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CONTENTS

SUMMARY

This is the first of four volumes which report the results of a simulator experiment in which crew performance in a traditional airline cockpit (McDonnell-Douglas DC-9-30) was compared to that in an MD-88, a highly automated ("glass cockpit") derivative of the DC-9 family. In this experiment volunteer airline crews who were qualified in one of the two aircraft flew a predetermined scenario designed in the same manner as line-oriented flight training (LOFT) scenarios employed for training purposes by the airline.

The purpose of this study was to examine jointly cockpit automation and social processes. Automation was varied by the choice of two radically different versions of the DC-9 series aircraft, the traditional DC-9-30, and the glass cockpit derivative, the MD-88.

The goals of the study were achieved primarily by comparing various performance measures of the crews in dealing with the situations introduced by the LOFT, and particularly by examining the effect of the automation (two models of the same aircraft) on crew performance, coordination, and communication. The simulator runs were videotaped and examined in detail. In addition, two experts, the LOFT instructor, and a line qualified pilot-observer rated crew performance, and the crew rated their own performance and perception of workload. Errors in procedures were also recorded, analyzed, and classified as to severity. Attitude questionnaires were administered to all members of the volunteer group, those who flew the LOFT as well as those who did not.

Results show that the performance differences between the crews of the two aircraft were generally small, but where there were differences, they favored the DC-9. There were no criteria on which the MD-88 crews performed better than the DC-9 crews. Furthermore, DC-9 crews rated their own workload as lower than did the MD-88 pilots. It should be noted that while both groups were about equal in total flying experience, the DC-9 pilots were more experienced in type, and it is difficult to separate out the effects of this factor. There were no significant differences between the two aircraft types with respect to the severity of errors committed during the LOFT flight. The attitude questionnaires provided some interesting insights, but failed to distinguish between DC-9 and MD-88 pilots.

Further results from this experiment will be reported in subsequent volumes. A summary of the contents of Volumes II, III and IV can be found in Appendix 5.

I. INTRODUCTION

A. BACKGROUND: AUTOMATION, CRM, LOFT, and AQP

> 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.
>
> Human nature being what it is, it is very easy for a pilot (Capt. or F/O) to want to do all the tasks associated with flying the aircraft (programming the FMC, selecting autopilot functions, setting MCP altitude window) by himself, and not bother the other guy, or get it done faster than him, or do it just because "I'm the captain and I want to do it all." The pilot not flying (PNF) rapidly becomes a non-revenue passenger and either sits back and tunes out, or the situation becomes a little tense. It's imperative that this not happen, by stressing coordination during training.
>
> --- B-757 pilot interviewees (from Wiener, 1989)

Human participation in system operation has always been a mixed blessing: on the one hand, many systems would never have achieved operational status without the flexibility and resourcefulness of human operators (e.g. manned space flight). On the other hand, errors and inappropriate actions on the part of human operators have caused untold numbers of incidents and many accidents. Some of these, such as the collision of two B-747s at Tenerife; the capsize accident of the ferry Herald of Free Enterprise at Zeebruge, Belgium; the nuclear accidents at Three Mile Island and Chernobyl; and the chemical disaster at Bhopal, must be considered catastrophic. In each there were documented failures of information flow from machine to human, human to machine, and most important for this study, human to human.

There are also several parallels between manned space flight and aviation, and one of them is the relative importance of technology and human factors. In the early days of both fields, technology was the primary limitation to mission success, and human factors considerations were minimized because the crew members exhibited "the right stuff". The right stuff means that by superior skill, and perhaps daring, test pilots were able to overcome various adversities. Romantic as it may be, the right stuff is not an approach to air safety that we would recommend.

The role of human factors was realized in World War II, starting with the recognition of the importance of the human's physical interaction with the system (e.g., viewing instruments, hearing alarms, etc.). However, technological and other changes in the late 1970s highlighted other aspects of human factors which were not being addressed by the traditional approaches. Two of these, the impact of cockpit automation, and crew coordination and communication, are the subject of this study.

From the days of World War II, the human factors considerations for such systems involved the human's physical interaction with the system: viewing instruments, hearing alarms, reading instructions, reaching controls, shape coding to avoid mistaken actions, etc. Technological and other changes in the late 1970s highlighted other aspects of human factors which were not being addressed by the traditional approaches. Research directed toward airline operations in three important areas was initiated at the NASA Ames Aerospace Human Factors Research Division. The relationship between these areas is depicted in Figure I-1 below.

1. <u>Automation</u>. Wiener and Curry (1980); Boehm-Davis, Curry, Wiener, and Harrison (1983); Curry (1985); Wiener (1985, 1988, 1989) and others brought awareness of the drawbacks as well as the benefits of flight-deck automation.

2. <u>Social Processes</u>. Ruffell Smith (1979); Cooper, White, and Lauber (1979); Foushee and Manos (1981); Foushee (1984); and Kanki and Foushee (1989) are only a few of the works describing the importance of social processes (leadership, communication, crew interaction) in the aviation domain.

3. <u>Fatigue</u>. Graeber's research (1988) investigated the effect of fatigue, shift work, and related factors on subjective responses and human/system performance.

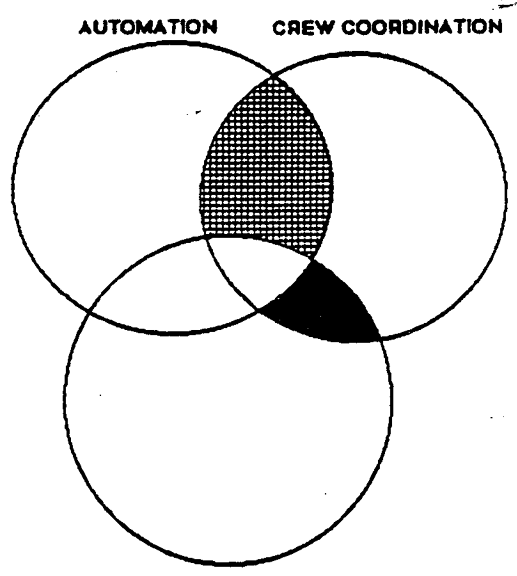


Figure I-1. Graphic representation of three primary areas of research into air carrier human factors. The shaded area represents the study by Foushee, Lauber, Baetge, and Acomb (1986); the hash-marked area represents the present study.

For the last decade the research programs have concentrated on studying one of the main variables at a time. The early phases of these programs were characterized by problem definition, and all three programs found it difficult to define their problem even when considering only one factor at a time. By the second half of the decade of the 1980s the research had matured to the point where combinations of the main variables could be studied, and their interactions determined

To date the work of Foushee, Lauber, Baetge, and Acomb (1986) has been the only investigation to examine two of the factors simultaneously: cockpit resource management (CRM) and fatigue, depicted as the shaded area in Figure I-1. The surprising results of this experiment emphasize the importance of crew coordination rather than fatigue. The present study explores the two-way intersection between automation and crew coordination. There has not been, to our knowledge, any investigations of the intersection of fatigue and automation, although it is generally presumed that automation reduces fatigue.

Automation

In 1979, as a result of several committee hearings into air safety which identified automation as a salient, though little understood area, Congress mandated that NASA study the human factors issues of cockpit automation. Renwick Curry and Earl Wiener began their studies at Ames, first attempting to determine the nature of the problem, and later to produce guidelines for the safe design and operation of automatic equipment. An early publication (Wiener and Curry, 1980) provided an overview of the human factors problems, and some rudimentary guidelines. The following year they began a series of field studies, working with airlines and crews, examining actual line operations (Curry, 1985; Wiener, 1985, 1989).

These field studies have indicated that the basic assumptions behind automation are subject to question. Very briefly, it would appear that:

1. Workload is changed, not reduced by the new equipment, and may simply be relocated in time, sometimes to the benefit of safety, sometimes not.

2. Human errors are not eliminated, but their nature may be changed. In many cases, the errors may be more critical: that is, automation may eliminate small errors and create the opportunity for large ones.

3. There are wide differences of opinion about the usefulness and benefits versus risks of automation in the minds of line pilots, and therefore wide differences in patterns of utilization.

It also became clear in NASA's field studies that the type of equipment on board exerted an influence on crew coordination, communication, and resource management. However clear, this statement is based only upon observations by Curry and Wiener, not on any empirical investigation. The need to examine this observation empirically led to the present study.

Cockpit Resource Management (CRM)

In the 1970s, following a series of disastrous accidents in which the failure appeared to be not with individual performance of the crew members, but with their performance as a team, the worldwide aviation community began to recognize that a crew must be viewed more than a group of highly skilled individuals, but as a close-knit two- or three-person team.

A recent example can be seen in the report of a B-737 which ran off the end of the runway at Charlotte (National Transportation Safety Board (NTSB), 1987). Such a phenomenon, the lack of crew coordination during an in-flight emergency, had previously been illustrated in the simulator experiments by Ruffell Smith (1979). In this experiment, airline crews, faced with a simulated in-flight abnormal condition, often did not take advantage of the resources, human or inanimate, available to them, and as in the accidents mentioned, failed to work together as a team. Often the captains did not function in proper leadership roles, and the junior officers did not perform as effective subordinates. Over the last decade NTSB reports have frequently cited poor crew coordination and communication as contributing factors in aircraft accidents, and they have repeatedly urged the FAA to require CRM training for pilots (Kayten, in press).

Ruffell Smith's findings led to a new thrust in the study of flight-deck human factors known as cockpit resource management (CRM), pioneered by NASA scientists and university grantees (Foushee and Manos, 1981; Foushee, 1984; Helmreich, Foushee, Benson, and Russini, 1986). For an overview of CRM research, see Foushee and Helmreich (1988).

At the same time several airlines and consultants began developing CRM training programs for crew members, with the intention of schooling them in the art of effective management, communication, and crew coordination on the flight deck, and emphasizing <u>team</u> performance rather than individual prowess. Today CRM training is recognized and encouraged by the FAA, but is still not an FAR requirement. FAA Advisory Circular 121-51 defines the need for CRM training and provides a theoretical framework for its development, but stops short of telling the airlines either that they must provide this training, or how to do it if they chose to. The circular wisely notes that the concept is still in the developmental stage, and more can be gained by allowing the carriers to develop new concepts, than by forcing them to follow a government-specified program.

Most FAR Part 121 airlines in the U.S. now offer some form of CRM training, ranging from two or three day courses of intensive training to an hour or two during recurrent training. Part 135 airlines are also now beginning to develop programs. Numerous commercial vendors have entered the market with CRM curricula and materials, and several contract flight training centers now offer CRM programs to their customers.

Advanced Qualification Program (AQP)

While air carriers for the foreseeable future will not be required to offer CRM training, the emergence of the concept of Advanced Qualification Program (AQP) will provide a strong financial and perhaps quality incentive to do so. Under Special FAR (SFAR) 58, which governs AQP requirements, airlines may elect to present AQP proposals on a fleet-by-fleet basis to the FAA for approval, or to continue with traditional training as governed by FAR 121 Appendix E, F and H. The principal difference between traditional and AQP flight training lies in the fact that under AQP, the carrier may train their pilots to a criterion of proficiency, rather than "filling in the squares" with fixed hours of practice or numbers of maneuvers. It is the obligation of the carrier, however, to demonstrate that the criteria have been met, and this includes CRM proficiency.

Should an airline elect to train under AQP, a strong CRM training program and self-evaluation will be required. AQP offers the incentive of more flexible ground school and simulator training, and more effective utilization of training resources, hopefully resulting in a higher quality product at lower cost. This alone will probably accelerate the pace of development of CRM training and evaluation in the U.S., and since much of the rest of the aviation world usually follows the lead of U.S. in the training technology, other nations as well.

Line Oriented Flight Training (LOFT)

Concurrent with the development of CRM was the emergence of a simulator training concept known as Line Oriented Flight Training (LOFT). (The more general term, Line Operational Simulation [LOS], is now being used by the FAA. LOFT is considered a sub-category of LOS). The FAA's view of LOFT is covered in Advisory Circular 120-35B. A review of LOFT can be found in Orlady and Foushee, 1987. Wiener (in press) discusses the design of LOFTs for high technology aircraft.

In traditional flight training conducted in simulators, emphasis was placed on individual skilled performance, primarily in handling abnormal situations: e.g. the ability to perform difficult maneuvers and to cope with emergencies. While handling the emergencies clearly required team effort of the crew members, little emphasis was placed on team functioning, leadership, or role definition: they were viewed merely as necessary elements in successfully completing required procedures.

The CRM movement was largely responsible for the development of the LOFT concept. Training specialists came to recognize the need to emphasize teamwork and leadership concepts by giving the crews the opportunity to fly an entire leg which would simulate as closely as possible the typical airline mission. Crews would be evaluated and debriefed not only on maneuver completion, but also on their ability to work together as a team. Debriefing with the aid of video tapes recorded during the flight were most revealing to the crews. Thus CRM and LOFT were complementary movements in air safety, CRM emphasizing the team performance concept, LOFT offering the opportunity to practice it.

B. THE RATIONALE FOR THIS STUDY

What the authors asserted in planning this research is that the modern, high technology ("glass") cockpits may require some special considerations. The assertion is that the equipment may drive a social atmosphere that is distinct from the traditional cockpits, and hence the interaction of automation and CRM must be considered. If this could be demonstrated to be true, at least a portion of a CRM training program might be tailored to a generic advanced technology cockpit. It should be noted that already several airlines have added, or are in the process of preparing, CRM instruction with respect to the high technology aircraft, either in formal CRM training or in recurrent training.

There is now good reason to believe that automation and social processes in the cockpit influence each other, in both airline and space flight operations. The field studies by Curry (1985) and Wiener (1985, 1989) on the impact of automation have revealed the importance of crew coordination in avoiding many of the "traps" posed by the new equipment. We have noted as well that traditional role assignments, such as pilot-flying vs. pilot-not-flying, even though spelled out by the airlines' operations manuals, often break down, particularly under high workload (Orlady, 1982; Wiener, 1989).

Numerous B-757 pilots commented during interviews and in questionnaires in Wiener's 1989 study that there is a lack of obedience to the standardized procedures of "who does what", a problem usually not present in well-standardized traditional cockpits. This may not necessarily be bad: it could be an adaptation to the demands of the high technology cockpit, not anticipated by those who write regulations, procedures, and checklists, and provide flight training. But for the present, we must accept the doctrine that adherence to procedures, including a strict definition of "who does what", is a basic foundation of cockpit safety (Degani and Wiener, 1990).

For example, the field study of B-757 crews at two major airlines (Wiener, 1989) tentatively indicates that automation in these highly advanced aircraft may impact on crew coordination, supervision, and CRM in the following ways:

1. Supervision by the captain of the first officer may be more difficult: at the very least, it may be considerably different from that found in traditional two-pilot cockpits.

For example, although standard operating procedure calls for the captain to review information loaded into the control-display unit (CDU) before it is actually executed, this step is often ignored in high workload situations. This can produce two undesired effects: a) insufficient redundant checking of information to eliminate errors; and b) insufficient situational awareness on the part of the captain, possibly resulting in the captain being "surprised" (a word often used pilot volunteers in this study) by maneuvers of the aircraft.

2. There may be a <u>de facto</u> transfer of authority from the captain to the <u>first officer</u> due to the fact that many of the first officers are more proficient than the captains on the CDUs by which the pilots enter information into the flight management computers. As some interviewees have opined, "He who controls the CDU controls the airplane." This is not to imply an intentional usurpation of authority, but more likely an unintended by-product of the automated systems. This is also in part due to an equipment-induced impairment of the captain's ability to supervise the flight.

3. There is often a breakdown in the traditional "who does what" (standard operating procedures) in the "glass cockpit" aircraft, which is computer-induced. Pilots will often do tasks assigned to the other pilot, usually with his/her consent and awareness, for a variety of reasons. While this may at times be effective cockpit resource management in the short run, in the long run it can be injurious to standardization, which is the foundation of safe piloting.

C. OBJECTIVES OF THIS STUDY

The purpose of this study was to examine jointly cockpit automation and social processes. Automation was varied by the choice of two radically different versions of the DC-9 series aircraft, the traditional DC-9-30, and the glass cockpit derivative, the MD-88. The research design was not intended to be a competition; it was not a question of which aircraft crews did "better", but to enable an examination of the strengths and weakness of the two cockpit technologies in flying identical LOFT profiles. We felt that such a study is particularly important at this time for several reasons.

1. This work may contribute to the technology base for not only transport aircraft, but also long duration space station operation. Many of those experienced in space flight feel that attention to automation and social processes are the two most critical requirements for a successful mission.

2. This work may contribute to safer operation of present aircraft and to design of future aircraft where multi-member crews use advanced cockpit technology, and may provide data and examples upon which CRM programs can be tailored to

modern aircraft.

3. The advent of AQP, with its heavy emphasis on CRM training and evaluation, creates a need for a sound foundation for CRM and LOFT program design. Since each aircraft type (fleet) must be presented with its own individual proposed training package, it would seem highly advisable to determine some of the differences between crew performance in traditional and high technology cockpits.

Details of the research methodology can be found in the next chapter, and as well in subsequent volumes in this series (see Appendix 5).

D. ORGANIZATION OF THIS REPORT

This report is organized in chapters designated by Roman numerals. Chapters I, II, and III deal with the background, purpose, and methodology of the study. The results are reported in Chapters IV and V.

Figures and tables are designated by chapter number (Roman) and serial order in the chapter (Arabic). Thus Figure III-2 would be the second figure in Chapter III. The 28 histograms reporting the data from the Likert attitude scale items carry their own serial number and thus do not have a figure designation as described above.

References to other publications cited in this report are found in Chapter VII. We have made no attempt to offer a comprehensive review of the automation or CRM literature. A recent review of human factors in automation can be found in Wiener (1988), and of CRM/Crew coordination can be found in Foushee and Helmreich (1988). For a review of communication in aviation, the reader is directed to Kanki and Foushee (1989), and Kanki, Greaud, and Irwin (1989).

Further results of this experiment will be reported in subsequent volumes, listed below. A brief summary of the contents of Volumes II, III, and IV can be found in Appendix 5.

VOLUME	EXPECTED PUB. DATE	TOPICS
II	Early 1992	Further analysis of errors; analysis of procedures
III	Early 1992	Analysis of communications
IV	Mid 1992	Summary of first three volumes

E. SUMMARY

This chapter outlines the need for a study of the influence of cockpit automation on crew communication and coordination, and the goals of this study. The motivation for the study was that previous field studies of automation had observed, but had not experimentally validated, the fact that communication patterns in the modern, high-technology aircraft appeared to be different than in the traditional cockpits.

Another factor motivating this study was the fact that research on the individual topics of automation and communication had matured to the point that they might be studied in combination. Rapid changes are taking place in training technologies and regulations that might make it advisable to recognize the need for certain differences in training pilots for communication and coordination in the modern versus traditional cockpits.

II. CHARACTERISTICS OF THE VOLUNTEER PILOT GROUP

A. OVERVIEW

This study was based on data received from pilot volunteers at a cooperating U.S. airline. The three sources of information were:

1. Biographical and flying experience data from the one-page sign-up sheet by which the pilots volunteered. A total of 84 pilots was recruited by this method. A copy of this form can be found in Appendix 3. Two joined the study later.

2. Questionnaires were mailed to 86 volunteers in January 1990. 73 questionnaires were returned. The questionnaire contained both biographical and flying experience information, a 28-item attitude scale, and other questions pertinent to the study. Eight open-ended questions were also included. A copy of the questionnaire can be found in Appendix 2.

3. A simulator experiment was conducted during the summer of 1989 in which 24 crews (12 DC-9 and 12 MD-88) flew a specially designed LOFT mission. Two of the MD-88 runs were discarded from the data due to instructor error. The LOFT runs produced a variety of data, including flight evaluation forms filled out by a special observer, and by the simulator instructor, self-reports from the pilots themselves, and a variety of measures derived from video tapes taken during the flights and analyzed at NASA's Ames Research Center. These data are discussed fully in Chapter III and IV. The rating scales can be found in Appendix 1.

B. RECRUITMENT OF THE VOLUNTEERS

Recruitment Procedures

In preliminary meetings with airline management and the Safety Committee of the Air Line Pilots Association (ALPA) a recruitment procedure to obtain DC-9 and MD-88 volunteer pilots was determined. As a matter of convenience, only pilots from one base would be used, and the experiment would be open only to line pilots in those two aircraft. A brochure of the question and answer format described the purpose and methods of the study to the pilots. The final page was the sign-up sheet mentioned previously (Appendix 3). If a pilot wished to volunteer, he merely filled out the form, assigned himself an identification (ID) code, and mailed the form to the University of Miami.

