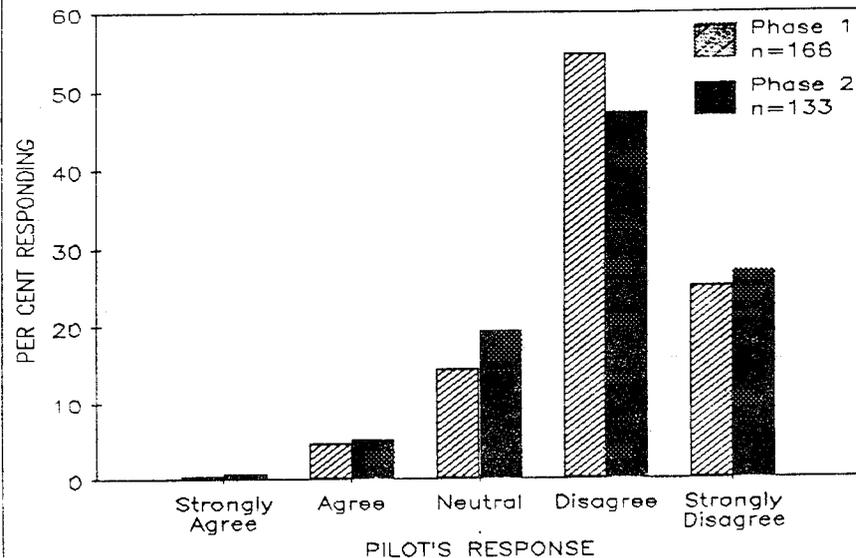
Note: The same graphics which appear in the next nine pages are also displayed separately in the appropriate chapters, but are repeated here for the convenience of the reader.



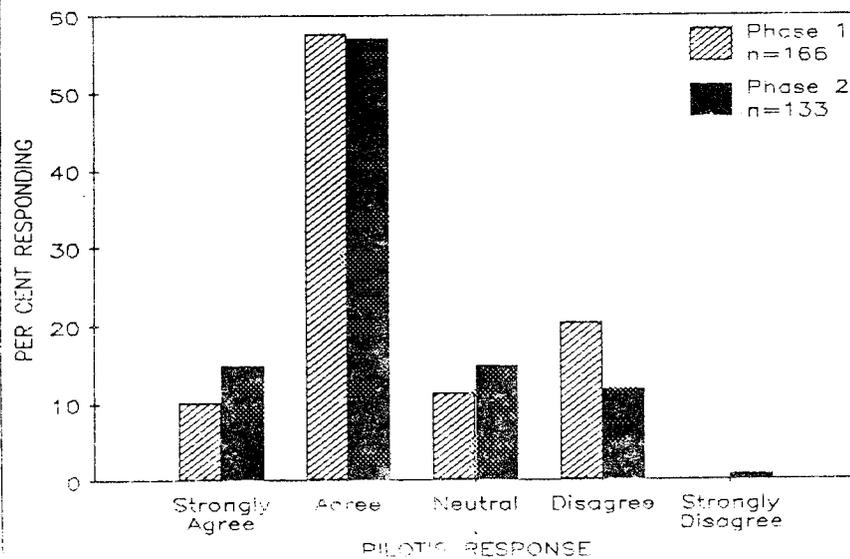
5. Younger pilots catch on to the new systems (like the CDU) faster than older pilots.



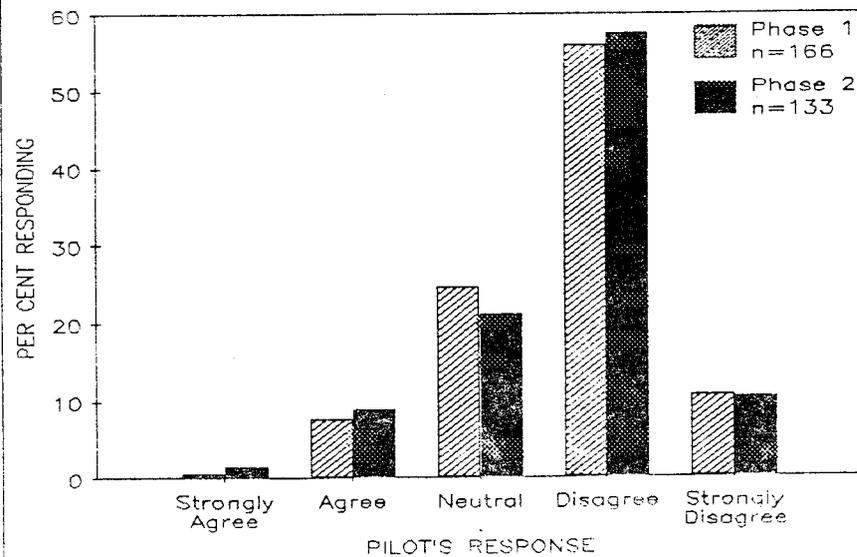
6. I think they've gone too far with automation.



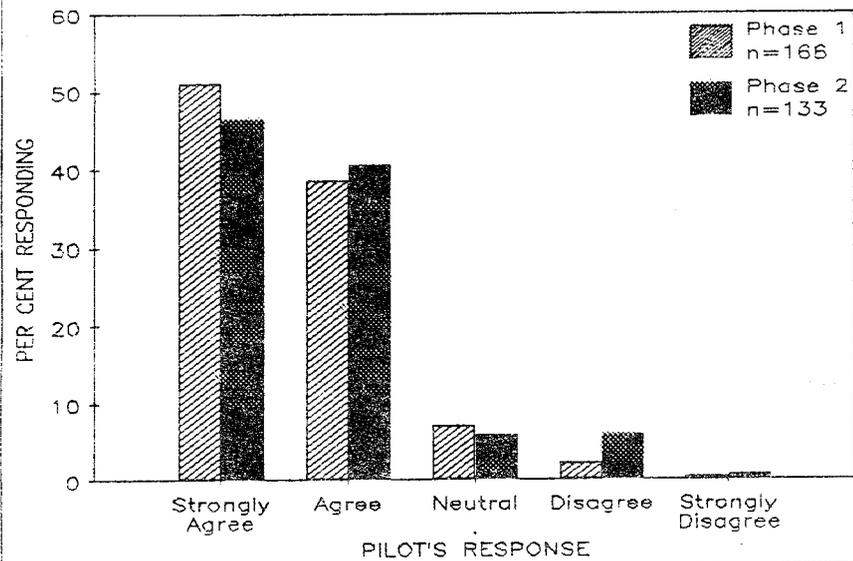
7. I always know what mode the autopilot/flight director is in.