The list was provided to the airline's simulator dispatch section, who scheduled the 48 pilots who actually flew the experimental simulator session. Of the 48 pilots, two were recruited by the scheduler on his own initiative from sources other than the original 84 volunteers. These two pilots were later sent a copy of the sign-up package, and they returned the sign-up sheet and from that point on were indistinguishable from the other volunteers. A copy of the questionnaire (Appendix 2) was sent to each volunteer.

Schedule compatibility of each pilot was the controlling factor in crew selection from the volunteer group, as all sessions were on the volunteer's own time.

The figure below shows the distribution of the 73 pilots who returned the questionnaire, by aircraft type and seat. This distribution did not differ in any way from the distribution of volunteers. Several pilots sent back blank questionnaires with the explanation that they were no longer on the DC-9 or MD-88, even though the cover letter that accompanied the questionnaire requested that all volunteers, regardless of their present aircraft seat, fill it out.

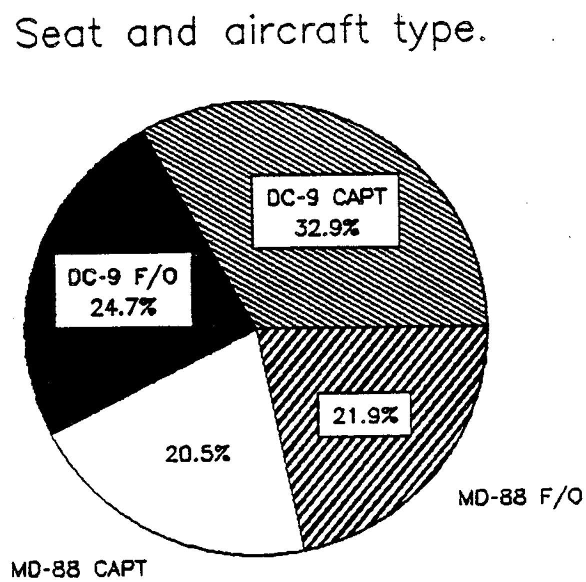


Figure II-1. Distribution by aircraft seat and type of the 73 volunteers who returned completed questionnaires.

The questionnaires were sent out during January 1990, following the completion of the simulator experiment (August 1989).

Confidentiality

Volunteers were assured of confidentiality by a system of self-assigned ID codes. The original sign-up sheet contained the volunteer's name, home address, and telephone number for administrative purposes, as well as his self-assigned ID code. No other document contained any identifying information, only the ID code. The code was entered into a computer database along with the other information on the sign-up sheet, but has since been removed, so that no pilot can ever be identified from his ID code. The simulator flights were identified serially from 1 to 24, and a separate computer file linked the run to the two pilots' IDs so that a match could be made between LOFT data and questionnaire data. This file has also been erased.

The LOFT flights were videotaped by two cameras simultaneously. One camera, already installed in each simulator by the host airline for their LOFT debriefing purposes, recorded a panoramic view of the cockpit from aft of the pilots' seats. A second camera supplied by NASA recorded a portion of the instrument panel. Audio was recorded from lapel microphones worn by the two pilots, and a third microphone suspended from the ceiling of the simulator near the instructor's panel.

Standard practice by the host airline was to use their tape for a debriefing session between the LOFT instructor and the crew. By agreement with ALPA, the tape is erased at the end of the session. ALPA granted the project team special permission to keep the recorded video tapes, based on the assurance that they would be promptly sent from the training center to Ames, and that no persons other than project staff would be allowed to see the tapes. Several pilots requested copies of the tapes of their own flights; these requests were denied.

Representativeness of the Sample

Experimenters can never be sure of the degree to which a group of volunteers faithfully represents the population from which they were drawn. Are people who volunteer for a project, who are willing to give their time for no direct gain, attitudinally different from those who do not respond? We are not prepared to answer this question, for by its very nature, we have no information about the non-responding group. Nor do we have data about why the volunteers were willing to do so.

It has been suggested that many of our MD-88 pilots may be from the low end of the seniority distribution within their group. During a brief period in 1989 new aircraft deliveries had slowed, and a number of newly trained MD-88 pilots were placed on reserve, and flew very little. Some persons in the training center suggested that a number of our volunteers came from that group, and were at least partially motivated by the desire to practice their skills by flying the "NASA LOFT."

The same question of representativeness may be asked about those who returned their questionnaire versus those who did not. This is commonly known in sampling theory as "non-response bias." However, since our response rate was so high (73 out of 86), it is unlikely that any such bias affects our results.

In summary, we believe that it is safe to assume that the volunteer group was fairly representative of the DC-9 and MD-88 pilots existing in 1989, though it may well be true that like any volunteer group, they possessed some intrinsic motivation that we would not be able to define.

C. FLYING EXPERIENCE OF THE CREWS

Flying Time and Experience in Type

Pilots were asked on their sign-up sheet to state the total number of flight hours they had accumulated at the host airline (including second officer time), and the number of months they had been in type, DC-9/MD-88. The results are displayed below in Figures II-2 and II-3. The difference between the samples with respect to total flying hours was not statistically significant.

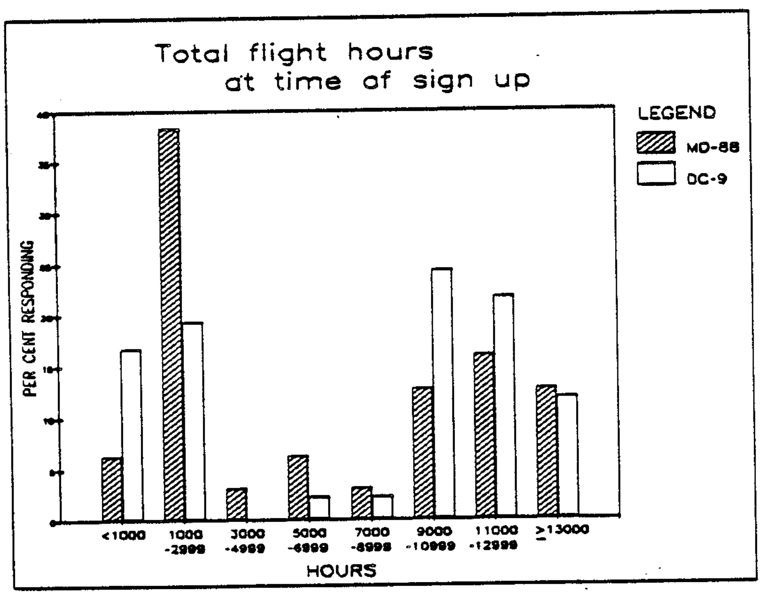


Figure II-2. Total flight hours of volunteers at time of sign-up (n = 83).

From 1989 to the end of 1990, the MD-88 fleet had nearly doubled, and increased by one-third in 1991. At the time of this writing (fall 1991) there are 85 MD-88s in the fleet. In contrast, the DC-9s are scheduled to be retired in 1993. Some have already been retired.

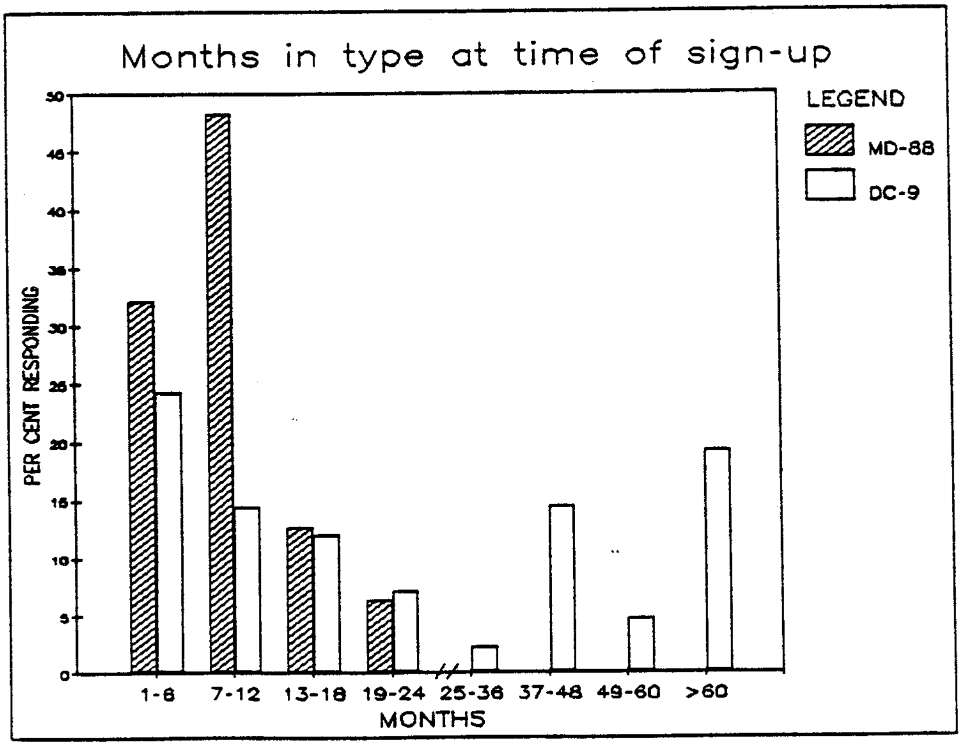


Figure II-3. Number of months in type for DC-9 and MD-88 pilots at time of sign-up.

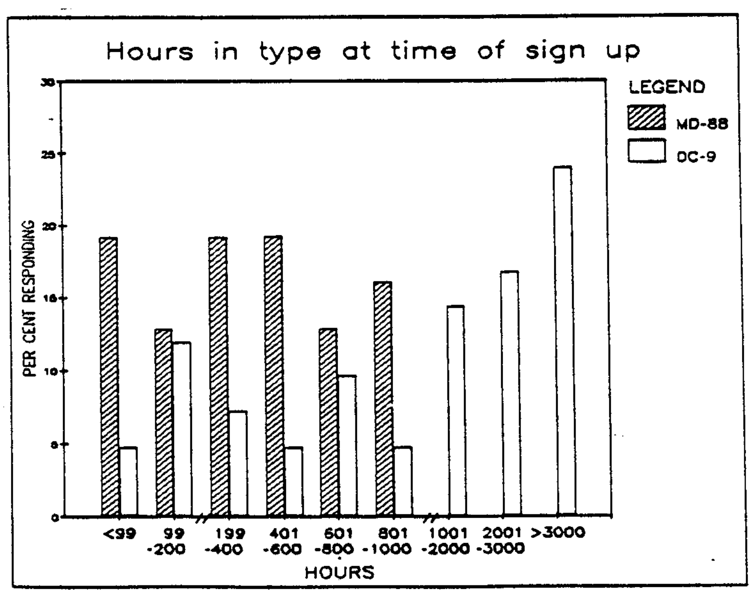


Figure II-4. Number of hours in type for DC-9 and MD-88 pilots at time of sign-up.

These facts, coupled with the fact that for various reasons many pilots tended to stay on the DC-9 a long time, produced in the volunteer group large differences in experience. As Table II-1 shows, the MD-88 and DC-9 samples had essentially equal flying experience, but Figures II-3 and II-4 and Table II-1 indicate that they had less experience in the aircraft. There is a simple explanation for the months-in-type data: it was almost impossible for MD-88 pilots to have much experience in type due to the newness of the plane. The greatest number of months reported by an MD-88 pilot was 24. For DC-9 pilots, it was 156 months.

Some DC-9 and MD-88 first officers obtained those positions relatively rapidly, not serving the customary years as second officers in B-727 and heavier aircraft. At the time of the experiment the airline was enjoying an expanding demand for its services, and was receiving new aircraft (MD-88, B-757,and 767s). The pilot work force was expanding rapidly. Also, for a variety of reasons, including seniority, bases, quality of trips and the like, many engineers were remaining in their seats, allowing rapid movement of new pilots into first officer seats.

TABLE II-1. Statistics on total flying hours.

MEAN FLYING EXPERIENCE OF VOLUNTEERS BY TYPE

	DC-9	MD-88	Signif. Level
TOTAL TIME (HOURS)	5569	6482	ns
MONTHS IN TYPE	30.4	9.5	.002
HOURS IN TYPE	1697	437	.0002

Migration Patterns

In order to appreciate the complexities of human factors in airline operations, and to understand the differences between the two experimental groups, it is necessary to explore further the movement of pilots from seat to seat. On the questionnaire pilots were asked to place a check mark in a matrix of aircraft type-by-seat indicating each of the seats they had previously held at the host airline. Those data are displayed in Tables II-2 through II-5. Likewise they were asked to indicate the seat held immediately before the present seat. Those data are displayed in four tables, II-6 through II-9.

The migration patterns displayed here are fairly typical, with a few noteworthy exceptions. Both the DC-9 and MD-88 captains showed the classic patterns, with most having served in the engineer's seat of the three-pilot jets listed, and a variety of first officer's seats in 727 and larger aircraft, before making captain in a lower seniority plane. Of the 39 captains in the study, fifteen listed experience in the 757/767 aircraft prior to going to the DC-9 or MD-88; eight of the 24 DC-9 captains and seven of the MD-88 captains.

Among the MD-88 captains, there were nine other captain's seats listed, most notably five in the DC-9. Why would captains leave seats in 727s, 737s and DC-9s for an essentially equal seniority and salary aircraft? The answer probably is that they saw their future in glass cockpit aircraft, with the next stop being the 757/767, and wished to start their exposure to the new technology as young captains, rather than waiting in an old technology cockpit for their chance to bid the 757/767. In contrast none of the DC-9 captains had previously held a captain's seat.

The first officers likewise showed typical patterns, with most having served as engineers on 727s. Similar patterns can be seen in 757 pilots from two other companies (Wiener, 1989). It is interesting that five of the 16 MD-88 first officers had previously held that seat in a DC-9. Their motivation to move to the same seat in the MD-88 was probably similar to that of the captains mentioned above. Transferring to the right seat of the MD-88 was essentially a lateral move, but it allowed early entry into glass cockpit technology. Their next step could be either the right seat of the 767, or to remain on the MD-88, awaiting captaincy, and thereafter captaincy of the 767. Both of these would be easy transitions for a first officer well versed in MD-88 technology.

The migration patterns seen in the DC-9 and MD-88 pilots at the host airline were generally typical of the industry for low seniority captains and first officers, with the added feature that the MD-88 was seen by many to be a "prep school" for a position on the 767. Likewise, the right seat of the 767 was viewed by many DC-9 and MD-88 first officers as a logical and advantageous position to be held prior to transition to captain on the MD-88.

TABLE II-2 and II-3. Seats previously held by DC-9 captains and first officers.

SEATS PREVIOUSLY HELD: DC-9 CAPTAINS (n=24)

	Capt.	F/O	S/O
DC-9	---	21	xxx
MD-88	0	0	xxx
B-737	0	2	xxx
B-757/767	0	8	xxx
B-727	0	17	19
DC-8	0	10	6
L-1011	0	15	14

SEATS PREVIOUSLY HELD: DC-9 FIRST OFFICERS (n=18)

	Capt.	F/O	S/O
DC-9	0	---	xxx
MD-88	0	0	xxx
B-737	0	0	xxx
B-757/767	0	0	xxx
B-727	0	0	16
DC-8	0	1	5
L-1011	0	0	1

TABLE II-4 and II-5. Seats previously held by MD-88 captains and first officers.

SEATS PREVIOUSLY HELD: MD-88 CAPTAINS (n=15)

	Capt.	F/O	S/O
DC-9	5	12	xxx
MD-88	---	0	xxx
B-737	2	1	xxx
B-757/767	0	7	xxx
B-727	2	12	10
DC-8	0	8	9
L-1011	0	7	8

SEATS PREVIOUSLY HELD: MD-88 FIRST OFFICERS (n=16)

	Capt.	F/O	S/O
DC-9	0	5	xxx
MD-88	0	---	xxx
B-737	0	1	xxx
B-757/767	0	1	xxx
B-727	0	0	15
DC-8	0	0	1
L-1011	0	0	1

TABLE II-6 and II-7. Last seat held prior to present DC-9 seat.

LAST SEAT PRIOR TO PRESENT: DC-9 CAPTAINS (n=24)

	Capt.	F/O	S/O
DC-9	---	0	xxx
MD-88	0	0	xxx
B-737	0	0	xxx
B-757/767	0	3	xxx
B-727	0	2	1
DC-8	0	3	0
L-1011	0	15	0

LAST SEAT PRIOR TO PRESENT: DC-9 FIRST OFFICERS (n=18)

	Capt.	F/O	S/O
DC-9	0	---	xxx
MD-88	0	0	xxx
B-737	0	0	xxx
B-757/767	0	0	xxx
B-727	0	1	12
DC-8	0	0	4
L-1011	0	0	1

TABLE II-8 and II-9. Last seat held prior to present MD-88 seat.

LAST SEAT PRIOR TO PRESENT: MD-88 CAPTAINS (n=15)

	Capt.	F/O	S/O
DC-9	1	1	xxx
MD-88	---	0	xxx
B-737	1	0	xxx
B-757/767	0	5	xxx
B-727	3	0	0
DC-8	0	0	0
L-1011	0	4	0

LAST SEAT PRIOR TO PRESENT: MD-88 FIRST OFFICERS (n=16)

	Capt.	F/O	S/O
DC-9	0	4	xxx
MD-88	0	---	xxx
B-737	0	1	xxx
B-757/767	0	0	xxx
B-727	1	0	8
DC-8	0	0	1
L-1011	0	1	0

Migration From the DC-9 and MD-88

During the roughly 14 months between the sign-up of the volunteer pilots and the return of the questionnaire, a sizable number of the pilots left the DC-9 and MD-88 for other aircraft. Ten of the 73 pilots who returned their questionnaires indicated such a move, with only one representing a promotion to captaincy. The old and new seats held by these 10 pilots at the time of the second questionnaire is summarized in Table II-10.

TABLE II-10. New seats occupied by pilots who left the DC-9 or MD-88 in the first 14 months of the study.

NEW SEATS OF THOSE WHO HAVE LEFT THE DC-9/MD-88

OLD SEAT	NEW SEATS
DC-9 Capt.	727 Capt.
DC-9 F/O	727 F/O 767 F/O (2) MD-88 Capt.
MD-88 Capt.	727 Capt. DC-9 Capt. 767 Capt. L-1011 F/O
MD-88 F/O	767 F/O L-1011 F/O

There is no clearly discernible pattern in these movements. Five of the moves were to glass cockpit aircraft (four 767, one MD-88). Furthermore it is difficult to understand some of the moves without knowing the motivation for the bid. In some cases the motivation may not have been an advance in equipment sophistication or salary, but bases or base security. Examples would be the DC-9 captain or first officer moving to the same seat on the 727. Although the 727 is a heavier aircraft, the pay differential is slight. The MD-88 captains who move to the 727 and DC-9 captain seats is somewhat in contradiction to what we have described as an upward progression through advanced technology aircraft. In future questionnaires, we must ask the volunteers who have moved to state their reasons for the new bid.

D. SUPPLEMENTAL INFORMATION

Volunteers were asked for information regarding advanced aircraft, and their ownership of home computers. The exact wording of the questions can be found in Appendix 2.

The table below speaks for itself. We were interested simply in knowing what each pilot thought was the most advanced aircraft he had flown. Note that the questionnaire made no effort to define "advanced", leaving this to the pilot.

TABLE II-11. Responses to query about the most advanced aircraft (in pilot's opinion) he had flown.

WHAT IS THE MOST ADVANCED AIRCRAFT THAT YOU HAVE FLOWN?

AIRCRAFT	MD-88 PILOTS	DC-9 PILOTS
DC-9		2
MD-88	21	1
B-757/767	9	10
B-727		1
DC-8		1
L-1011	1	12
A-310		1
Mil. Transp.		2
Mil. Fighter		12

Pilots were also asked to name the aircraft in their company's fleet that would be their first choice to fly if the quality of trips and salary were the same. Not surprisingly, the majority of pilots from both fleets chose the 767. What is interesting is the number of DC-9 pilots (20 per cent) who chose the DC-9. Another 20 per cent elected the 727 and L-1011. We cannot explain this result. It was clear throughout the study that the

DC-9 pilots shared a great sense of loyalty to their aircraft. But it is somewhat surprising that about 40 per cent chose aircraft with outdated technology in response to this question. We can only speculate that among DC-9 pilots there is a group who are devoted to traditional technology cockpits, and wish to fly them as long as they can. Perhaps responding DC-9 or B-727 was a wav of exhibitina their disdain for the new technologies.

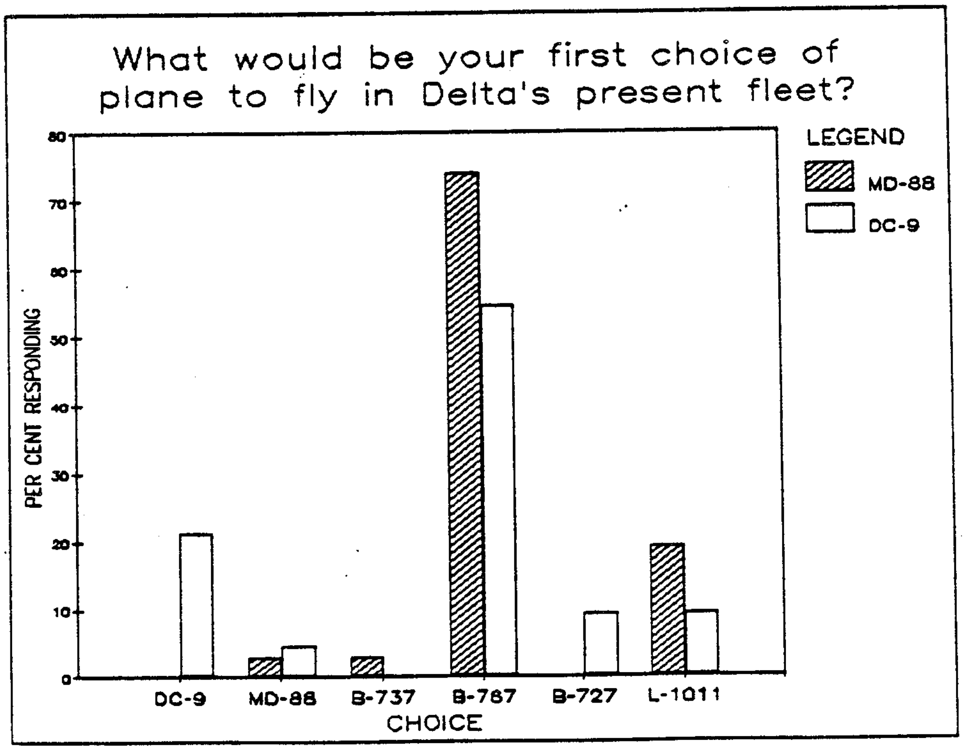


Figure II-5. First choice of aircraft in company's fleet.

Finally, the questionnaire asked the pilots about ownership of home computers. The data are displayed in Tables II-12 and II-13. These questions were designed simply to gather normative data about computer ownership, as this is often stated as one of the reasons that first officers seem to have an easier time in glass cockpit ground school than the captains. Prior to this study we could find no data on computer ownership by pilots. The assumption has been that more first officers own home computers. This was not borne out in this survey. Half of the first officers, about three-quarters of the captains reported owning home computers. For this sample, the differences between captains and first officers were not statistically significant. There also was no significant difference in computer ownership between DC-9 and MD-88 crews.

TABLE II-12. Number of captains and first officers reporting ownership of home computers.

DO YOU OWN A HOME COMPUTER?

	YES	NO	TOTAL
CAPTAINS	28	11	39
F/Os	17	17	34
Total	45	28	73

TABLE II-13. Type of computer owned by crew members.

TYPE OF HOME COMPUTER

TYPE	CAPTAINS	F/Os	TOTAL
None	11	16	27
IBM compat.	11	9	20
Macintosh	4	3	7
Apple II	9	2	11
Other	3		3
> 1 computer	1	2	2
Type missing		2	2

What we failed to ask, however, may have been more important: who uses the home computer? Aside from the obvious economic advantage of the captains, it is conceivable that more captains own computers since DC-9/MD-88 captains are about the age to have children in junior high and high school, and we cannot presume that the pilot is the user of the home computer. Be that as it may, we have failed to show any true differences between captains and first officers, let alone link this to success in MD-88 ground school. For now other explanations will have to be offered for the generally accepted fact that first officers tend to find ground schools in glass cockpit aircraft less forbidding than do captains.

III. STUDY METHODOLOGY

A. OVERVIEW

As explained in Chapter I, the fundamental purpose of this study was to determine the influence of cockpit automation on the performance of flight crews. The LOFT was designed to exercise the capabilities of the crews in a variety of areas, including flight guidance and navigation, systems management, monitoring, and crew coordination. The primary independent variable in the study was automation, varied by selecting two aircraft of the same family, the DC-9-30 representing a low level of automation, and its derivative, the MD-88, representing a high level of automation. The LOFT was written in such a way that it did not favor either aircraft, but should be equally difficult for both.

The data reported here and in future volumes flowed from two sources: 1) the LOFT experiment; and 2) a questionnaire that volunteer pilots filled out regarding their attitude toward automation, and other aspects of their flying job. The LOFT flights generated a large amount of data, only a small portion of which is reported in this volume. The remainder will be reported in Volumes II and III (see Appendix 5). All of the questionnaire data are reported in Chapter V of this volume.

B. EXPERIMENTAL DESIGN OF LOFT FLIGHTS

In addition to the automation level, a second independent variable which we had hoped to investigate was who was the pilot flying (PF) and pilot not flying (PNF) on each flight. The assignment as to which pilot would be the PF was determined before the crew arrived, and the experimenter asked the crew members in each case if they would agree to the assignment, which they always did. Thus the design consisted of two orthogonal independent variables, each at two levels, as depicted as a two-by-two matrix in Figure III-1.

Aircraft Type

Pilot Flying		DC-9	MD-88
	Captain	6	5
	First Officer	6	5

Figure III-1. Basic experimental design.

It was our intention to fly six crews in each cell for a total of 24 crews, and this was done, but data from two MD-88 crews had to be eliminated from the analysis due to departures from the script by LOFT instructors which invalidated the flight, yielding the unbalanced design depicted in Figure III-1. Though 24 crews completed their LOFT flights, two MD-88 crews (#16 and #20) were discarded from the analysis. In one case, the instructor inserted the wrong malfunction, then corrected it after the crew had detected the failure. In the other case, the instructor forced the crew to attempt to land at their original destination after the crew decided an approach would not be prudent. This leaves the design depicted in Figure III-1. In order to control for unequal sample sizes caused by deleting these two crews, the regression approach to calculating sums of squares was utilized in all analyses of variance.

Thus all LOFT data reported here are based on the 22 crews depicted in Figure III-1. Details of the LOFT scenario are given below and depicted in Figure III-2.

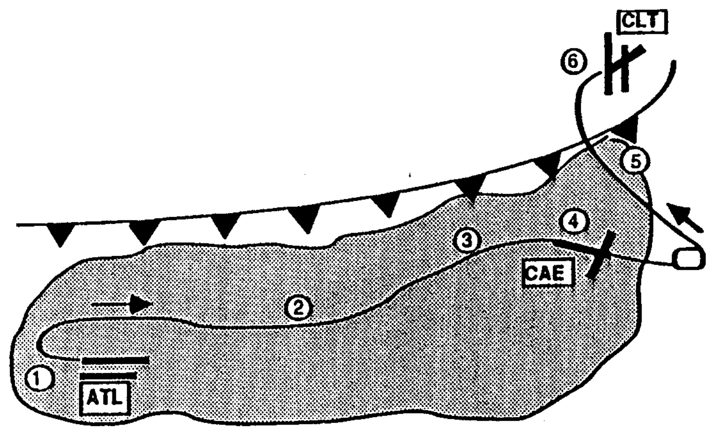
The choice of the PF/PNF did not turn out to be an effective variable. There was a point on the LOFT, as the crew began its descent to a Category II approach to Columbia, at which the captain had to take over as PF. For economic reasons, due to the high cost of maintaining training for Category II PF duties, first officers were not allowed to serve as PF on these approaches. Following the missed approach, some captains gave the PF assignment back to the first officer, others did not.

C. LOFT SCENARIO

The LOFT scenario design was a joint effort between the study team and the company's DC-9 and MD-88 simulator instructors. It was designed to include periods of high workload, generated by system failures, deteriorating weather at the destination, and complex ATC clearances. The flight was based on a regularly scheduled flight for DC-9s and MD-88s from Atlanta (ATL) to Columbia, SC (CAE). Due to low ceilings, a Category II approach was required at Columbia, and this was acceptable for both DC-9 and MD-88 aircraft at this company.

Figure III-2 displays the scenario for the study. The numbers in the figure correspond to the points that follow. (1) The scenario flown began at the gate in Atlanta. Weather was foggy at both Atlanta and Columbia. As the crew preflighted the aircraft, they had difficulty starting the auxiliary power unit (APU) which supplies electrical power on the ground or in the air if needed. The APU would start only after obtaining assistance from a mechanic. (2) Everything then went normally until the crew began their approach to Columbia. (3) At this point, one of the two constant speed drives (CSD), which transfers power from an engine to an electrical generator, began to overheat, but the temperature leveled off in a cautionary (yellow) range, short of the emergency (red) range. This required that the crew monitor

AUTOMATION SIMULATION SCENARIO



ATL	Atlanta, GA
A/C	aircraft
APU	auxiliary power unit
CAE	Columbia, SC
CLT	Charlotte, NC
CSD	constant speed drive (generator)

1
Departure

1. Fog ahead of cold front causing low visibility in ATL (at alternate minimums) and CAE (CAT II).
2. Dual alternates: ATL, CLT (VFR).
3. At gate, A/C on ground electric power, APU, will not start until mechanic starts it.

2
Cruise to CAE

1. Normal, low workload period.

3
Initial Approach to CAE

1. Problem: left CSD temperature warning light illuminates.
2. Checklist completion indicates approach and CSD operation can continue but CSD temp. must be monitored.

4
Approach/Miss Approach

1. Weather deteriorates requiring miss. Another A/C is in p published holding pattern so crew must enter non-published holding.
2. CSD overheats and fails upon entering holding. APU will not restart. High workload begins.

5
Cruise to Alternate

1. Crew must choose an alternate: ATL or CLT. CLT is best (ATL will deteriorate if the crew heads there).
2. High workload period: completion of CSD shutdown, electrical off-loading, preparation for landing.

6
Landing

1. Relatively routine approach to Runway 5, if procedures have been completed effectively.
2. Concern about possible failure of second generator.

Figure III-2. Simulation scenario.

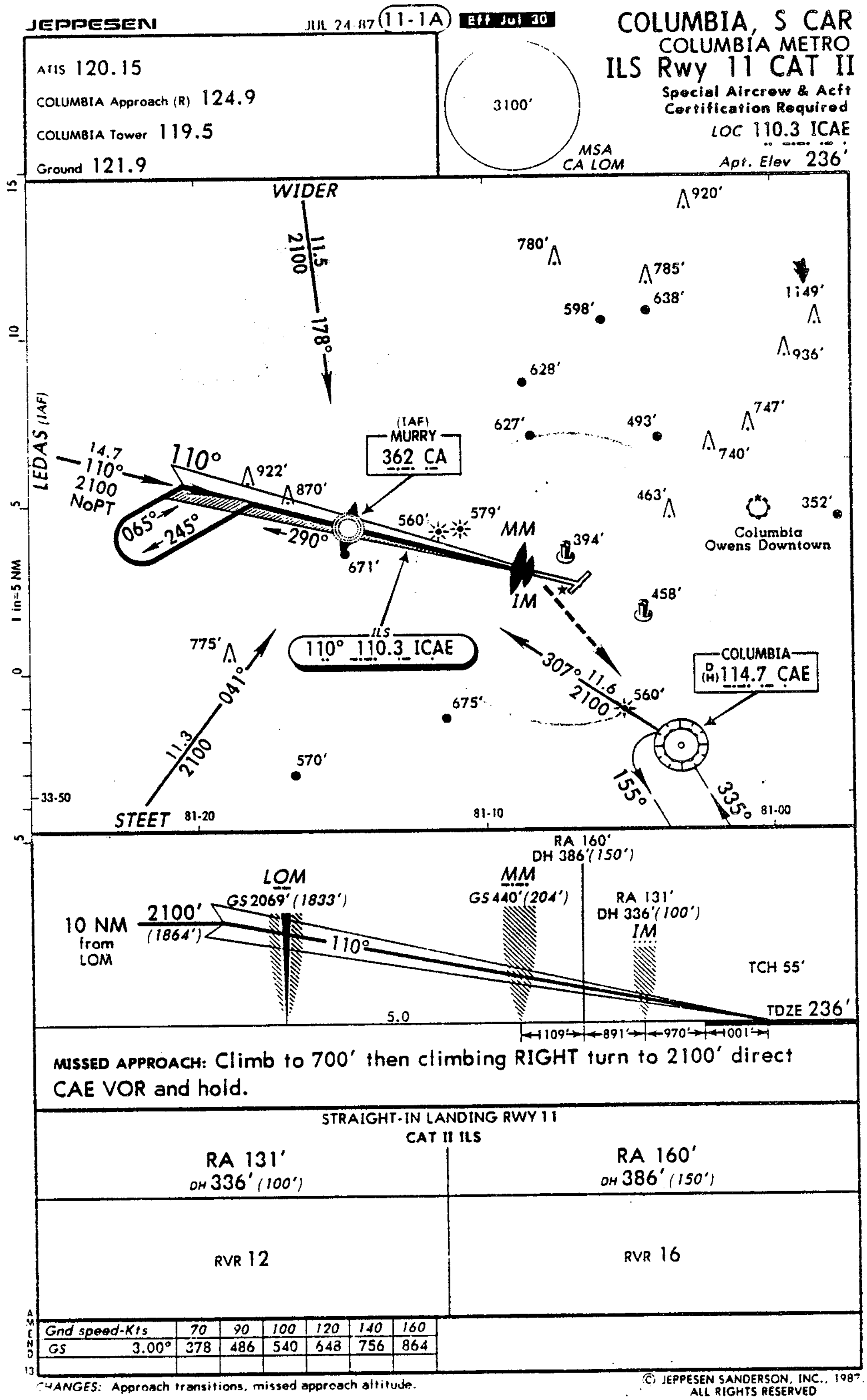


Figure III-3. Approach plate for Category II approach to Columbia, SC. (Copyright Jeppesen Sanderson, Inc.)

the temperature after completing the associated checklist, rather than disconnect the CSD and its generator, and continue the approach to Columbia. (4)

The weather was poor at the airport, and the crew ultimately had to abandon the approach at a low altitude. Because another "no radio" aircraft had missed the approach immediately ahead of them, and could not be contacted by ATC, the crew had to fly an unpublished missed approach course to an unpublished holding pattern. During the missed approach, the CSD temperature began to climb to the red range, and if the crew did not detect this before reaching the holding pattern, the CSD failed, shutting down one of the generators. The missed approach threw the crew into a very heavy workload environment. They had to enter and maintain the holding pattern, secure the failed CSD and generator, talk to the company dispatcher and weather, and choose an alternate airport (5,6). Additionally, the APU, which would not start initially at the gate requiring a maintenance call, would not start at this point either, leaving them with only one operating generator.

The crews eventually established themselves in the required holding pattern at CAE VOR, and contacted the company dispatcher. The dispatcher attempted to persuade the captain to return to Atlanta, a reasonable demand since Atlanta could provide adequate passenger convenience and aircraft maintenance for the airline. However due to the deteriorating weather at Atlanta, most crews elected to go to Charlotte (CLT), which had clear weather (being north of the advancing cold front), and was one of the alternates on the flight plan.

This often was a period of intensive communication between the crew members, and with the Atlanta dispatcher. Various captains called dispatch and requested the weather at numerous nearby airports. Only one captain had briefed his first officer in advance of the approach at Columbia that if they had a missed approach they would file to Charlotte, thus making the decision in advance. Those captains who attempted to return to Atlanta were "forced out" by warnings from ATC of the deteriorating weather, and likewise for all other airports forward of the cold front. Although CLT was the obvious alternate, and was on the flight plan as such, it sometimes took some inveigling on the part of the LOFT instructor, acting as ATC or Meteorology, to head the crew there.

D. DATA ACQUISITION

Instrumentation

All of the company's training simulators are equipped with a low light level video camera, as well as microphones that are worn by the crew during LOFT exercises. This camera is mounted from the ceiling of the simulator, behind the pilots at about the position of the LOFT instructor. It shows a panoramic view of the cockpit area, and the backs of the pilots' heads. The recorder is located outside of the simulator in an equipment bay.

In addition, a NASA video camera was installed in the same location, recording the central instruments on the captain's panel. A microphone suspended from the ceiling near the instructor's station recorded his commentary as well. The LOFT instructor played the role of Maintenance, ATC, Dispatch, Meteorology, or anyone the pilots would contact by radio. He also played the role of the maintenance crewman who was sent to start the APU on the ground in Atlanta. All of this was recorded on a channel on the NASA video tape. The confidential handling of the tapes was discussed in the previous chapter.

The tapes were viewed by qualified analysts at NASA Ames. They constructed a variety of logs of the actions of the crew, the errors made by the crew, and the verbal behavior. For purposes of this volume of the report, the creation of the error database from the tapes will be covered in the next chapter. More detailed information on the extraction of data from the tapes will be found in Volumes II and III.

Observers

Two observers in the simulator rated the performance of the crews following the flight. One was the company LOFT instructor, who filled out the usual CRM Evaluation Sheet (see Appendix 1). The LOFT instructor also conducted a post-flight debriefing of the crew, according to the normal procedure for a company LOFT. The company's video tape was used, and self-critique by the crew, rather than that of the instructor, was encouraged.

The other was the "NASA observer", a highly qualified company captain on medical leave, who was retained for this purpose. He had served as a line pilot and instructor on the DC-9, a line captain on the B-767, and at our request attended ground school on the MD-88. During the flight he took notes and filled out the Detailed Rating Form. Following the flight he filled out the Overall Rating Form, which can be seen in Appendix 1, and wrote a free text summary of the flight, detailing the strong and weak points of each crew's performance. These were used for the determination of the "most serious error" which will be discussed in the next chapter.

At least one member of the NASA study team was present for each run. He greeted the pilots when they reported, attempted to set them at ease and emphasized that they should regard this as a normal company LOFT, and reiterated the confidentiality agreement. No volunteers expressed any concern about confidentiality. During each flight the study team member monitored the recorders, and observed the flight via the two video terminals outside the simulator cab. He also attended the post-flight debriefing, but did not provide any ratings or data. Following the debriefing, the experimenter again thanked the pilots and answered their questions, without revealing the full purpose of the experiment, and asked them not to discuss the LOFT scenario with other pilots. We found no reason to believe that any crews arrived with prior information about the LOFT.

Rating Forms

Four rating forms were used in each flight. These can be found in Appendix 1. The data derived from these forms will be discussed in the next chapter.

1. Each pilot independently filled out the Participant Survey, which was essentially a self-report on the workload and demands of the LOFT. This form is derived from the NASA Task Load Index (TLX) developed by Sandra Hart of NASA Ames (Hart and Staveland, 1988).

2. Overall Rating Form (one page) and a Detailed Rating Form (two pages) were filled out by the NASA observer. The Overall Rating form stressed crew communications, decision-making, management and coordination. These were essentially global scales of crew behavior, not related to particular duties or phases of flight. This form was derived from earlier work by Helmreich and Wilhelm (1987).

3. The Detailed Rating Form covered each step of the flight and each duty of the crew and each phase of flight, from prestart to approach and landing. This form was first used in a simulator study by Foushee, Lauber, Baetge, and Acomb (1986).

4. Finally, the company LOFT instructor made his evaluation on a 17-item, five-point scale, ranging from "Poor" to "Excellent", with "Normal" in the middle. This form was an adaptation by the company of the Line/LOFT form developed by Helmreich and Wilhelm at the University of Texas, and used by numerous airlines world-wide.

Questionnaire

An extensive questionnaire was mailed to the volunteers in January 1990, several months after the completion of the LOFT experiment. The questionnaire, which is duplicated in Appendix 2, contained certain biographical questions on flying experience with respect to total hours and hours in type, types of approaches flown in their current type, a 28-item Likert attitude scale with probes regarding flying, safety, and automation, eight open-ended questions, and several miscellaneous questions. Results of the questionnaires are given in Chapter V, and elsewhere in this volume in graphic form.