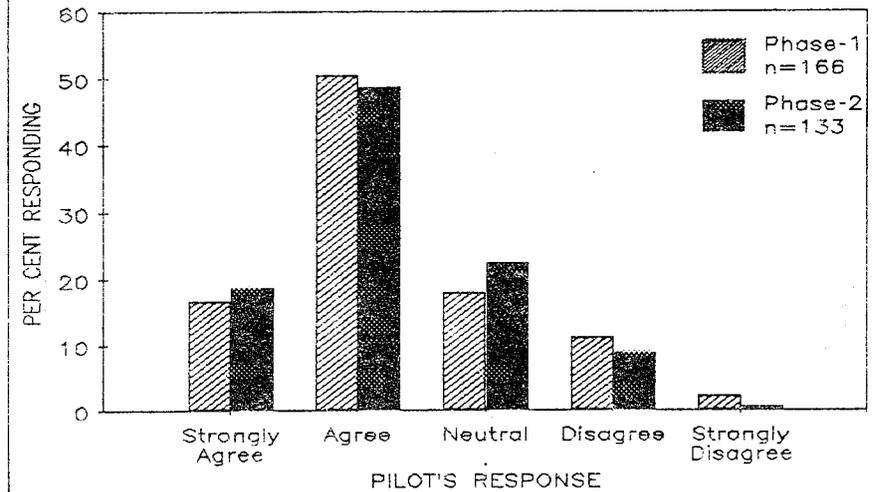
8. I use the automation mainly because my company wants me to.



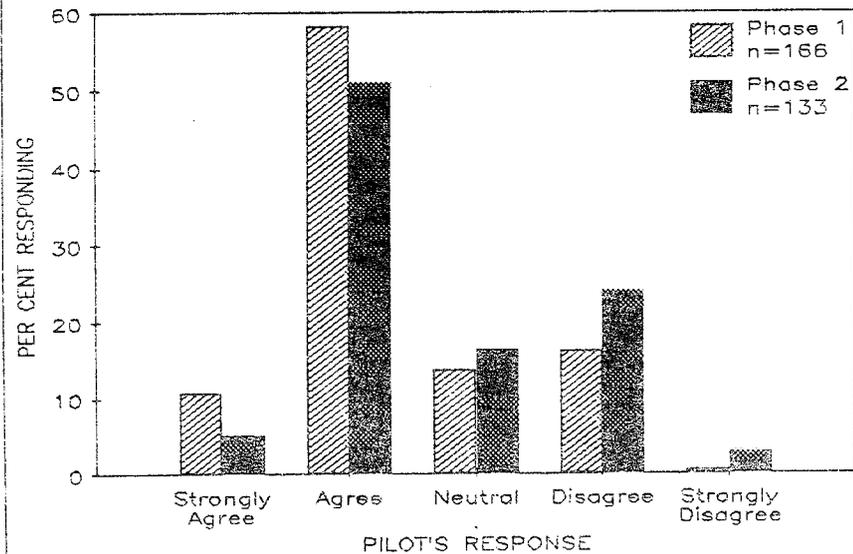
9. I prefer to hand-fly part of every trip to keep my skills up.



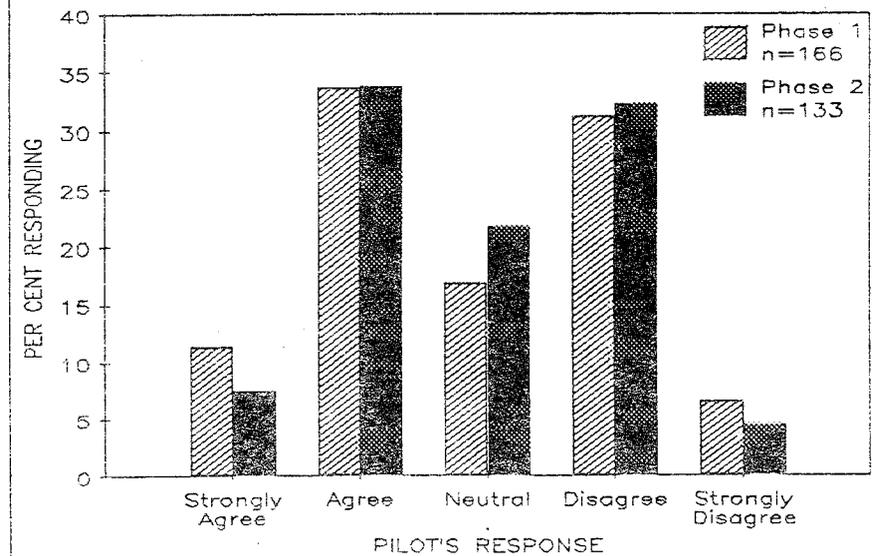
10. Automation frees me of much of the routine, mechanical parts of flying, so I can concentrate on "managing" the flight.