IV. RESULTS OF SIMULATION EXPERIMENT

A. OVERVIEW

In this chapter we shall discuss the results of the simulator experiment, in which various measures of performance were recorded or derived. These included self-assessed measures of workload by the pilots; observer and instructor ratings of crew performance on the LOFT; and analyses of two independent sets of ratings by expert observers of the severity of crew errors during the LOFT. Additional analyses of crew errors will be found in Volume II.

B. ASSESSMENT FORMS

Measures of subjective workload and performance effectiveness were assessed on several forms that had been used before in NASA simulation experiments. Each of the forms used in this study is reproduced in Appendix 1. We will discuss them in the order that they appear in the appendix.

Pilot Self-Assessment of Workload

Each pilot assessed his own workload subjectively at the end of the flight using the "Participant Survey", an unweighted version of the NASA Task Load Index (Hart and Staveland, 1988). This rating form consists of six workload-related dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration. Pilots reported their responses along a seven-point Likert scale ("Low" to "High") with high numbers indicating greater amounts of the dimension in question, e.g., a rating of "7" on, for example, Item No. 2, would represent a maximal self-rating of mental demand, etc.

Hart and Staveland (1988) advocate the completion of a scale-weighting procedure wherein respondents evaluate the importance of each dimension to their perception of workload in the performance setting. However, in another full-mission simulation study, Chidester, Kanki, Foushee, Dickinson, and Bowles (1990) reported that a simple summed composite of the six items correlated .92 with the weighted scale scores. As a result, the procedure typically used to weight individual items of the TLX was eliminated and only the summed rating will be reported. In summary, each pilot circled a numeral from 1 to 7 representing his self-assessed value for each of the six dimensions (mental demand, etc.). These were summed to produce a mean for each dimension.

NASA Observer's Assessments of Performance

The NASA observer was present in the simulator cab with every crew, and evaluated crew performance following completion of each flight segment using: 1. the "Overall Rating Form", and 2) individual performance during specific phases of the segment, using the "Detailed Rating Form."

Overall rating form (crew performance)

This form was adapted directly from Helmreich and Wilhelm's (1987) Line/LOFT Checklist, which was, in turn, derived from previous NASA simulation studies. The observer was instructed to complete the form evaluating the crew as a unit, not as two individual pilots. Ratings were made on five-point Likert scales and were intended to assess the expert observer's overall impression of performance on each dimension. Sixteen of the 21 items on this form were analyzed. The selection of these items was consistent with the Chidester, et al. (1990) study, in which a factor analysis suggested these 16 items represented a common dimension. The remaining five items were excluded from the analysis. The numbers of the deleted items are circled in Appendix 1.

These ratings were summed and averaged to form a crew-level composite for the flight. This means that for each crew a single number was derived that represented the NASA observer's opinion of the quality of the crew's performance. The new scale had a range from 1 to 5.

The internal consistency of this scale as assessed by the coefficient alpha was .96. This indicated a high degree of internal consistency within the scale. Items composing this scale can be found in Table IV-1 and the form itself in Appendix 1. The scale will be referred to as "observer ratings of crew performance."

Detailed rating form (individual pilot performance)

This form was adapted from Foushee, Lauber, Baetge, and Acomb (1986). Within each section of the form (preflight, taxi/take-off, climb, cruise, etc.) the observer rated the performance of both individual crew members. Ratings were on a 5-point Likert scale.

LOFT Instructor's Assessment of Performance

At the end of the LOFT session, the company simulator instructor filled out the "CRM Evaluation Sheet." This was the only assessment made by the LOFT instructor.

From the 15 items contained in this scale, 12 items were selected (see Appendix 1); they are displayed in Table IV-5. These 12 items were selected from the 15 based upon a simple correlational analysis which revealed 12 of the items to be highly correlated. The remaining three items were dropped from analysis. Three measures were calculated based on the 12 items, and these will require some explanation.

Summary of Rating Forms

The four rating forms that were employed during and after the LOFT flights are summarized below. Only the Detailed Rating Form was filled out during flight; the rest were completed during the flight.

Form	Filled out by
Participant Survey	Each pilot
Overall Rating Form	NASA observer
Detailed Rating Form	NASA observer
CRM Evaluation Sheet	LOFT instructor

C. SELF-ASSESSMENT OF SUBJECTIVE WORKLOAD

Method

Following the flight, all crew members completed the Participant Survey (Appendix 1) derived from the NASA Task Load Index (TLX) (Hart and Staveland, 1988).

Self-assessment scores were analyzed by casting the data into a 2-by-2 (aircraft type-by-seat) analysis of variance (ANOVA). This allowed statistical assessment of the influence of cockpit technology (DC-9 vs. MD-88), duty assignment (captain vs. first officer), and the interactions (non-additive combined effects) of these two variables. The role of PF versus PNF was not examined.

Results

The total composite score, a global measure of workload described in the previous section, the contrast between the two aircraft was significant at the .051 level ($F(1,20) = 4.30$). The other main effect (seat) and the two-way interaction were non-significant. To examine further the main effect of aircraft type (automation), the results from the captains and the first officers were analyzed separately by t-tests for two independent groups (DC-9 vs. MD-88). The results for the captains were non-significant, however for the first officers the difference between the mean composite workload ratings for the two aircraft were statistically significant, indicating that MD-88 first officers attributed a higher workload to their cockpit duties than those assigned to the DC-9s.

The mean workload score for MD-88 F/Os was 30.50, for DC-9 F/Os was 26.67. The mean composite scores for the four combinations of aircraft and duty position ("seat") are displayed below.

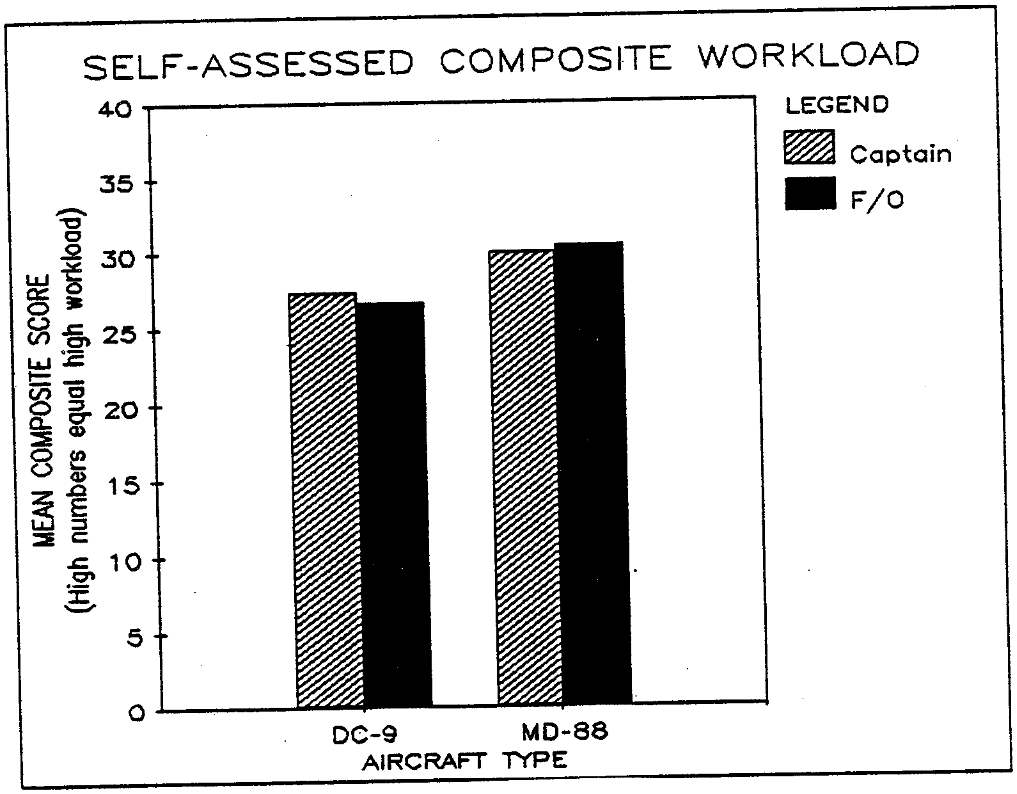


Figure IV-1. Mean composite self-assessed workload scores aircraft type and seat.

Each of the six individual items that made up the composite score of the self-assessment form was also subjected to ANOVAs of the same design (type-by-seat). Of the six, two resulted in significant results in the contrast of aircraft type: Physical Demand (Item No. 3) and Frustration Level (Item No. 7). In both cases, the means were higher for MD-88 crews than for DC-9 crews, meaning that MD-88 pilots perceived their jobs as being more physically demanding, and more frustrating. The means for the four groups on these sub-scales are displayed in Figure IV-2.

In none of the six ANOVAs was the seat assignment, or the interaction of seat and aircraft type statistically significant. However, additional t-tests were run separately on the captains and first officers, testing MD-88 crews' rating against DC-9 crews. These showed that in the two significant scales, for the first officers, Physical Demand was viewed as significantly higher for MD-88 crews compared to DC-9 crews, but for captains there was no significant difference. The Frustration Level ratings were significantly higher for both crew members in the MD-88 compared to the DC-9 (see Figure IV-2). The differences between the mean ratings were similar: $t = 2.11$ for captains, and $t = 2.19$ for F/Os.

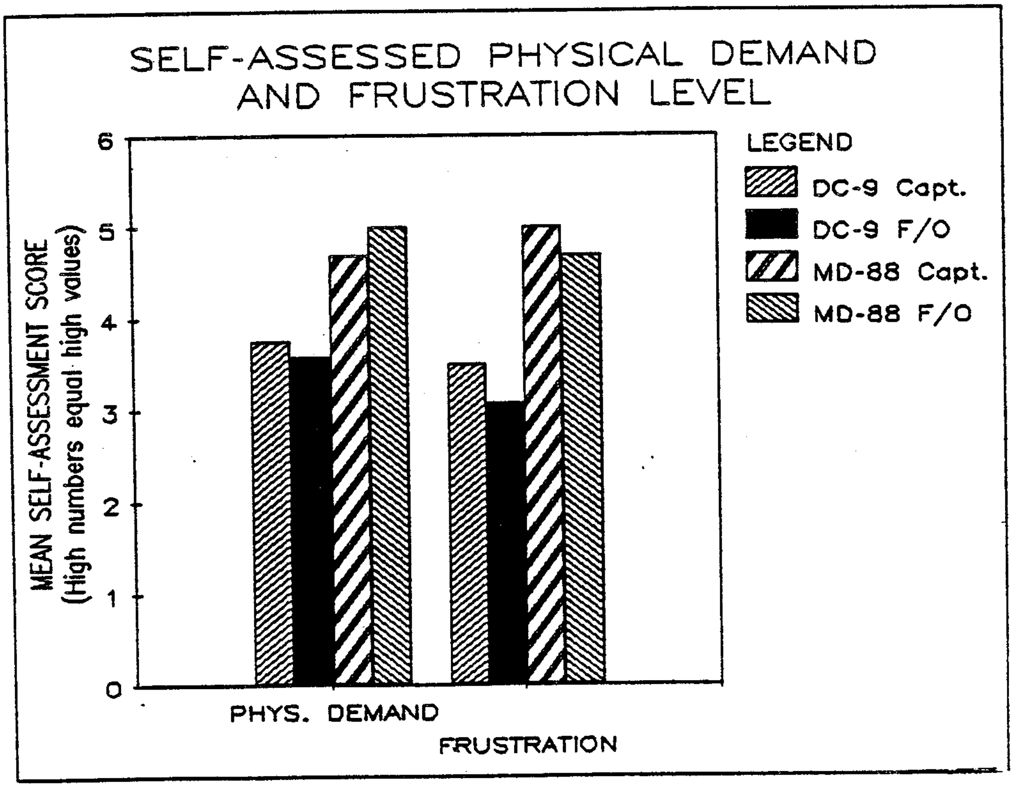


Figure IV-2. Mean scores on the Physical Demands and Frustration sub-scales by aircraft type and seat.

D. NASA OBSERVER'S RATINGS

Overall Rating Form (Crew Performance)

Method

The NASA observer completed an overall rating form after the flight (see Appendix 1). This form was developed from the University of Texas Line/LOFT form in use at many airlines.

Results

The mean composite rating for the two types of aircraft was computed. For the 12 DC-9 crews the mean was 3.43, and for the 10 MD-88 crews it was 2.91 (higher ratings represented more satisfactory performance). This difference was analyzed by the t-test for independent groups, and was found to be statistically significant ($t = -2.40$, $p < .05$). Thus in the eyes of the NASA observer, on a global measure of crew performance, DC-9 crews performed their duties on the LOFT more proficiently than the MD-88 crews, though the absolute difference was small (17 per cent).

TABLE IV-1. Sixteen items on Overall Rating Form administered by NASA observer. Note that these 16 items are taken from an original list of 21 items.

CREW COMMUNICATIONS AND DECISION MAKING

1. Communications were thorough, addressing coordination, planning,and problems anticipated.

2. Open communications were established among crew members.

3. Timing of communications was proper.

5. Active participation in decision making process was encouraged and practiced.

6. Alternatives were weighed before decisions were make final.

INTERPERSONAL (MANAGEMENT) STYLES AND ACTIONS

8. Crew members showed concern with accomplishment of all tasks at hand.

9. Crew members showed concern for the quality of interpersonal relationships in the cockpit.

WORKLOAD AND PLANNING

11. Work overloads were reported and work prioritized or redistributed.

12. Crew members planned ahead for high workload situations.

13. Appropriate resources were used in planning.

CREW ATMOSPHERE AND COORDINATION

14. Overall vigilance

15. Interpersonal climate

16. Preparation and planning

17. Distractions avoided or prioritized

18. Workload distributed and communicated

21. Overall crew effectiveness

Detailed Rating Form (Individual Pilot Performance)

Method

During the flight the NASA observer completed a second rating form that evaluated performance during each phase of flight (see Appendix 1), the Detailed Rating Form. This form was adapted from Foushee, Lauber, Baetge, and Acomb (1986). Within each section of the form (preflight, taxi/takeoff, climb, cruise, etc.), the observer rated the performance of each individual crew member. Ratings were completed using a five-point Likert scale and were summed and averaged to form a composite for each crew member during each phase of flight. Items forming this scale can be found on the Detailed Rating Form in Appendix 1, and will be referred to as "observer ratings of individual phase performance."

Results

The two-page Detailed Rating Form can be found in Appendix 1. During the flight the NASA observer completed this form, evaluating performance during each phase of flight. These were summed across phases, separately for two conditions, Normal and Abnormal. The first Normal phase began initiation of the LOFT on the ground at Atlanta and continued until the generator CSD high temperature warning light illuminated on the initial approach to Columbia, marking the beginning of the Abnormal phase. The Abnormal phase ended when the crew began its approach to Charlotte, marking the beginning of a second Normal phase.

The data were again aggregated across crew members, since we had abandoned the original plan of analyzing PF/PNF differences for the reasons stated in Chapter III. Also we learned that it was impractical to distinguish between captain and first officer proficiency, as their performance as a two-pilot crew was so highly interdependent. The ratings by the NASA observer are summarized in Table IV-3. The overall means, summed over the four phases of flight, are displayed in Table IV-2.

TABLE IV-2. Mean proficiency ratings by NASA observer by phases of flight.

	Abnormal	Normal	N
MD-88	2.90	2.96	10
DC-9	3.23	3.10	12

The only statistically significant difference found in these analyses was in the overall performance measure. Here the performance of the DC-9 crews was again significantly better than the MD-88 crews ($F(1,20) = 4.75$, $p < .05$). However the differences were slight, the ratings of the DC-9 crews being only about seven per cent higher than the MD-88 crews. These findings were consistent with the previous data showing small, though statistically significant, differences favoring DC-9 crews.

TABLE IV-3. Mean proficiency ratings by NASA observer by phase of flight. Larger numbers represent more proficient performance.

	Mean	S.D.
MD-88		
CC N	3.02	.15
CC A	3.07	.46
SIT N	2.97	.16
SIT A	2.95	.47
PRO N	2.91	.14
PRO A	2.75	.33
OVR N	2.96	.10
OVR A	2.90	.22
DC-9		
CC N	3.22	.59
CC A	3.36	.63
SIT N	3.13	.16
SIT A	3.19	.60
PRO N	3.09	.24
PRO A	3.04	.48
OVR N	3.10	.20
OVR A	3.24	.47

CODES

N = Normal phases; A = Abnormal phase

CC = Crew coordination/communication
SIT = Planning and situational awareness
PRO = Procedures/checklists/callouts
OVR = Overall performance and execution

Sample size is 10 for MD-88 crews, and 12 for DC-9 crews except in the CC-N where some data from one MD-88 crew was lost.

E. LOFT INSTRUCTORS' RATINGS

Method

One additional performance rating was completed by the simulator instructor. This utilized the LINE/LOFT checklist (referred to as a "CRM Evaluation Sheet" at the host airline; see Appendix 1). This form is currently being employed through the airline's participation in the NASA/University of Texas CRM evaluation.

There are some ambiguities in these data that can be attributed to the fact that we had a constantly changing instructor force, particularly in the MD-88. Ideally, for experimental purposes, we would have preferred to have had one instructor-evaluator for the entire experiment; the next best thing would be one DC-9 and one MD-88 instructor conduct all of the LOFTs. Neither of these was attainable for practical reasons.

On the DC-9 side, two instructors ran all of the LOFTS; however on the MD-88 side, there were many instructors, and some observed only one or two crews. As a result, comparisons across observers were difficult. Each rating may contain uncontrolled random variation which cannot be expected to sum to zero.

We made two attempts to "equilibrate" the instructors statistically. From the company's training records, we obtained each observer's average and standard deviation for crews observed in the CRM evaluation database. Based on those figures, we sought to standardize the present crew ratings.

The following statistical adjustments could be made:

1. We could analyze the uncorrected average of the 12 items.

2. We could compute a "deviation score", the scale value minus the average rating each observer had given all company crews he has observed and rated prior to the experiment. This would in effect "calibrate" the ratings each instructor gave our crews by "unbiasing", adjusting for his tendency to give high or low ratings in the past. This would yield for each measure a simple score adjusted for the instructor's bias.

3. We could create a "standard score" by taking the adjusted simple score (No. 2 above) and dividing by the standard deviation of all ratings the observer has given for company crews (a standardized score). This would adjust not only for each instructor's bias, but for his variability as well.
The simple score is just another overall rating. Deviation and standardized scores compare each observed crew to all others an instructor has observed and give us an idea whether he felt that each observed crew was better, the same, or poorer than the crews previously observed in LOFT. Thus the adjusted scores computed from the CRM Evaluation Sheets from our experiment would be directly comparable to regular company line crews who had been rated on the same form.

Results

The three indices of instructor ratings were highly correlated: the correlation coefficients are displayed in Table IV-4.

Also, the correlation between the instructor's rating (CRM Evaluation Sheet) and the expert observer's rating (Overall Rating Form) can be assessed. High correlations between the instructor and the observer would be the closest we can get to inter-rater reliability. Instructor simple scores correlated .80 with the expert observer's ratings, while deviation scores correlated .43 and standardized .49. The simple score correlation is impressive, and suggests substantial agreement between the two evaluators of each crew.

Each of the indices was submitted to analysis of variance. No contrasts were statistically significant. In brief, we could find no differences between the crews of DC-9s and MD-88s with respect to the LOFT instructors' ratings. The simple score came closest to discriminating the MD-88 and DC-9 ($F\ (1,18)=2.12$, $p=.167$). The means are displayed in Table IV-6 below. None of the differences was significant.

TABLE IV-4. Intercorrelations between simple scores and two adjusted scores on CRM form.

	Simple	Deviation	Standard
Simple	----	.65	.71
Deviation		----	.95

We should note two things concerning these data. First, simple scores approximate what was seen by the expert observer, but the effect (if any) was too small to be detected by our design.

TABLE IV-5. Twelve items (out of original 17) rated on LOFT form by the simulator instructor.

Briefing thorough, established open communications, addresses coordination, planning, team creation, and anticipates problems
Communications timely, relevant, complete, and verified
Inquiry/questioning practiced
Assertion/advocacy practiced
Decisions communicated
Crew self-critique of decisions and actions
Concern for accomplishment of tasks at hand
Interpersonal relationships/group climate
Preparation and planning for in-flight activities
Distractions avoided or prioritized
Workload distributed and communicated
Overall crew effectiveness

Table IV-6. Means for original and adjusted LOFT instructors' ratings.

	MD-88	DC-9
Simple	3.163	3.47
Deviation	-.08	-.13
Standard	-.11	-.42

Second, on the average, crews in this study were rated as performing less well than those crews that the instructor had seen in other company LOFT's. This second finding is not easy to interpret. It could mean simply that our scenario was more difficult than those typically used in the company's LOFT sessions, which was probably the case. Comments made by both the instructors and the volunteer pilots indicated that this LOFT scenario was considered quite difficult compared to other LOFTs which the company employed.

In summary, even with the statistical adjustments we made in order to attempt to compensate for the fact that we had a number of instructors rating the LOFT performance on the CRM form, we did not find differences in these ratings attributable to cockpit technology (DC-9 vs. MD-88). More will be said of this in Volumes II and III of this report, which will analyze the communication between crew members in the two aircraft.

F. ANALYSIS OF CREW ERRORS

In this section we present data from two analyses of crew errors: 1) ratings based on direct observation of the crews during the LOFTs by the NASA observer; and 2) analyses of the video tapes of each LOFT performed at NASA Ames by two qualified pilots who were trained to rate the error data.

NASA Observer's Ratings - Most Serious Error of Each Flight

Method

During the actual LOFTs the NASA observer kept a log of errors that he had observed during the flight. He did not rate or classify these errors at the time. When all of the flights were completed, we asked the NASA observer to determine for each flight the most serious error committed. When he had done this for the 22 successful flights, we asked him to then rank order the 22 "most serious errors" from the least serious (rank 1) to the most (rank 22). Thus he produced a rank-ordered list of the most serious errors from merged data of the two aircraft. We then analyzed these data using rank statistics for two independent groups (White rank sum test).

Results

Our directional experimental hypothesis was that the MD-88 crews would commit errors which were more serious than those produced by the DC-9 crews. This was based on the observation by Wiener and Curry (1980) and Wiener (1988) that one of the effects of cockpit automation appeared to be that crews committed fewer but more serious errors. If this were the case, then the larger ranks would tend to be assigned to the 10 MD-88 flights and smaller ranks would go to the 12 DC-9 flights. The mean rank of the errors of the 12 DC-9 and 10 MD-88 "most serious errors per flight" should be different, namely that the mean of MD-88 ranks should be larger, if the hypothesis were correct.

In fact this was not the case. The ranks of the most serious errors were almost perfectly intermixed, yielding a Z of 0.20. Thus our hypothesis was not supported: the crews of the two aircraft types produced most serious errors of equal magnitude.

Video Tape Analysis of Errors - Categories of Seriousness of the Error

Method

Videotapes recorded during the experimental LOFT sessions were sent to NASA-Ames Research Center for analysis. At Ames, error analyses were undertaken employing a complete review of the videotape records. Using these records, two highly qualified observers reviewed each flight for operational errors. Both observers were recently retired pilots. One retired from an airline with substantial experience line flying and instructing in the B-767. The other retired from the military and had served as an observer in previous NASA investigations. Both observers studied the host airlines's DC-9 and MD-88 training and flight operations manuals prior to initiating error identification.

The observers worked together to review videotapes of each performance. When an error was recognized by one or both observers, the tape was stopped and the segment containing an alleged error reviewed. After this process, both observers had to agree that an error had occurred and had to agree on a description of the error or it was not counted in the analysis. This was a conservative error tabulation process that ensured that every error data point was reviewed at least twice. Since some performance errors were more operationally significant than others, errors were categorized according to level of severity. This process was accomplished by both of the observers involved in the videotape error analysis

Error classifications

A three-level classification, based on previous work by Foushee et al. (1986) was utilized. The three levels of error severity and their operational importance is listed in below.

Type 1 - minor, with a low probability of serious flight safety consequences.

Type 2 - moderately severe, with a stronger potential for flight safety consequences.

Type 3 - major, operationally significant errors having a potentially negative impact upon flight safety.

Examples of Type 1 errors included: unnecessary interruption of a normal checklist, incorrect clearance readbacks that were quickly corrected, and missing an item required during the takeoff briefing.

Examples of Type 2 errors included: failure to complete a normal checklist not accompanied by significant missed items, and failure to check in with the tower in a timely manner as instructed by approach control.

Examples of Type 3 errors included: troubleshooting a significant system failure (CSD) without using the written procedure, turning the wrong direction (reciprocal heading) on exiting holding, and either disconnecting the CSD before it was required or failing to monitor CSD temperature allowing overheating to shear its shaft.

Results

A total of 273 errors were identified by the video observers across the 22 crews. A consensus was reached by the two observers on the severity classification of each error. They replayed the tapes until they could agree on the severity. If they could not agree, the less severe rating was adopted. A tally of these errors by phase of flight (normal vs. abnormal) summed across the two aircraft types is displayed in Table IV-7. The same data by phase and by aircraft type are shown graphically in Figure IV-3. The means, broken down by aircraft type, are displayed in Table IV-9. It is clear from the data displayed in Table IV-7 that the most severe errors (Type 3) prevail in the abnormal phases of the LOFT flight.

TABLE IV-7. Error frequencies by normal and abnormal phases of flight, summed across two aircraft types.

	Normal	Abnormal	Total
Type 1	16	13	29
Type 2	51	95	146
Type 3	11	87	98
Total	78	195	273

Error frequencies were correlated with evaluations of performance by the expert observer and by simulator instructors, as summarized in Table IV-8. Those which were significant were negative, indicating that instructor ratings showed an inverse relationship to errors, as one would expect. An absolute value of *r* greater than .243 indicates significance at the .05 level (two-tailed).

TABLE IV-8. Correlations between errors and observers' ratings.

Error type	Total	1	2	3
NASA observer	-.45	.18	-.29	-.62
LOFT instructor	-.46	.04	-.38	-.46

With the exception of minor (Type 1) errors, high error frequencies were associated with poor performance ratings. However, when submitted to analyses of variance, total error frequencies did not reveal significant effects for aircraft type.

The data in the table reveal only minor differences between aircraft type in severity of errors. Based on an ANOVA, there were no differences between the DC-9 and MD-88 with respect to severity of errors in any category. This is consistent with the data produced from the examination of "most serious errors" by the NASA observer. Though none of these comparisons was significant, they do tend to show MD-88 crews making more errors than DC-9 crews overall. A case can be made that in the glass cockpit MD-88 there is simply more to do, and more errors can be made (e.g. attempting to reprogram the FMS while on the glide slope at low altitude). Volume II will discuss the nature of the errors in the two cockpits. Our sample size is not sufficient to detect effects of this magnitude. We can only conclude that we have failed to produce evidence to support the hypothesis that more severe errors are made in highly automated cockpits.

<u>Errors by phases of flight</u>

As a follow-up to these overall analyses, error frequencies were broken down by phase of flight, to determine whether significant differences between aircraft might occur during some periods. Each tape was coded to identify eight phases: pre-takeoff, climb, cruise, descent, CSD overheat and procedure completion, approach to CAE (including missed approach and holding), diversion, and approach to CLT. As might be expected, errors were very closely associated with the abnormal phases of flight.

Of the 273 total errors identified, only 78 (29%) occurred during normal flight (though these periods averaged approximately 50% of the total LOFT time) as previously defined as the period from initial cockpit activities in Atlanta up to the CSD failure light appearance at cruise between Atlanta and Columbia, and the period during the approach and landing at Charlotte. The means of the errors by error type (severity), phase of flight, and aircraft type are shown in Table IV-9, and Figure IV-3.

TABLE IV-9. Mean frequency of errors by error type (severity), flight phase (normal vs. abnormal, and aircraft type.

	ERROR TYPE		
	1	2	3
<u>DC-9</u>			
Normal	0.92	1.83	0.33
Abnormal	0.67	4.50	4.33
<u>MD-88</u>			
Normal	0.56	3.22	0.78
Abnormal	0.56	4.56	8.89

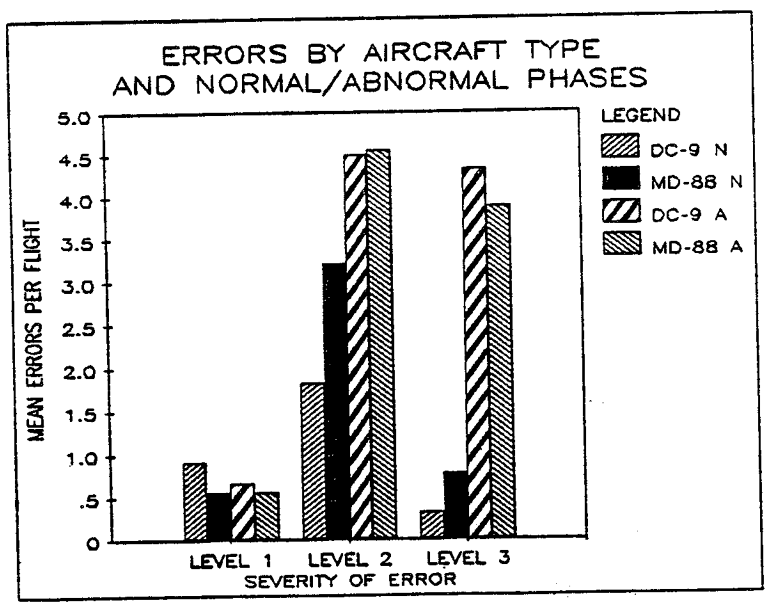


Figure IV-3. Operational errors by aircraft type, phase of flight, Normal (N) vs. Abnormal (A), and severity.

In order to ascertain what portion of the flights was spent in the normal and abnormal phases (as defined above), the time was computed from the video tapes for each flight, and the means were determined. These means are shown in Table IV-10. An analysis of variance was performed on these data with aircraft type and phase as main effects. Neither was statistically significant. The mean time in the normal versus abnormal phases of flight were virtually identical. Although the mean time in both phases was slightly higher for MD-88 crews, this difference was not significant. The interaction term was also non-significant.

Since the times spent in the normal versus abnormal phases were so nearly equal, the frequencies of errors can be viewed as error rates. One may convert these to mean errors per minute by dividing by the appropriate mean time (approximately 40 minutes).

TABLE IV-10. Mean time in normal versus abnormal phases of flight by aircraft type (in minutes).

	PHASE OF FLIGHT	
	Normal	Abnormal
DC-9	39.8	39.9
MD-88	43.7	42.0
Overall	41.5	40.9

Follow-up analyses were overall something of a disappointment. We had hoped that they would clarify the performance ratings by isolating where errors were more likely to occur in each aircraft. It appears either that these differences are very slight, or that the effects are so small that our design cannot detect them. In-depth analyses of the error data will be presented in Volume II of this report.

The question remains whether the error data supports confidence in the observer ratings and self-reports of crew workload. Error frequencies reported here are highly correlated with independent ratings, which would tend to bolster observer validity, but they do not appear to provide independent evidence of operationally significant problems in the MD-88. This will be discussed further in Chapter VI.

G. SUMMARY OF LOFT DATA

The preponderance of data presented in this chapter points toward a consistent, but slight, superiority of the DC-9 performance over the MD-88. In the areas of self-report of workload, the MD-88 crews saw their workload as higher than did the DC-9 pilots, but again the differences were small. The ratings by the NASA observer and the LOFT instructor tend to favor the performance of the DC-9 crews, but again the differences were very slight.

Considering the fact that the experience level in type was much higher in the DC-9 than the MD-88 crews (see Chapter II), the picture is even less clear. There were no measures on which the MD-88 crews were seen to perform in a manner superior to the DC-9 pilots, but the time-in-type factor cannot be ignored. One way to look at the data is to say that the automation made it possible for the MD-88 crews to compensate for their lack of experience in type.

As a way of estimating the importance of time in type, taking the DC-9 and MD-88s separately, we correlated the months-in-type with a variety of performance measures: overall performance rating, Type 1, 2, and 3 errors, captains' and first officers' assessment of total workload, and captains' and first officers' assessment of frustration and physical demand. No significant correlations were found. Thus we cannot say that, at least within fleets, the experience level in type affects any of our performance measures, and by inference, the differences between DC-9 and MD-88 time-in-type figures may not be important.

Another interpretation would ask why it is that the crews of a technologically superior aircraft could not do better, compared to those flying a 1965-era cockpit technology? Still another interpretation would be to say that crew experience we saw in this experiment was not an artificial experimental factor, but a representation of the "real world" of line flying; that for at least a few years to come, at most airlines world-wide will continue to consist of a large group of pilots highly experienced in type in technologically unsophisticated aircraft, and a somewhat smaller group of less experienced (in type) pilots in advanced cockpits. Thus our samples represent the present-day "real world" of airlines with technologically mixed fleets, with the highest experience being by far in the less advanced cockpits.

The results of this LOFT experiment provide both good and bad news to those who design, build, regulate, and operate modern aircraft, and reflect the typical dilemma faced by those who must provide training. On the positive side, despite pilot reports and concerns raised in a variety of previous research studies, the <u>performance</u> of crews in the automated aircraft was as a practical matter no worse than those in the corresponding traditional aircraft. On the negative side, despite the design goal of workload reduction on the automated aircraft, crews in the MD-88 performed no better, and reported perceptions of higher workload than DC-9 pilots flying the same LOFT.

As a general conclusion, it appears that the automated environment is neither better nor worse than the electro-mechanical: it is simply different. These differences will be emphasized in the volumes that follow.

Pilots, through their training and efforts are adapting, as pilots always have. But in the current era of enlightened human factors awareness, the designs should be more "user friendly" to the pilots and not require so much adaptation. The human pilot can only adapt so much - and then an incident occurs and it is attributed to "pilot error".

The question for the research and development community remains: how do we provide the best pilot-aircraft interface? The question for the operational community remains, given the current aircraft designs, how do we provide the best training, procedures, and support necessarily to operate a new generation of equipment?

V. QUESTIONNAIRE RESULTS

A. OVERVIEW

Questionnaires were designed to elicit pilot opinions, experience level, and specific information and viewpoints. It was somewhat difficult to design a questionnaire that would be equally responsive to the needs and opinions of DC-9 and MD-88 crews. Most MD-88 pilots had flown traditional cockpit aircraft; but only eight of the 42 DC-9 pilots (all captains) had experience in advanced airliners (B-767/757). In this study we do not take into account military or corporate aircraft the volunteers may have previously flown.

The questionnaires were mailed to the volunteers in January 1990. The LOFT flights had been completed at the end of August 1989. Most of the questionnaires were returned by the end of the March; a few straggled in during April and May. They were designed with the goal that they 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.

<u>Questionnaire Components</u>

The questionnaire contained the following parts:

1. Biographical information on flying experience at the host airline, total flying time, time in type, etc. These results are summarized in Chapter II.

2. A 28-item Likert attitude scale, adapted from the one previously used by the author in his field studies on the MD-80 (Wiener, 1985) and the B-757 (Wiener, 1989). Some probes were identical to those in the previous studies, others were tailored to this study. An attempt was made to design probes that were equally sensible for the DC-9 and the MD-88 crews, however it is clear that many of the DC-9 pilots had no experience with advanced technology aircraft, so their answers would be based on their general knowledge of automation, what they had seen and heard.

3. Information was sought on the number of various types of instrument approaches (e.g. VOR, ILS, LOC) that had been made in the last year by the crews. Questions about Category III approaches and autolands are not appropriate for the DC-9; otherwise these questions applied equally to both types of aircraft.

4. Eight open-ended questions allowed the respondents to express in their own words attitudes regarding various aspects of their flying experience. 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). The final question was the most general. Volunteers were asked to relate anything about the human factors of their flying jobs that they wished to discuss.

B. ATTITUDE SCALES

Likert Scale Construction

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 to 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. Note that in the histograms that follow, we have labeled the center response as "neutral" for brevity. This word did not appear in the questionnaire.

Handling of Numeric Data

The probes are referred to as Item 1 through Item 28, and data are displayed as histograms. The 28 histograms which follow simply report the percentage of responses to each probe at the five levels, by type of aircraft the respondent was currently assigned to.

Numerical data from the questionnaires were entered into a computer-based file, and statistical analyses were performed. For each of the 28 attitude items (P1 to P28), two-way factorial 2-by-2 analyses of variance were performed. The two dimensions were automation level (DC-9 versus MD-88) and seat (captain versus first officer).

In none of the 28 Likert probes was there a significant difference between the responses of the DC-9 and the MD-88 pilots. Thus it appeared that one's current aircraft type, which we take as a surrogate for level of automation, did not affect one's attitude in a variety of questions on automation and other aspects of line flying, equipment, and safety.

In only one of the contrasts of captain versus first officer was there a significant difference. This was in Item No. 27, "Automation capability enhances safety", the results of which are displayed in Figure V-1. It appears from the figure that the captains agreed with the probe more than the first officers.

One of the two-way interactions (automation-by-seat) was statistically significant. This was Item No. 7, "I use the automation mainly because my company wants me to." These data are displayed in Figure V-2. The significant result indicates that the effect of automation and of aircraft seat did not combine linearly to produce the results. This interaction is difficult to interpret. The main source of the interaction seems to be in the "neutral" and "disagree" responses. Looking at these responses in the graph, one can see a disordinal interaction between aircraft and seat. More MD-88 captains than first officers are neutral, and the opposite for DC-9 crews. When one examines the "disagree" response, the opposite is true.

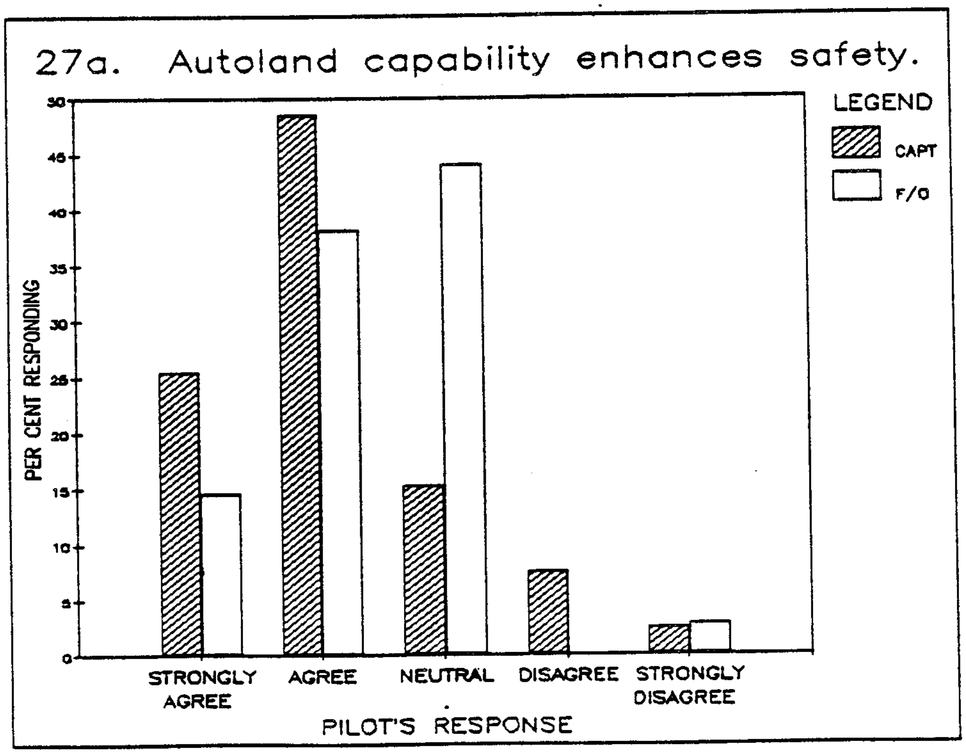


Figure V-1. A significant difference between captains and F/Os.