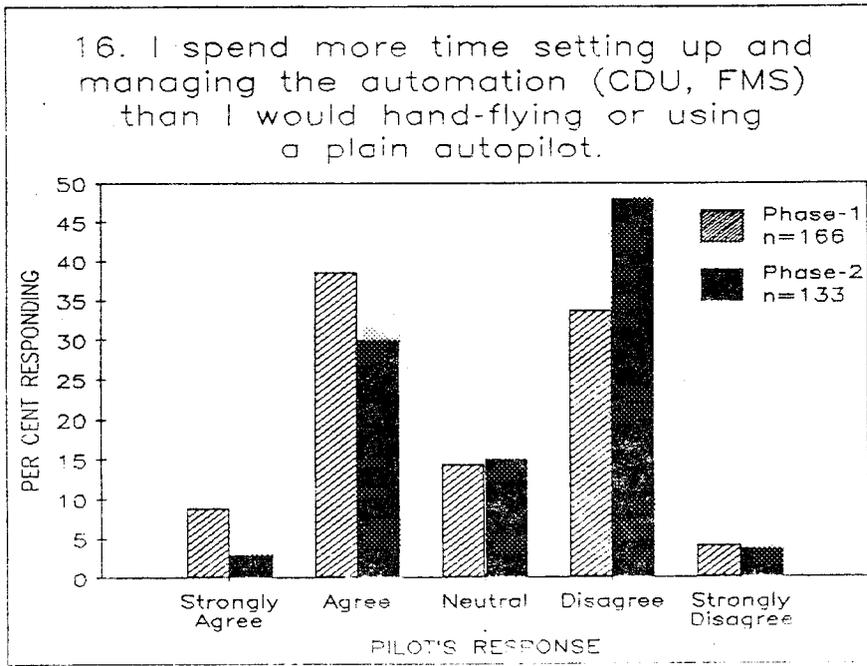
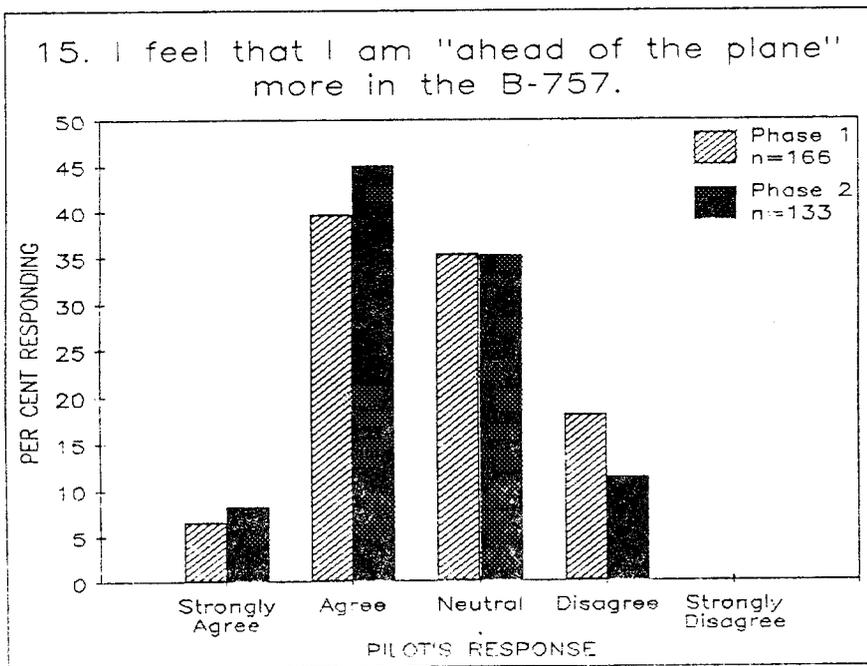
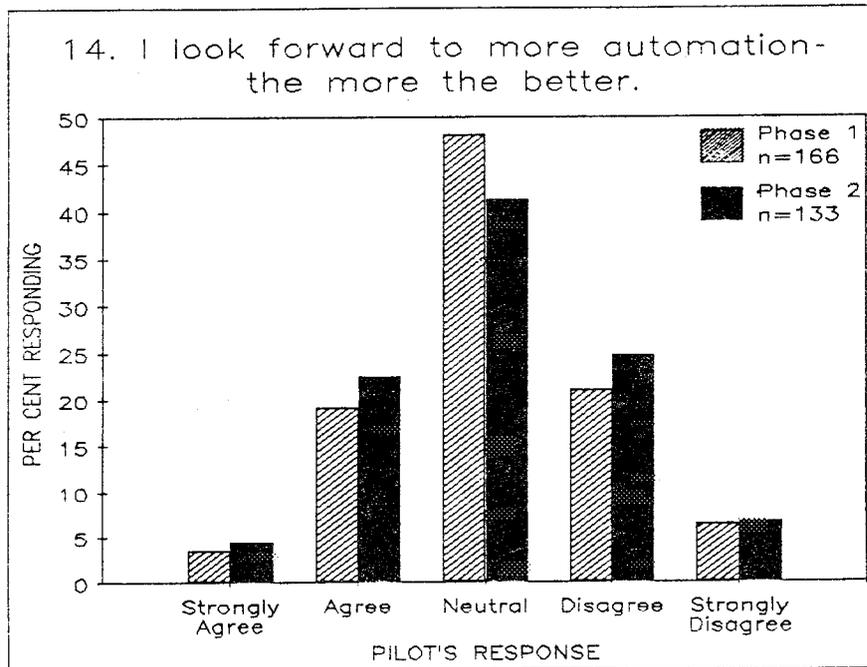
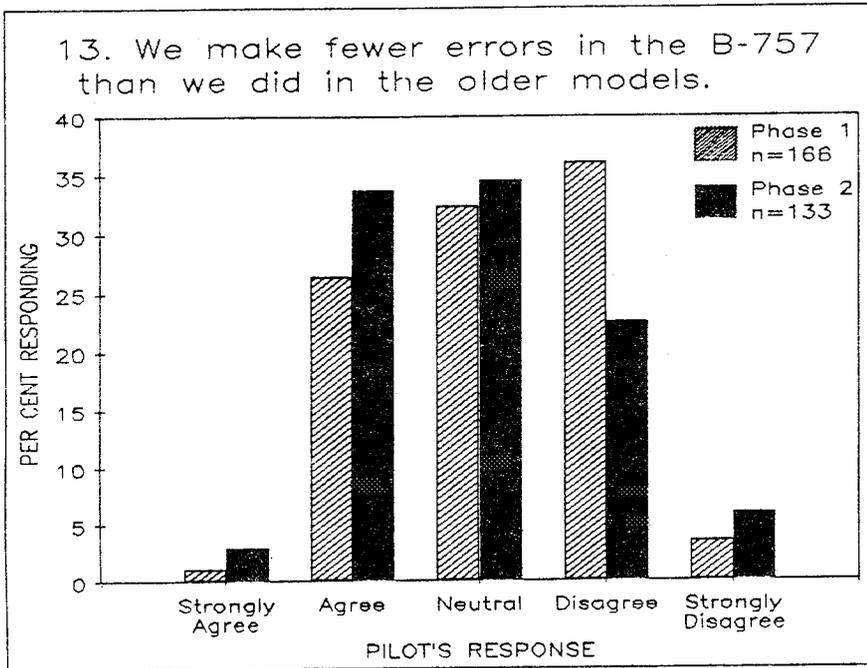