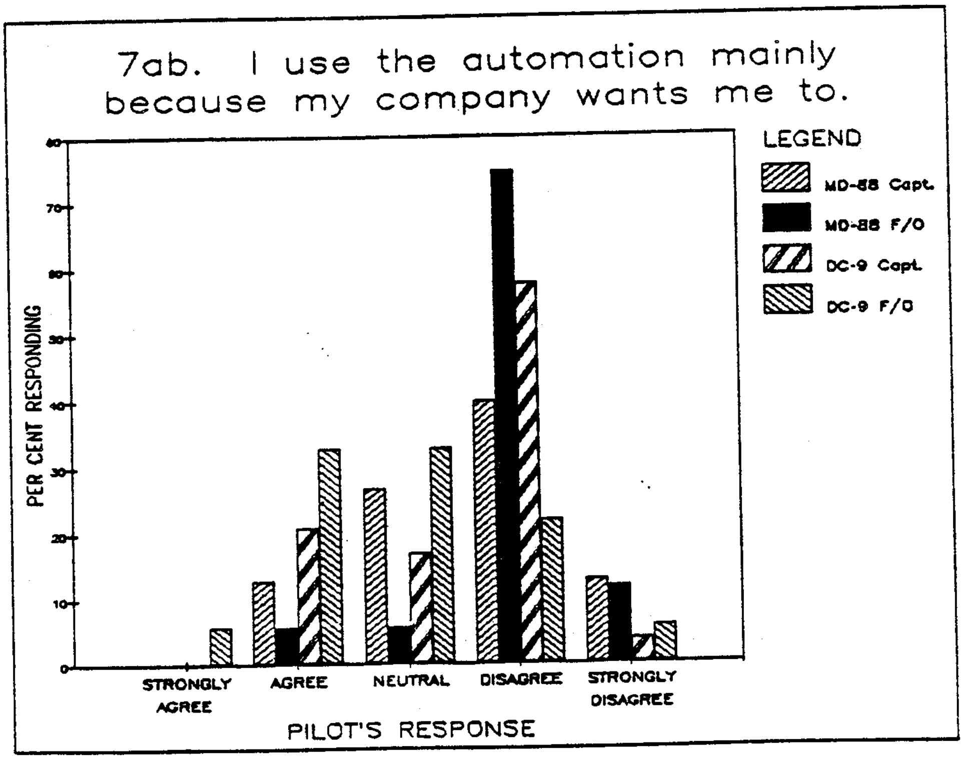


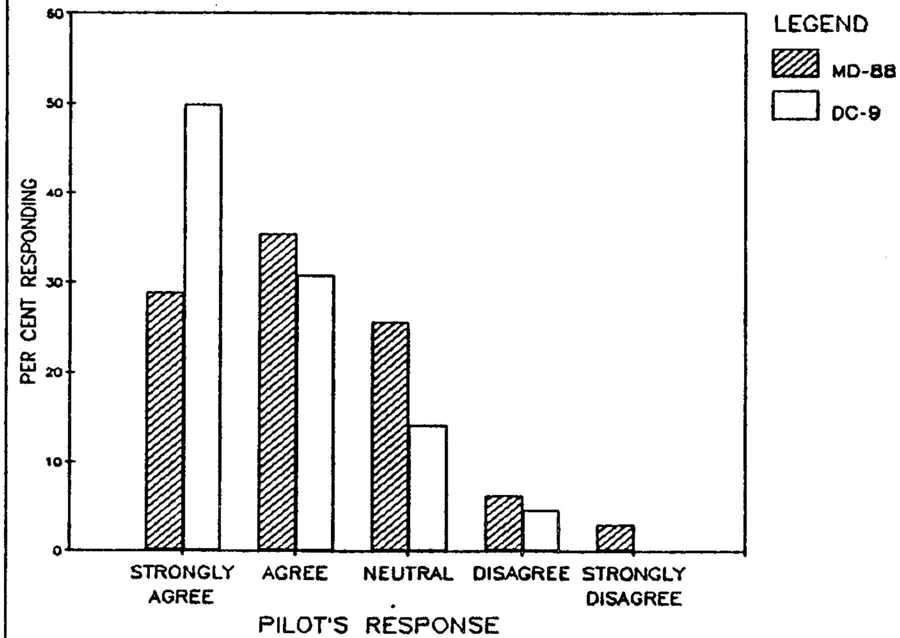
Figure V-2. A significant interaction between seats and aircraft type.

Interpretation of Attitude Scales

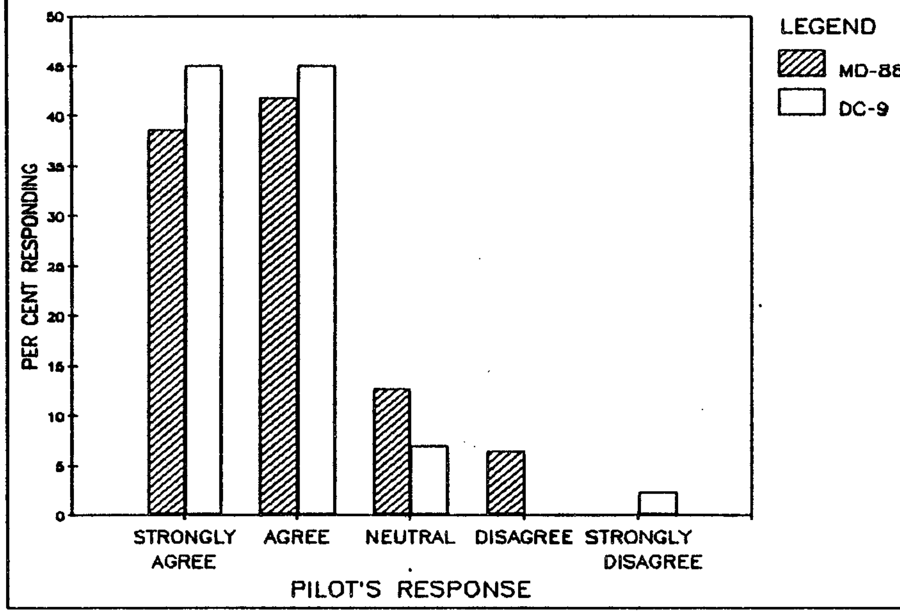
The reader is cautioned that the information in the attitude scales, as in the open-ended questions, is subjective opinion of the volunteer pilots. It is valuable information, both for researchers and persons in the aviation industry, attitude questionnaire data should be taken seriously. But likewise, it is important that any particular result not be over-interpreted by the reader, and that be clear that such data are not from essentially experimentally controlled conditions.

The following seven pages contain in histogram form the results of the 28 Likert scale attitude questions.

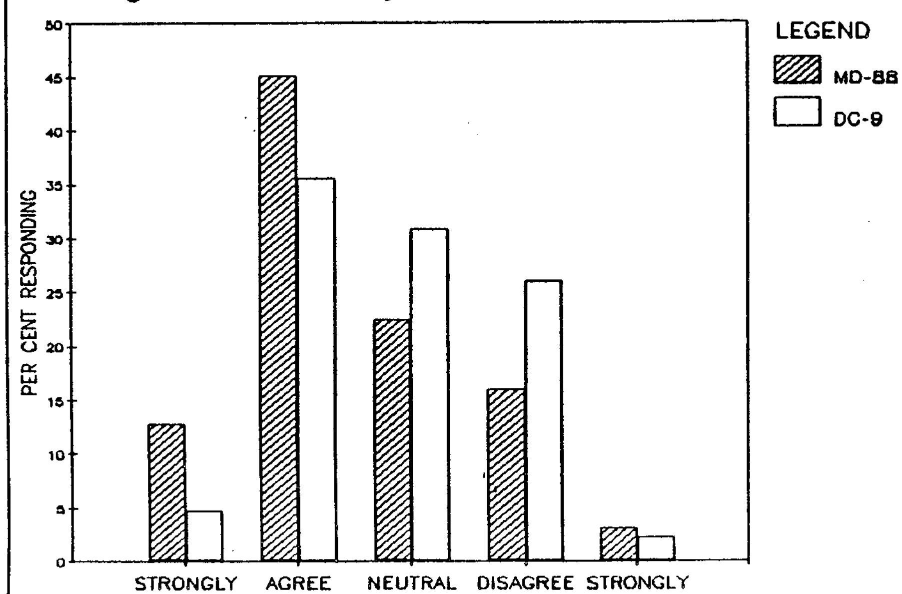
1. Flying today is more challenging than ever.



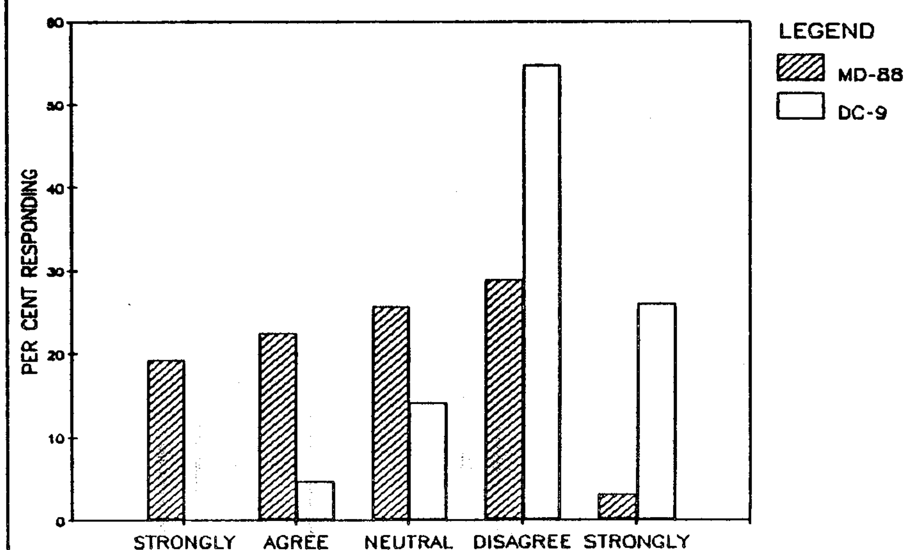
2. I take active measures to prevent a loss of my flying skills due to too much automation.

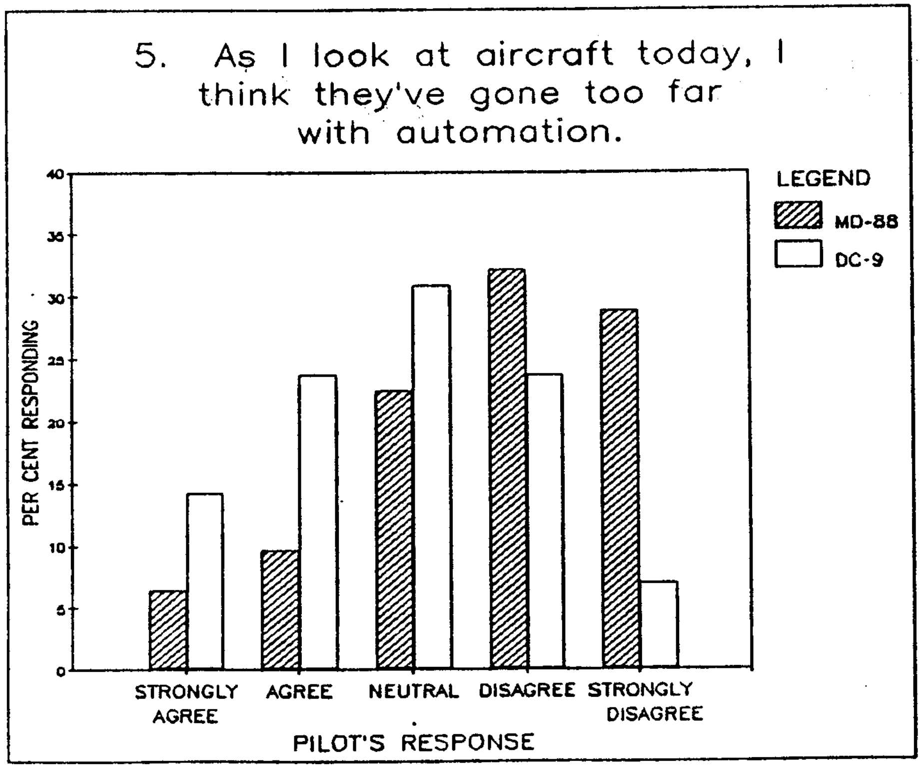


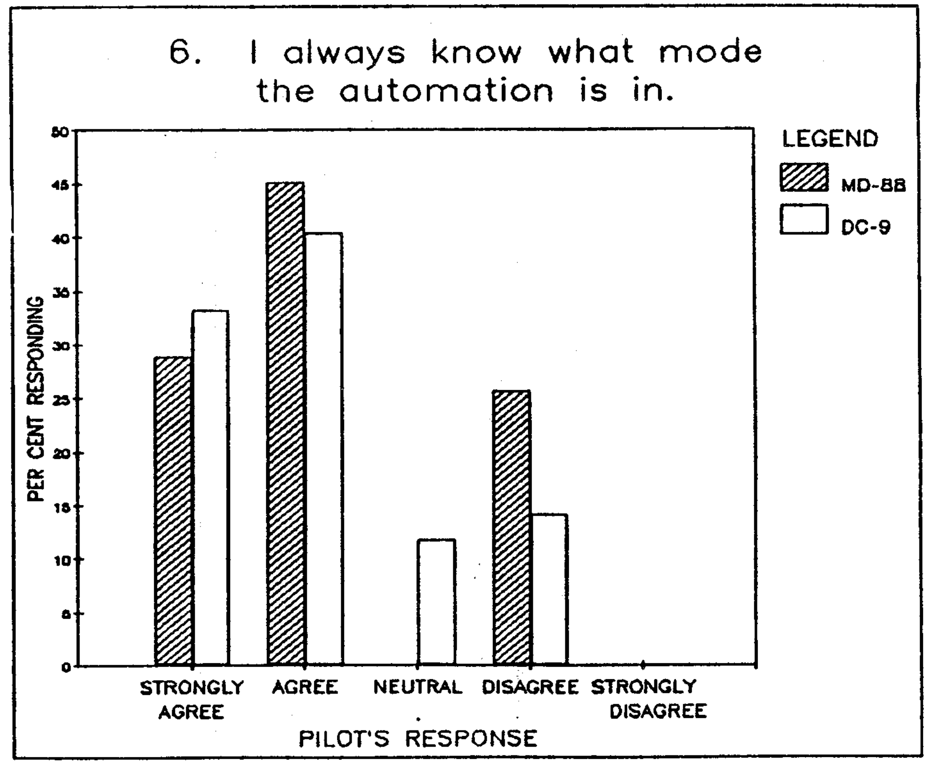
3. The DC-9/MD-88 automation works great in today's ATC environment.

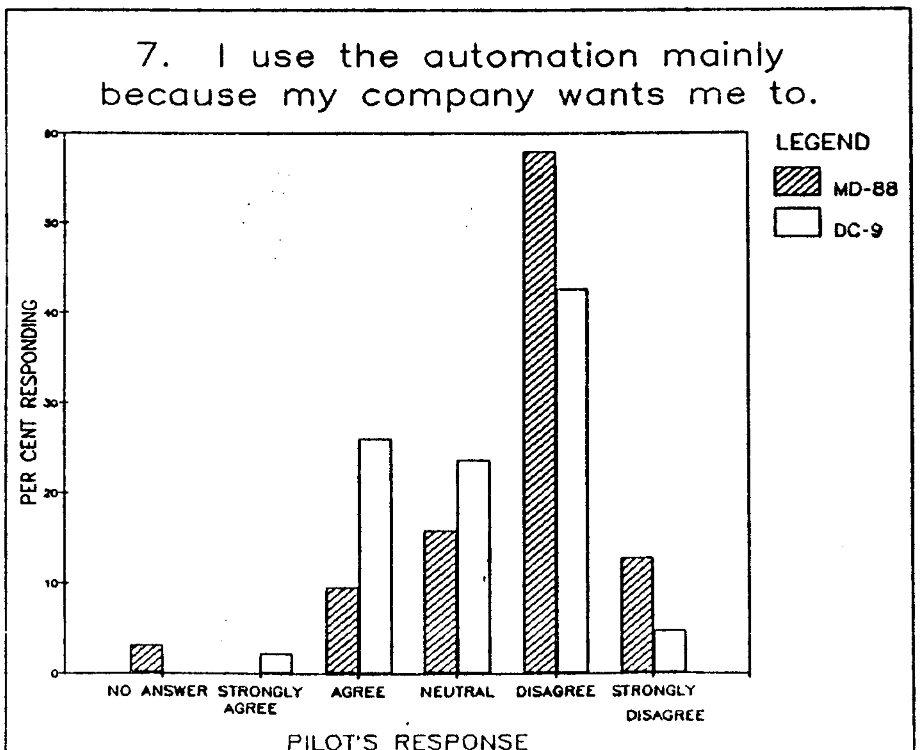


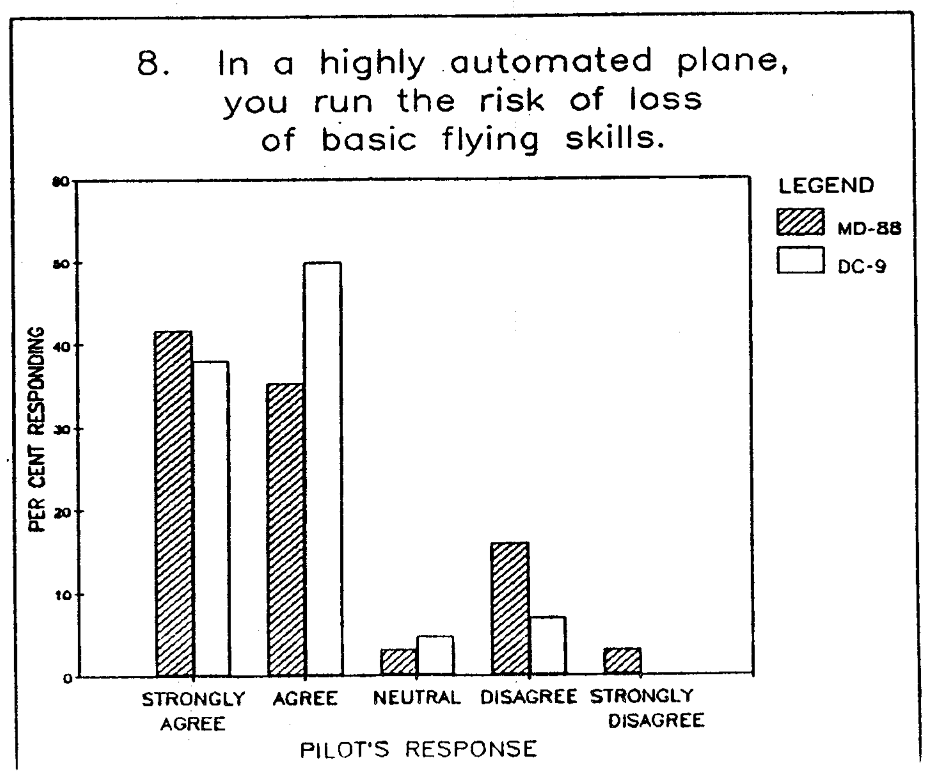
4. It is important to me to fly the most modern plane in my company's fleet.