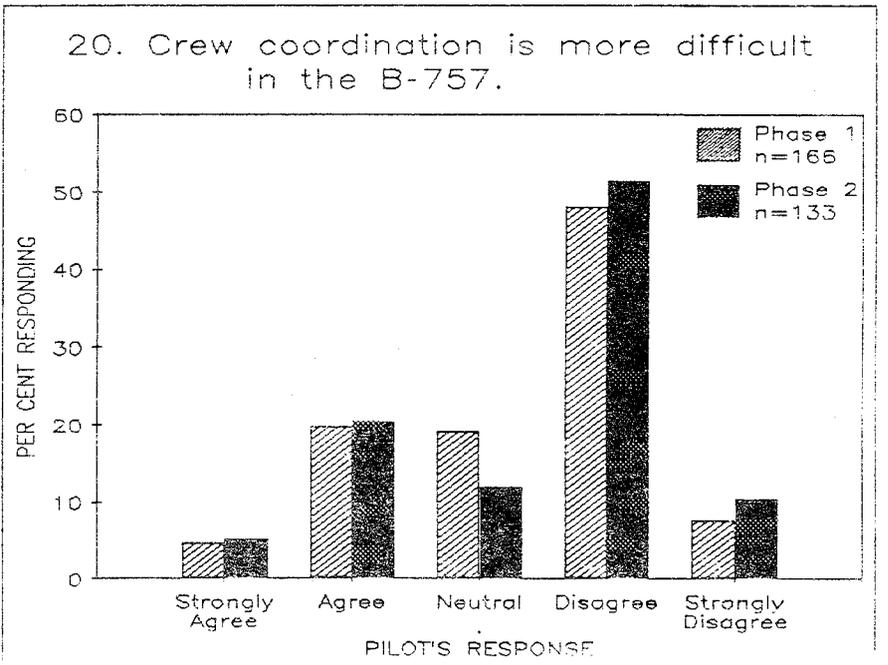
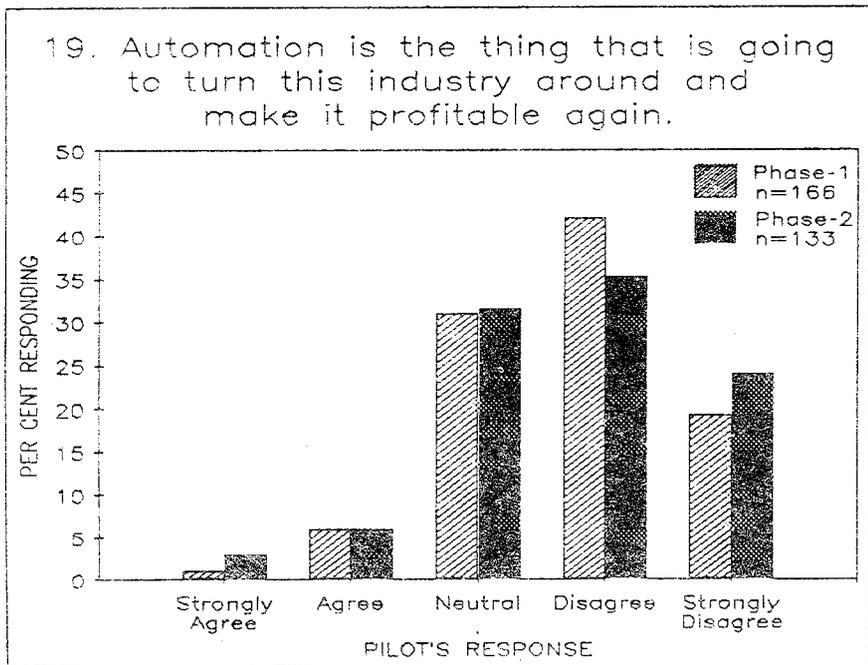
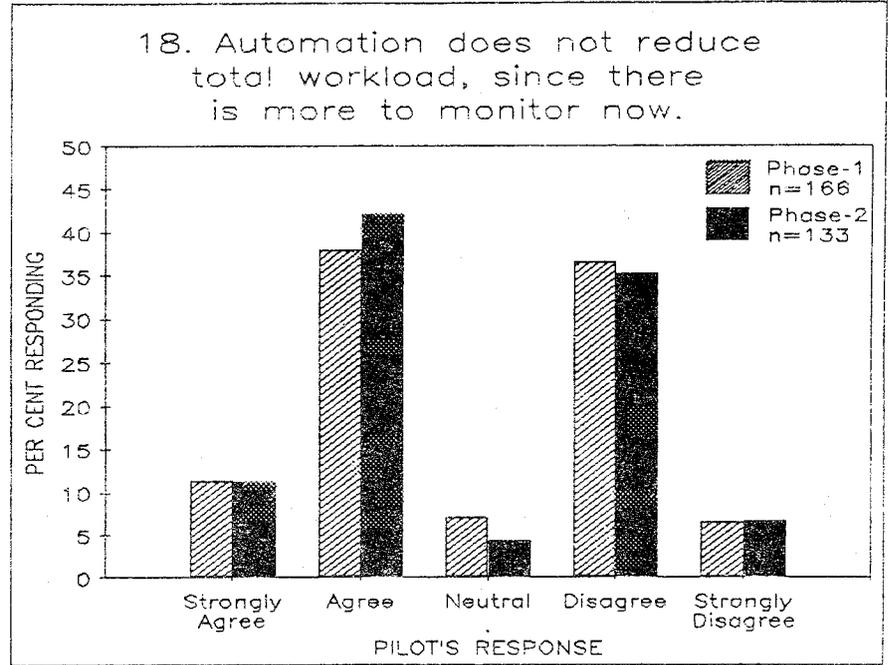
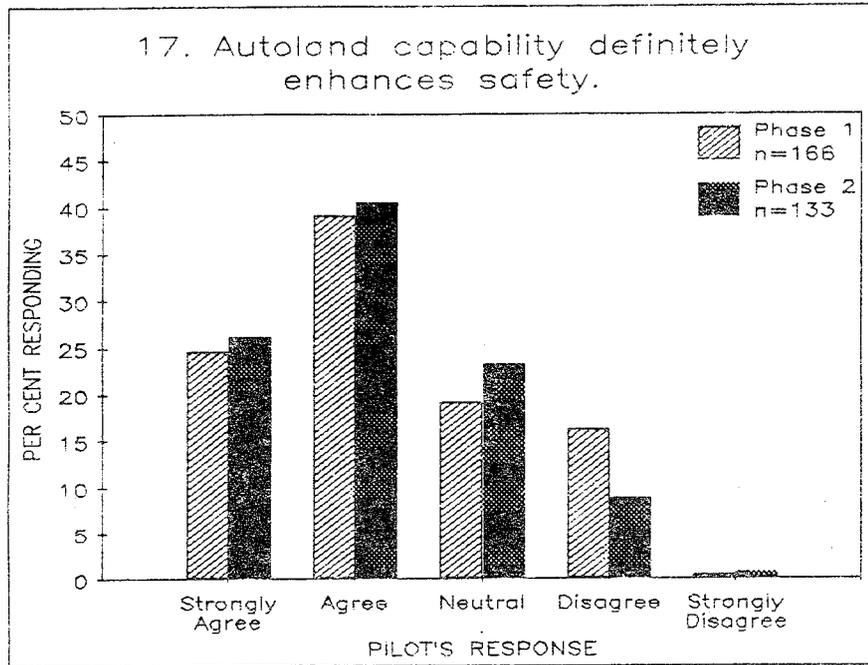
11. In the B-757 automation, there are still things that happen that surprise me.

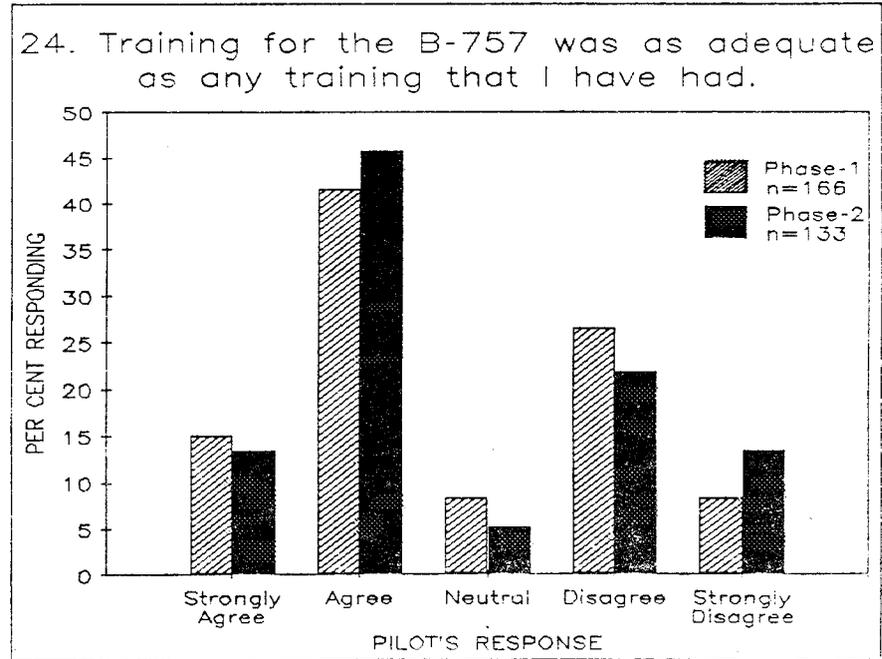
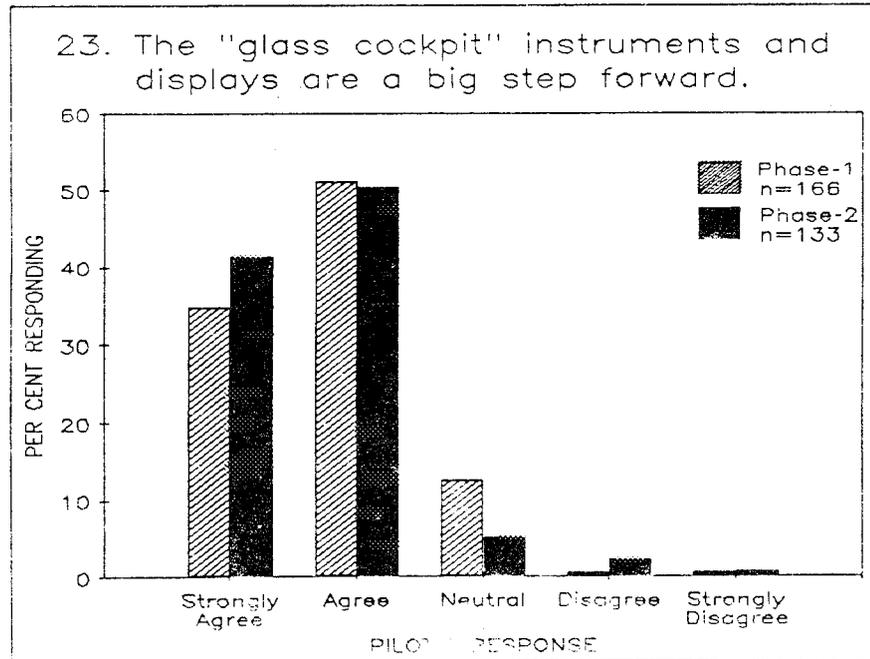
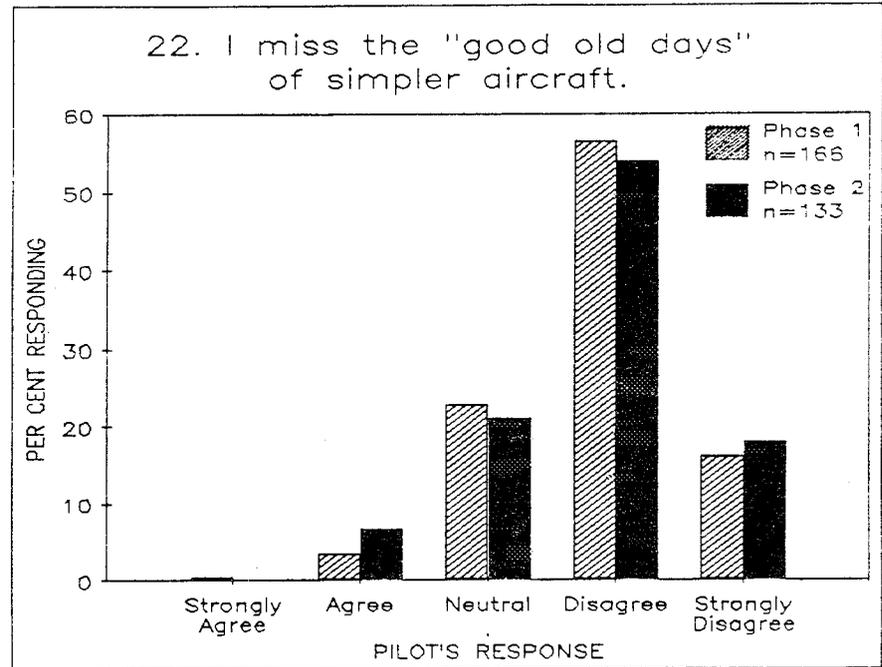
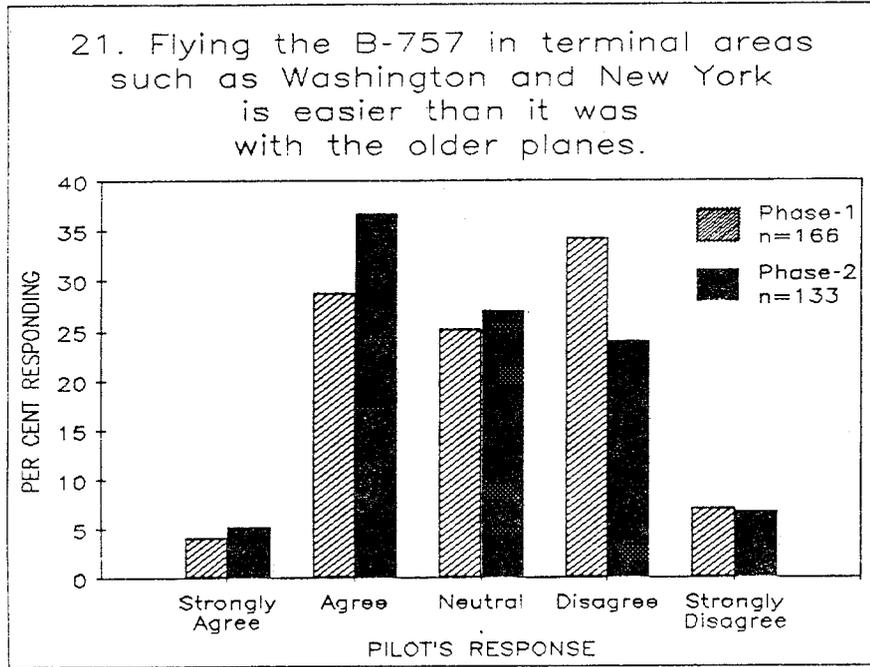