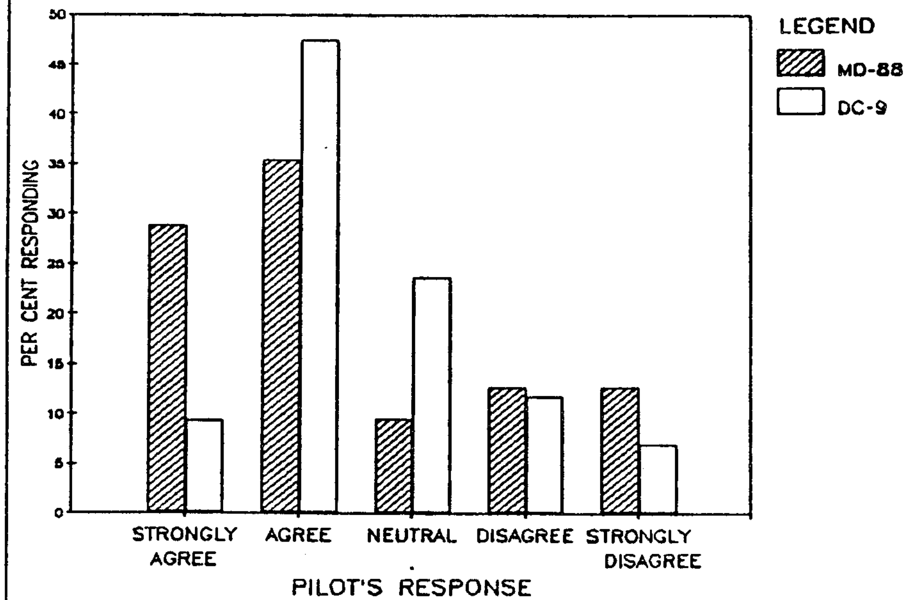

5. As I look at aircraft today, I think they've gone too far with automation.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
5
10
15
20
25
30
35
40
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE


6. I always know what mode the automation is in.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
5
10
15
20
25
30
35
40
45
50
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE

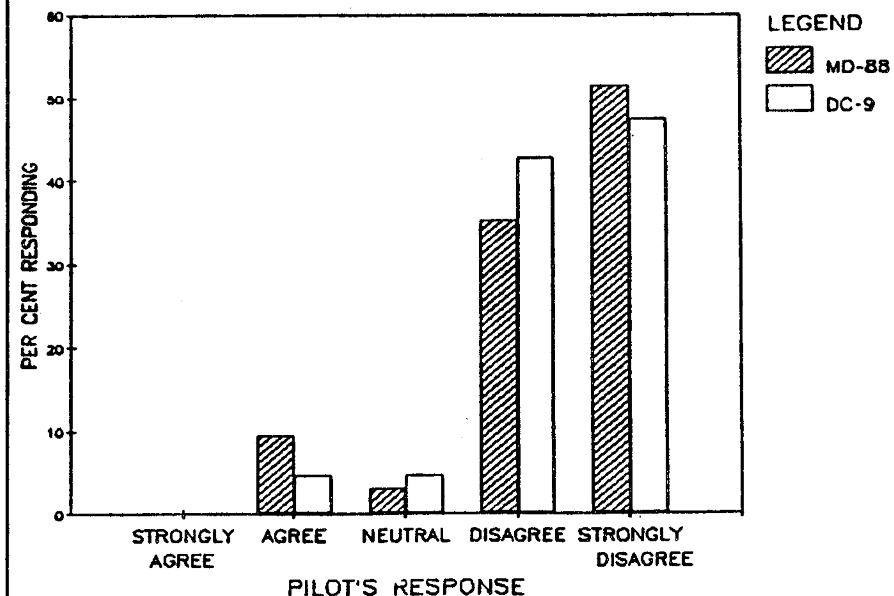

7. I use the automation mainly because my company wants me to.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
10
20
30
40
50
60
NO ANSWER
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE


8. In a highly automated plane, you run the risk of loss of basic flying skills.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
10
20
30
40
50
60
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE

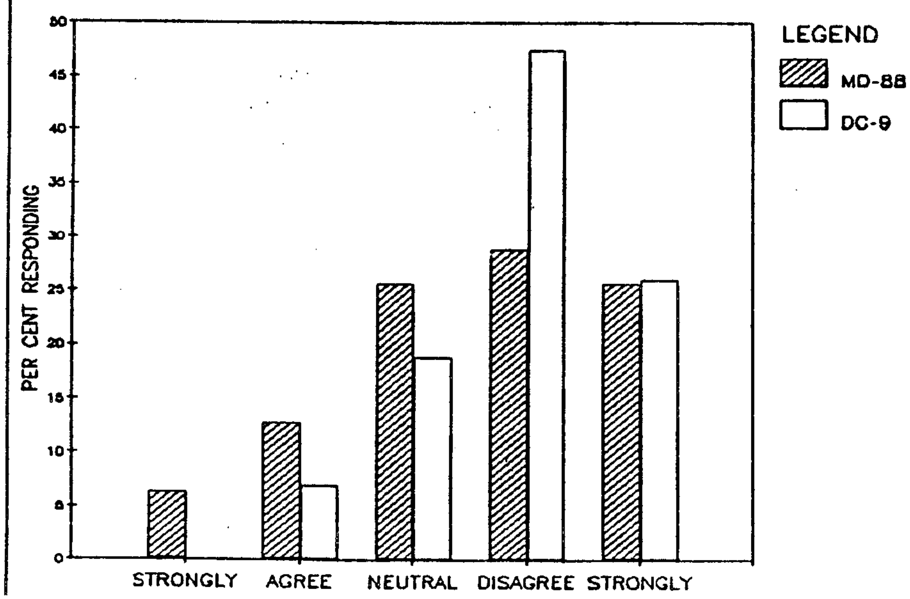
9. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "managing" the flight.



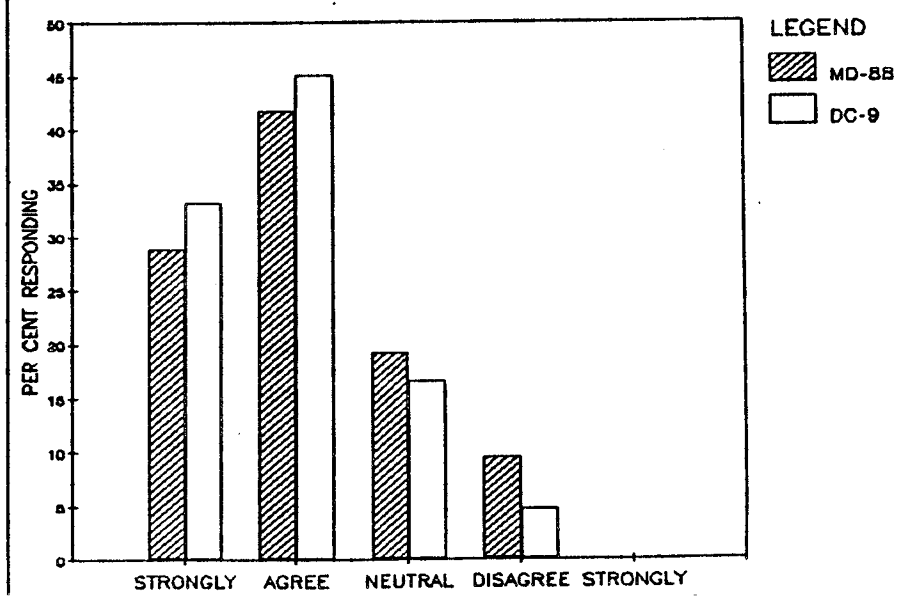
10. I am not concerned about making errors, as long as we follow procedures and checklists.

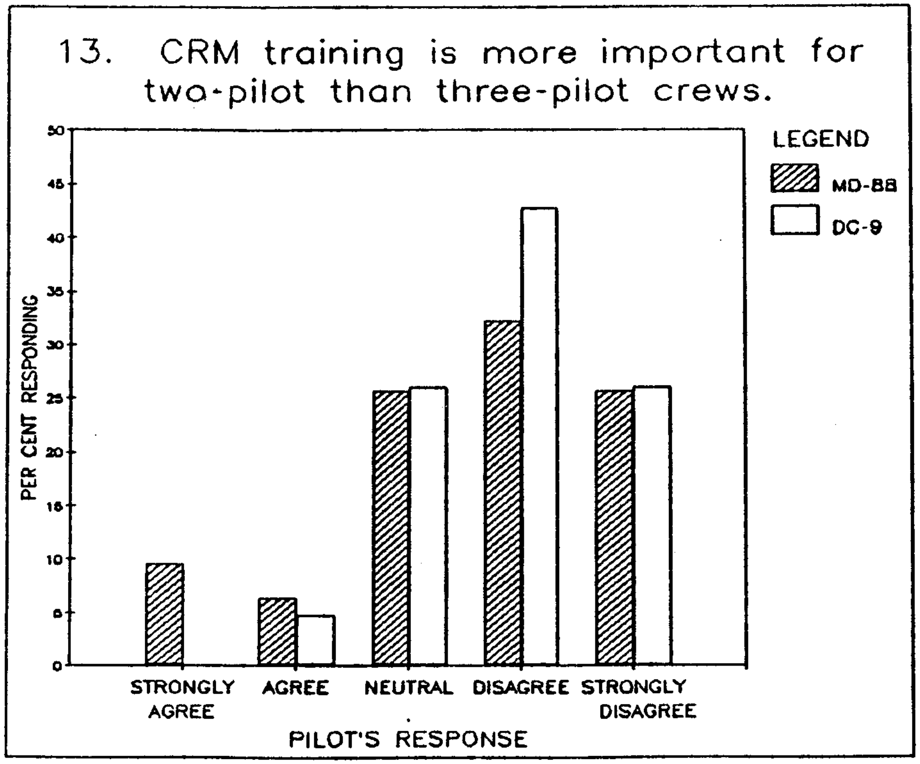


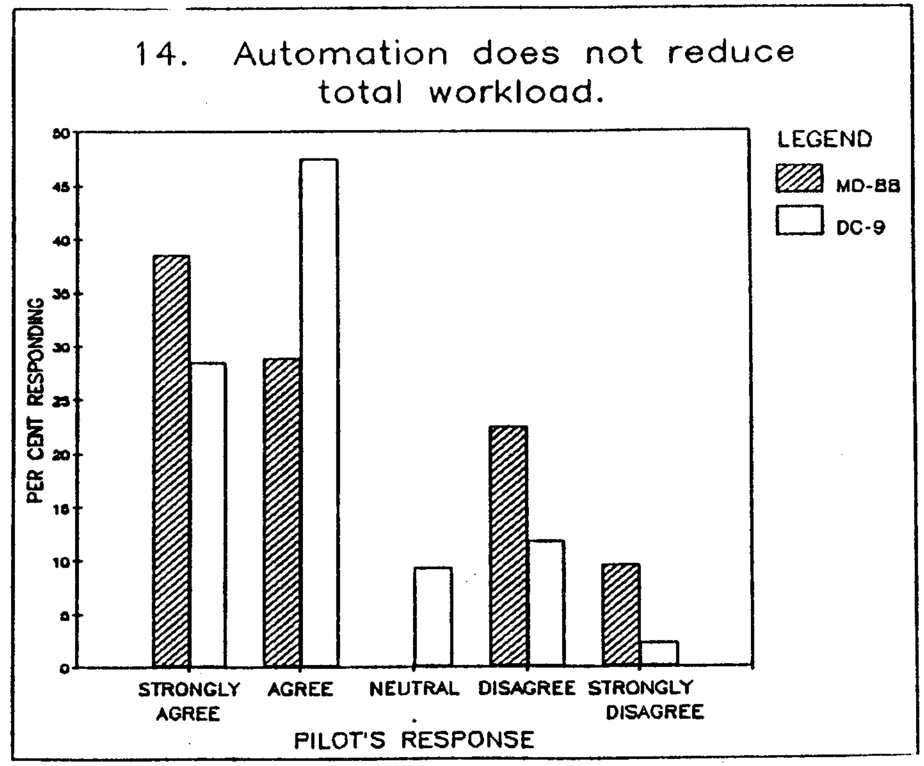
11. I look forward to more automation - the more the better.

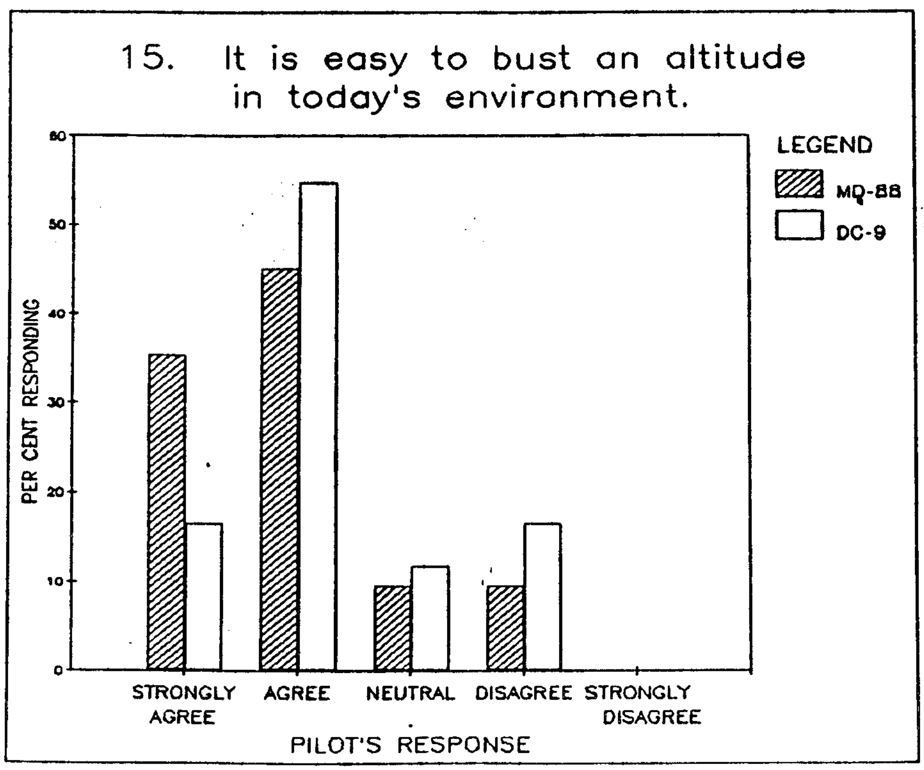


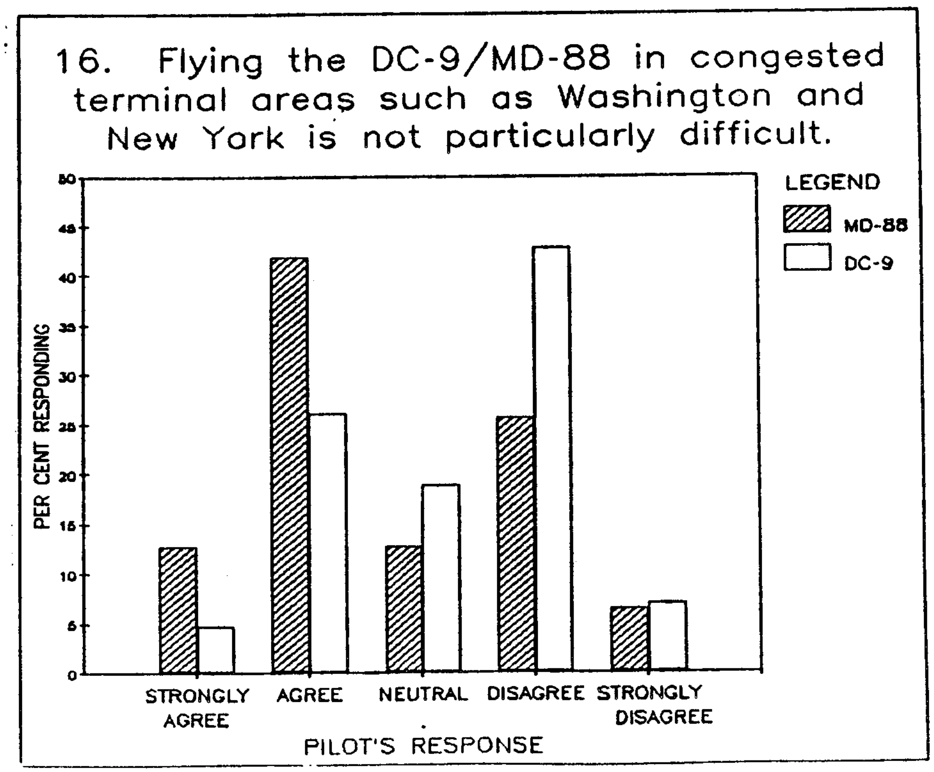
12. I have no trouble staying "ahead of the plane".



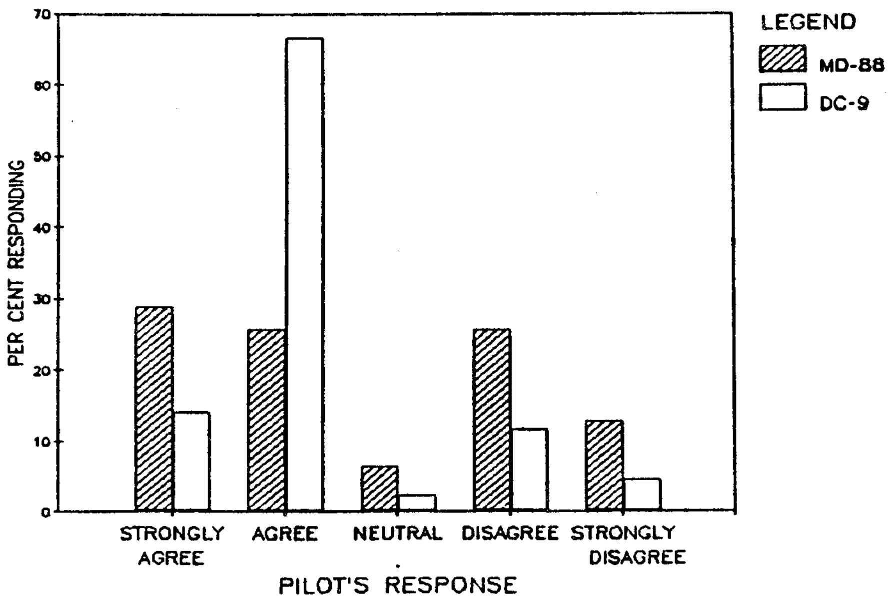

13. CRM training is more important for two-pilot than three-pilot crews.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
5
10
15
20
25
30
35
40
45
50
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE


14. Automation does not reduce total workload.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
5
10
15
20
25
30
35
40
45
50
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE

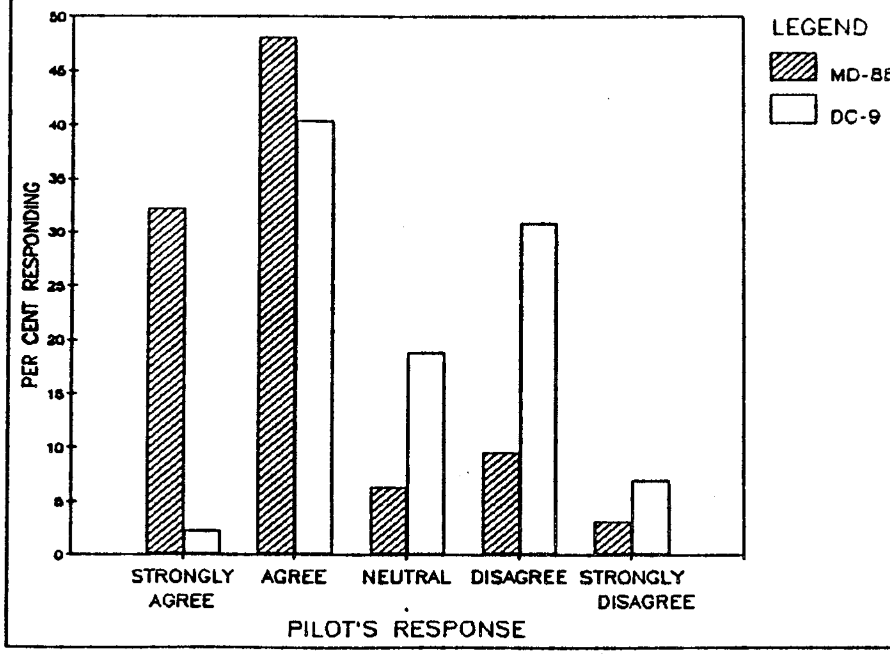

15. It is easy to bust an altitude in today's environment.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
10
20
30
40
50
60
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE


16. Flying the DC-9/MD-88 in congested terminal areas such as Washington and New York is not particularly difficult.
LEGEND
MD-88
DC-9
PER CENT RESPONDING
0
5
10
15
20
25
30
35
40
45
50
STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE
PILOT'S RESPONSE

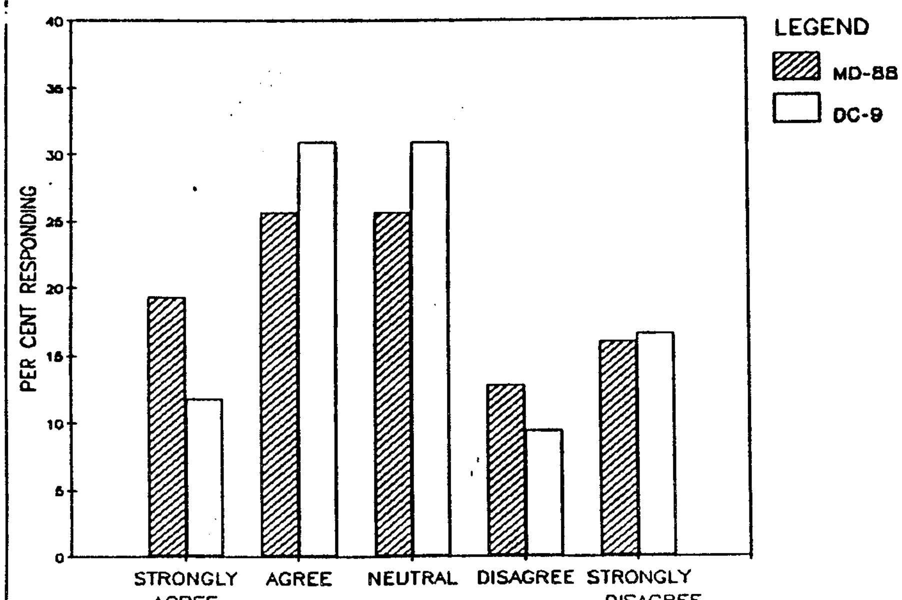
17. Training for the DC-9/MD-88 was as adequate as any training that I have had.