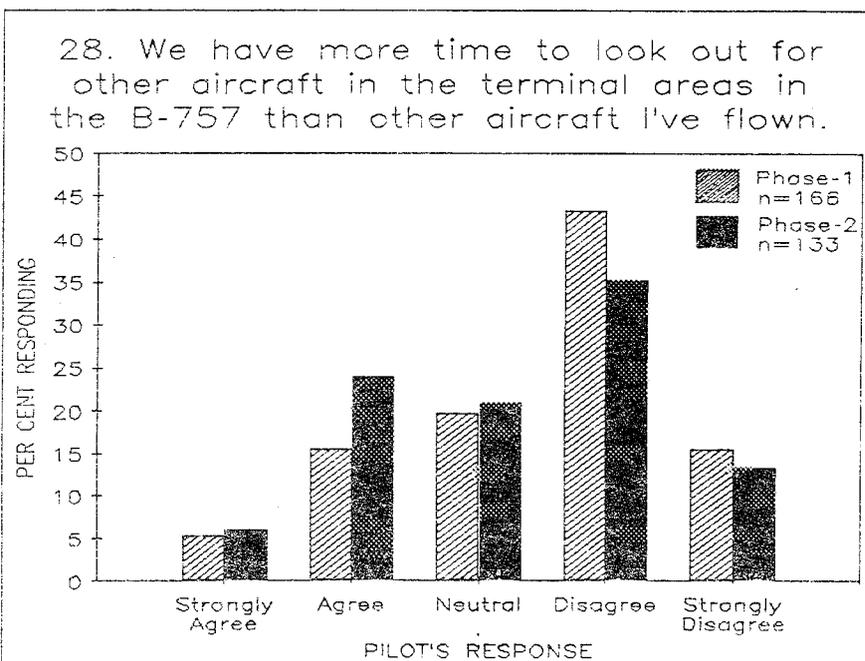
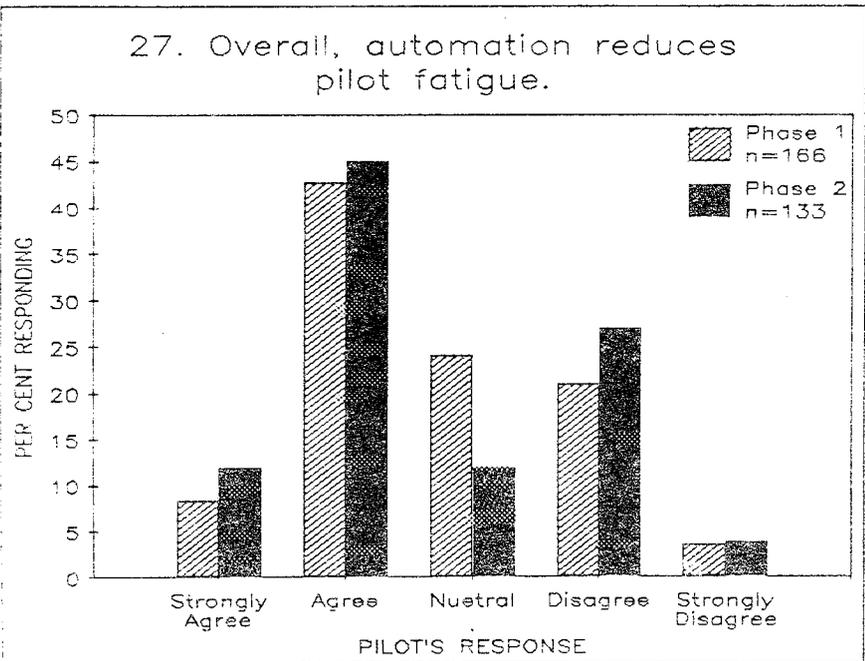
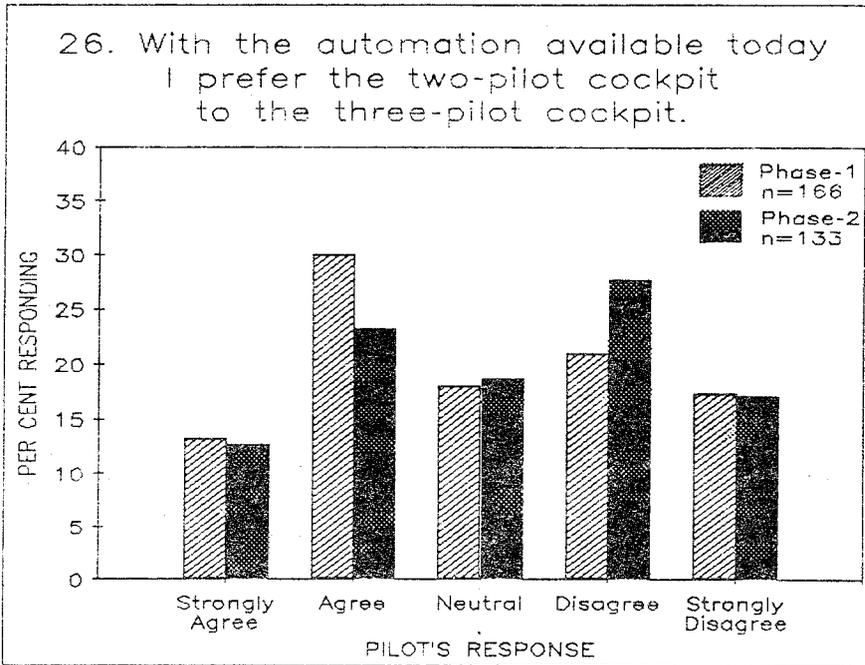
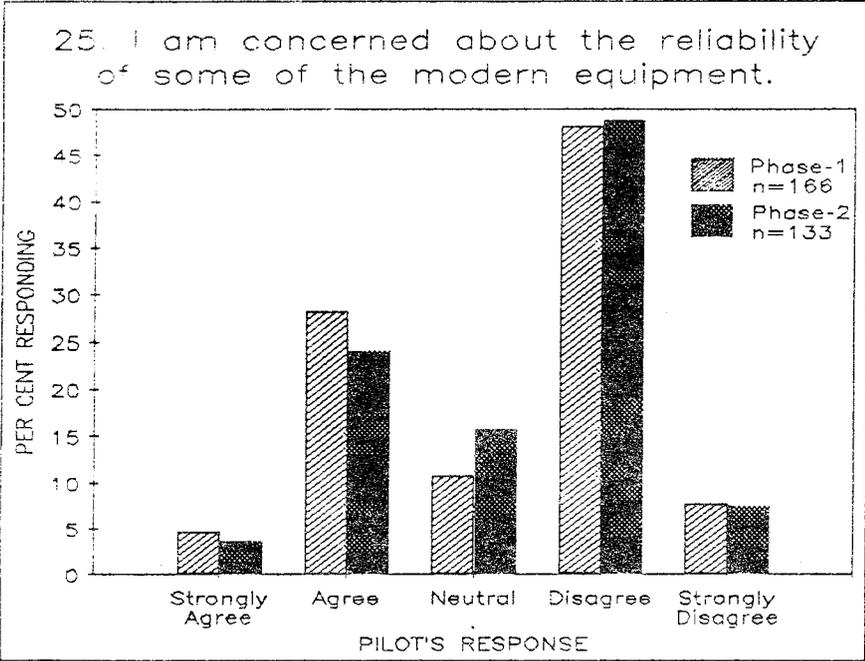
12. I can fly the plane as smoothly by hand as with the automation.

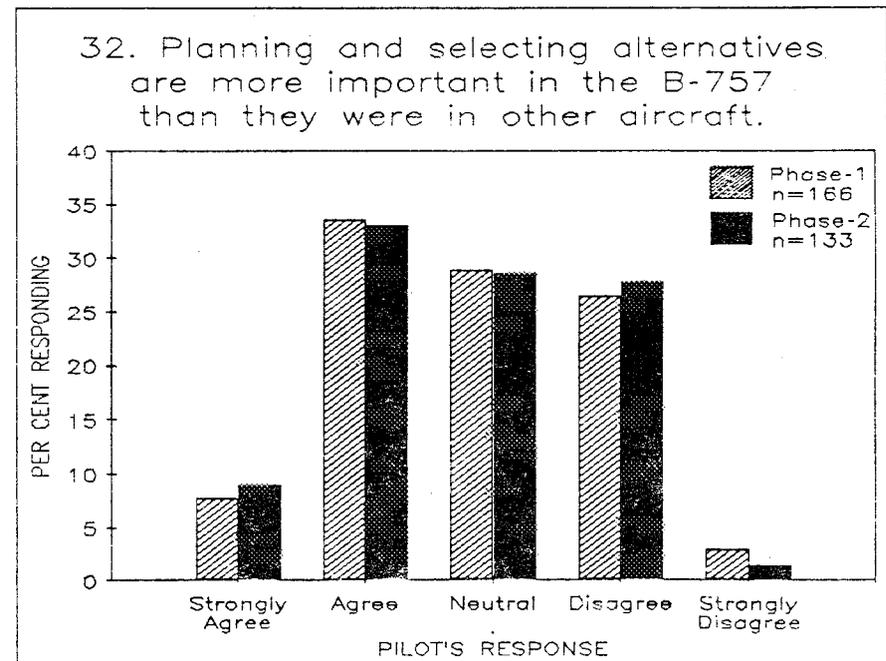
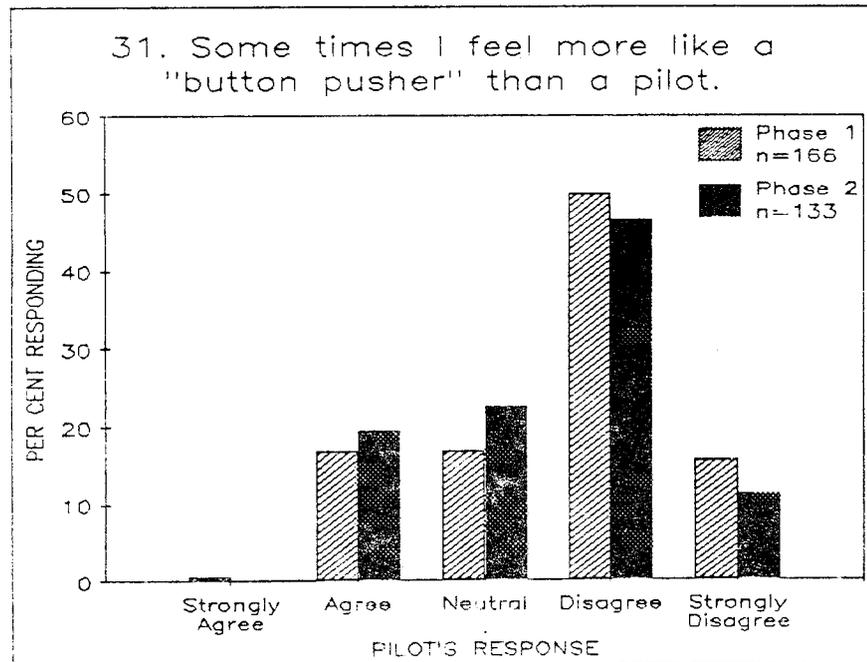
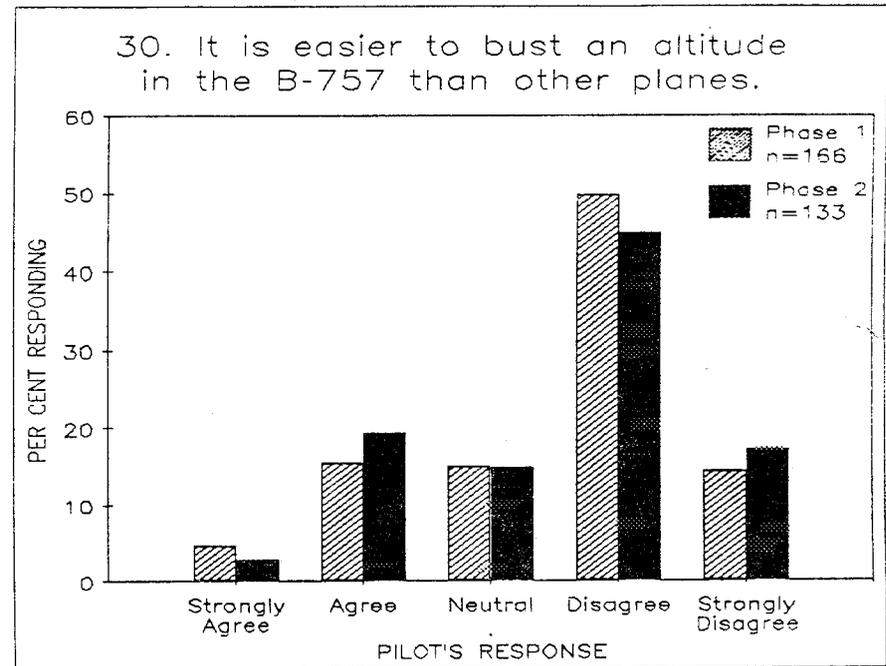
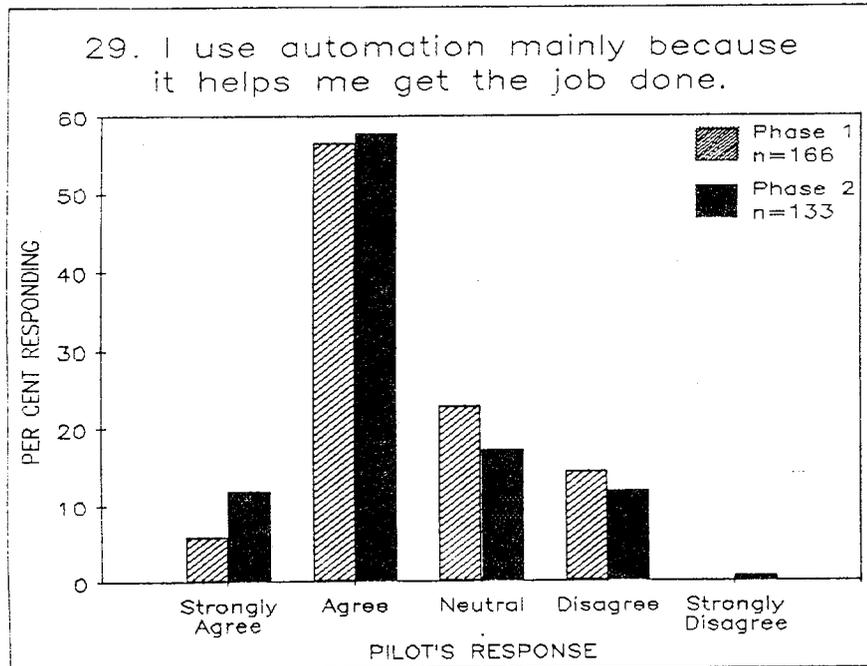




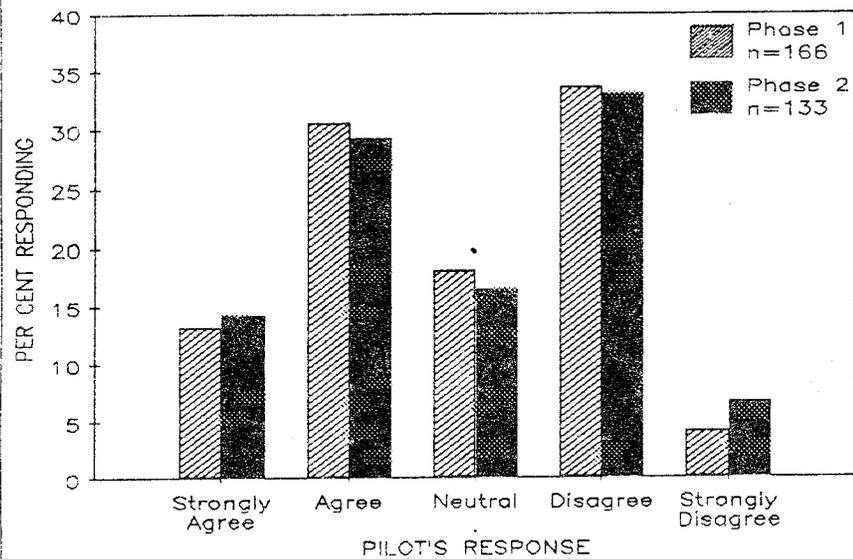




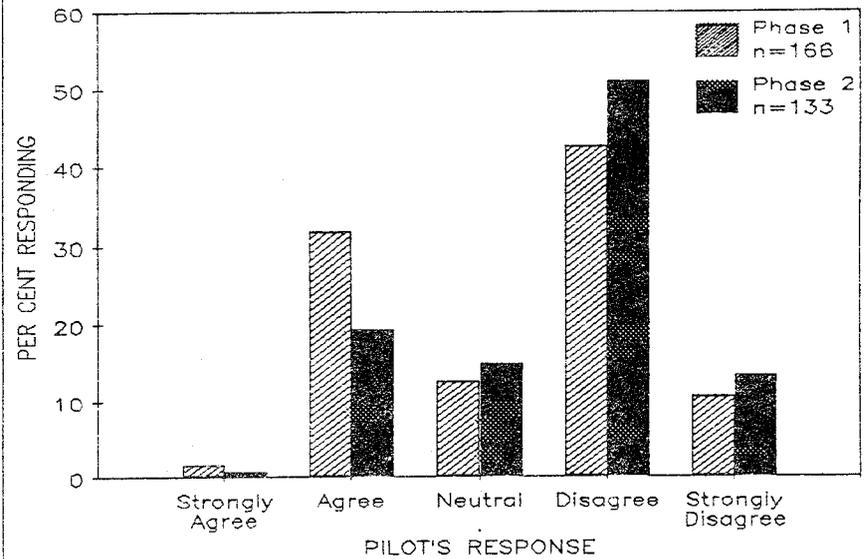




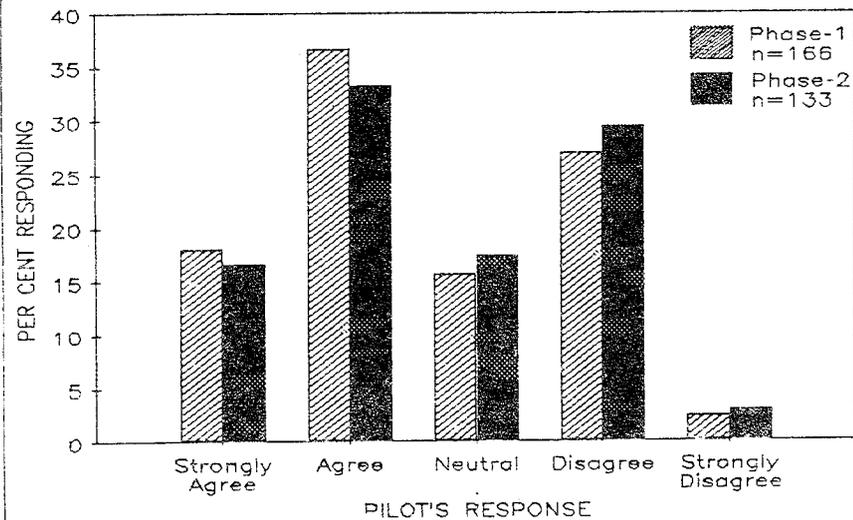
33. After flying the B-757, I would never want to go back to old types of planes.



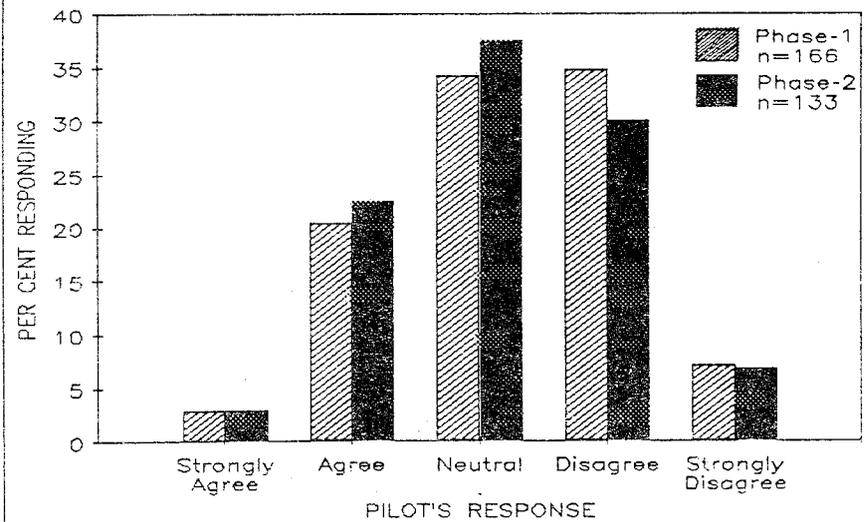
34. There are still modes and features of the B-757 FMS that I don't understand.



35. In the B-757 there is too much programming going on below 10,000 feet and in the terminal areas.



36. In the B-757, it is easier for the captain to supervise the first officer than in other planes.





# Report Documentation Page

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12. Sponsoring Agency Name and Address National Aeronautics & Space Administration Washington, D.C. 20546-0001		15. Supplementary Notes Point of contact: Dr. Everett Palmer, MS 239-21, Ames Research Center, Moffett Field, CA 94035 (415) 694-6073 or FTS 464-6073	
16. Abstract This is a report of three-year study of airline crews at two U.S. airlines who were flying an advanced technology aircraft, the Boeing 757. The study addresses the opinions and experiences of these pilots as they view the advanced, automated features of this aircraft, and contrast it with previous models they have flown. The report addresses a large number of aspects of automated flight, but concentrates on the following topics: <ol style="list-style-type: none"><li>1. Training for advanced automation</li><li>2. Cockpit errors and error reduction</li><li>3. Management of cockpit workload</li><li>4. General attitudes toward cockpit automation</li></ol> The limitations of the air traffic control (ATC) system on the ability to utilize the advanced features of the new aircraft is discussed. In general the pilots are enthusiastic about flying an advanced technology aircraft, but they express mixed feelings about the impact of automation on workload, crew errors, and ability to manage the flight.			
17. Key Words (Suggested by Author(s)) Automation Workload Human Error Human Factors		18. Distribution Statement Unclassified - Unlimited Subject Category - 03	
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