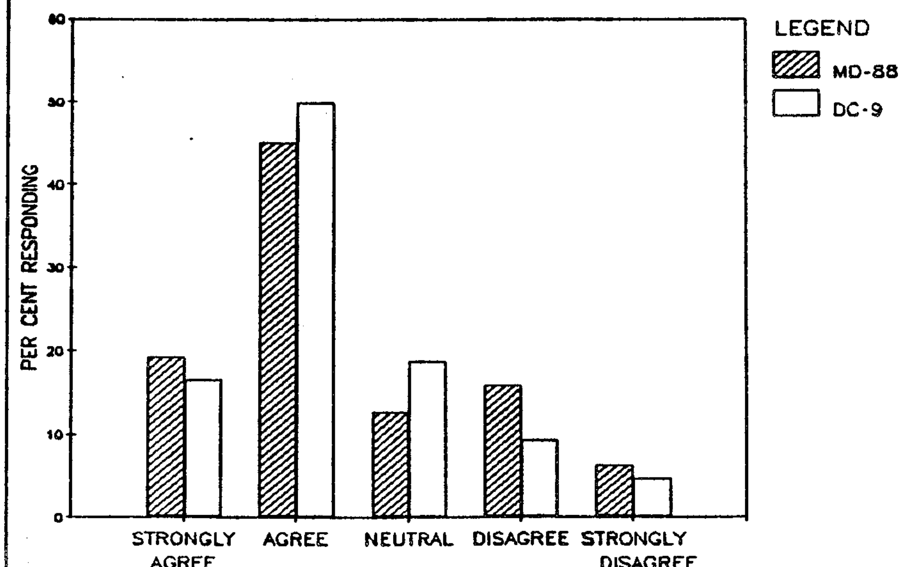
18. I am concerned about the reliability of some of the automation equipment.



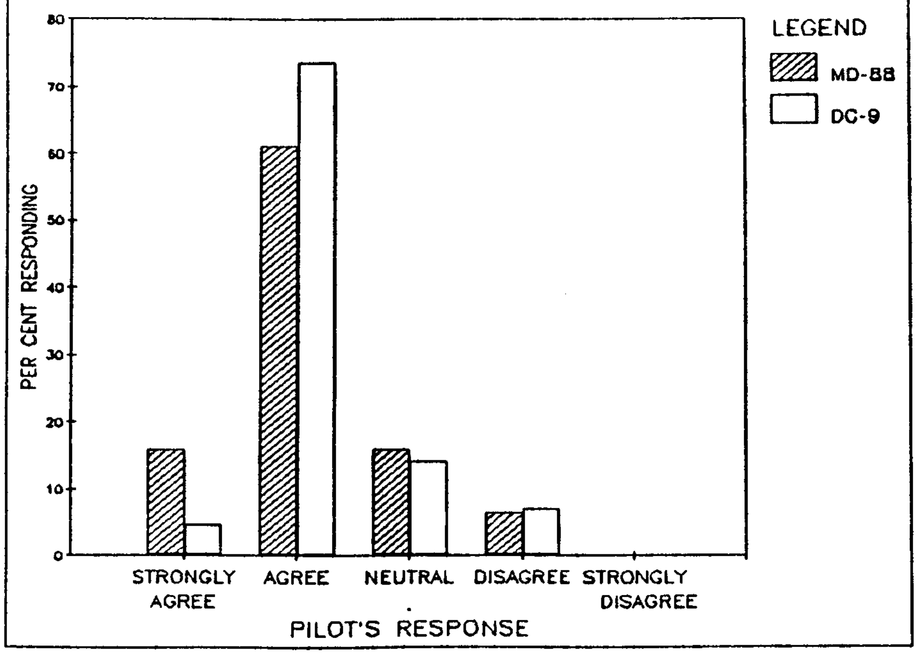
19. I prefer the two-pilot cockpit to the three-pilot operation.



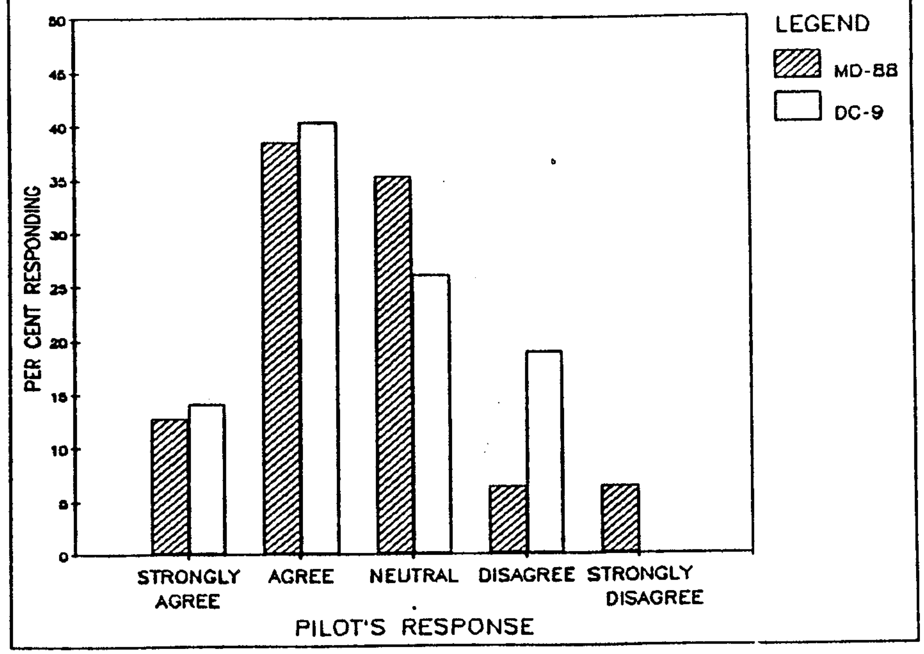
20. I am concerned about the lack of time to look outside the cockpit for other aircraft.



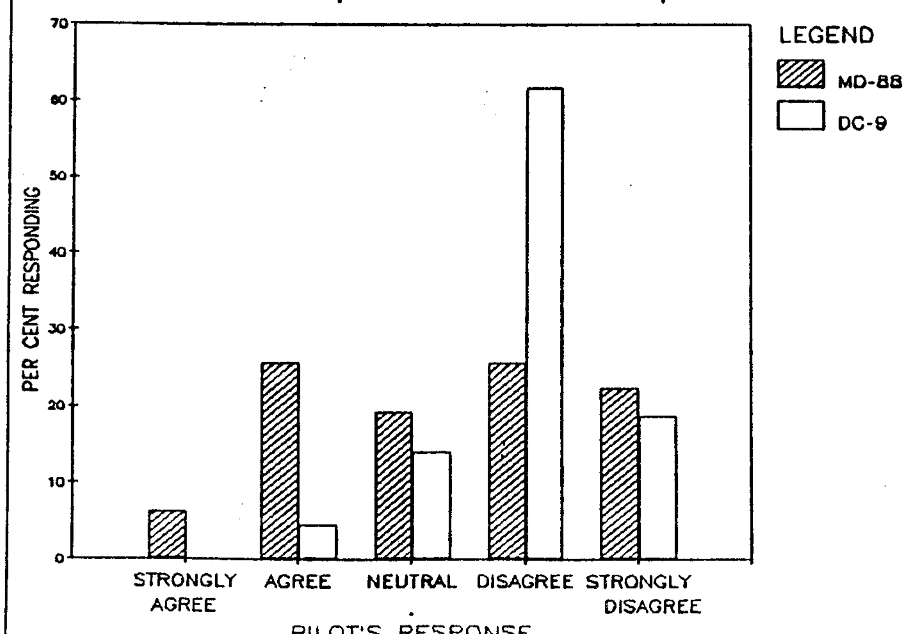
21. I use automation mainly because it helps me get the job done.



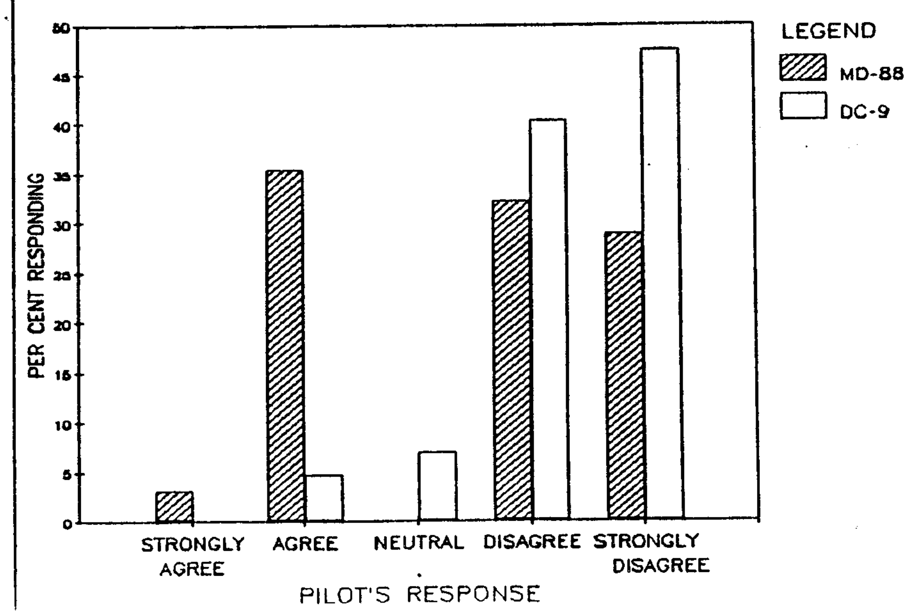
22. Our CRM training has been helpful to me.



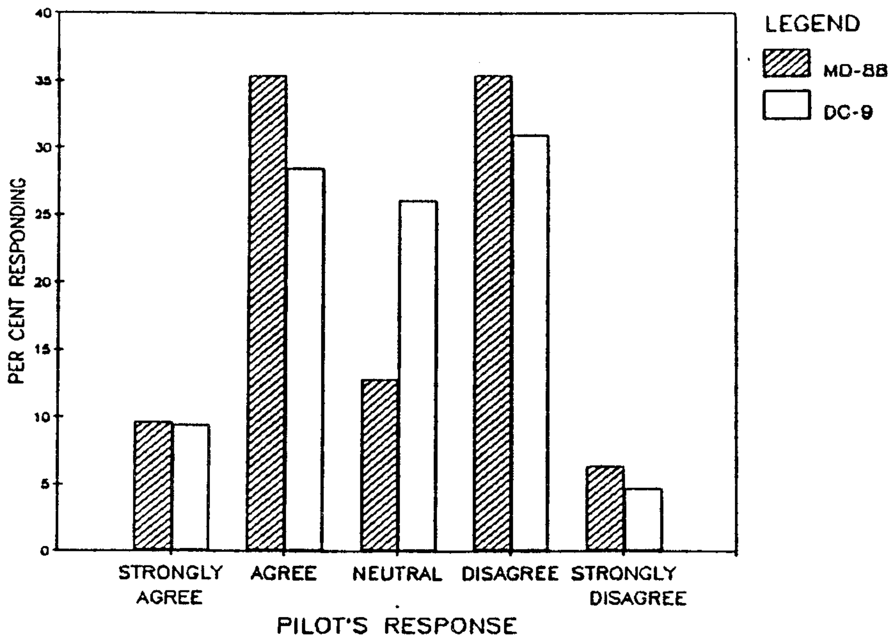
23. Sometimes I feel more like a "button-pusher" than a pilot.



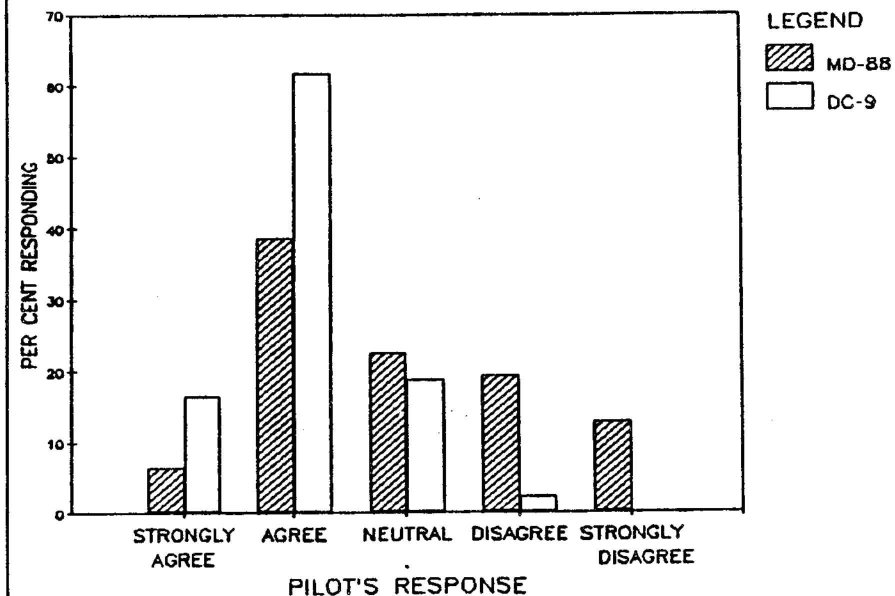
24. There are still modes and features of the DC-9/MD-88 automation that I don't understand.



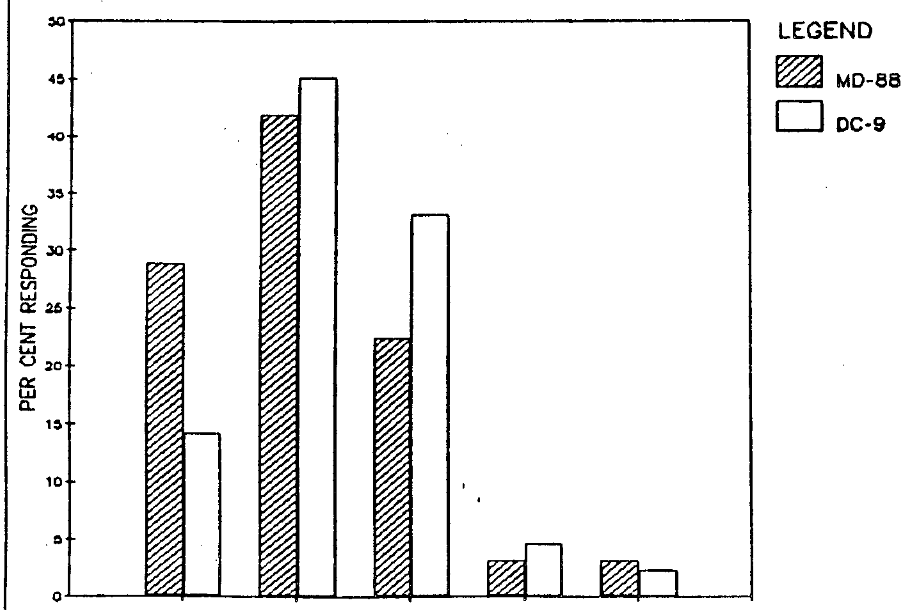
25. There is too much workload below 10,000 feet and in the terminal areas.



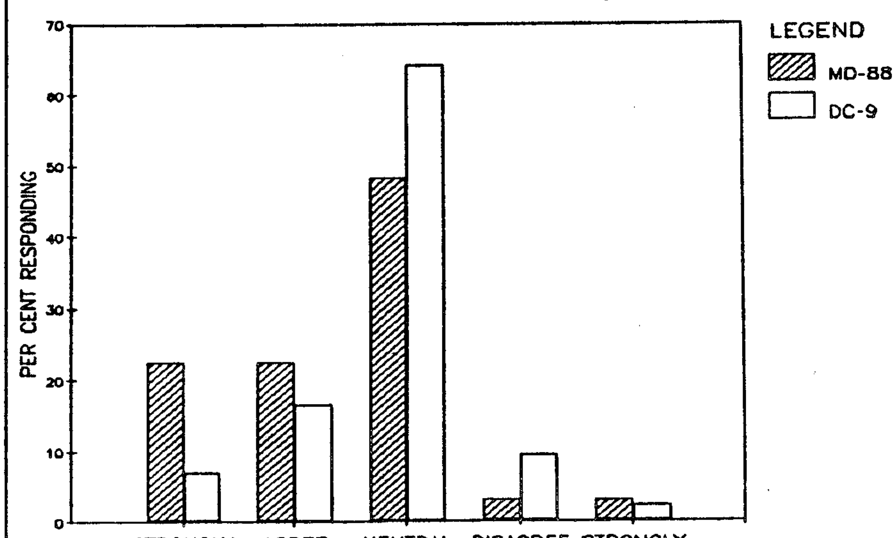
26. In the DC-9/MD-88, it is easy for the captain to supervise the first officer.



27. Autoland capability enhances safety.



28. Electronic flight instruments ("glass cockpits") are a big advance in safety.



C. FREQUENCY OF USE - INSTRUMENT APPROACHES

Volunteers were asked to indicate in blanks on the questionnaire forms the number of times in the last year (1989) that they had used various instrument approach modes: autolands (MD-88 only), Category III ILS (MD-88 only), Category II ILS, VOR, LOC and ADF. The data are displayed in graphic form on the pages that follow. No attempt was made to perform statistical analyses on the data, or to contrast DC-9 with MD-88 usage. These figures represent documentary data, for the purpose of reporting an estimate of the level of usage of various modes in the traditional and automated aircraft in daily line flying.

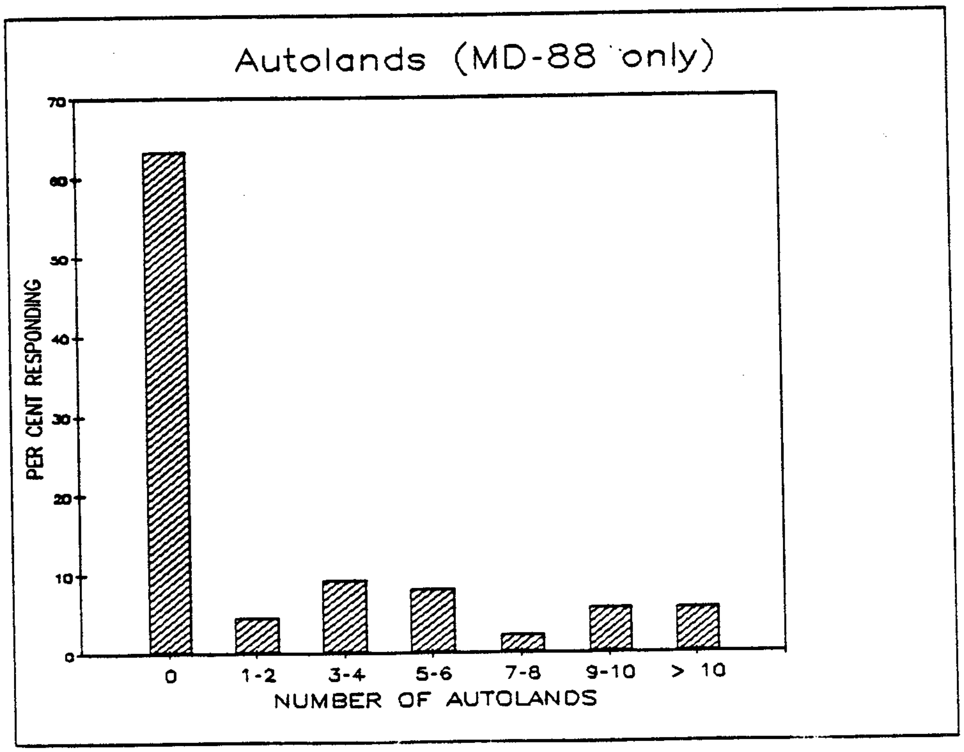


Figure V-3. Number of autolands in the last year, MD-88 only.

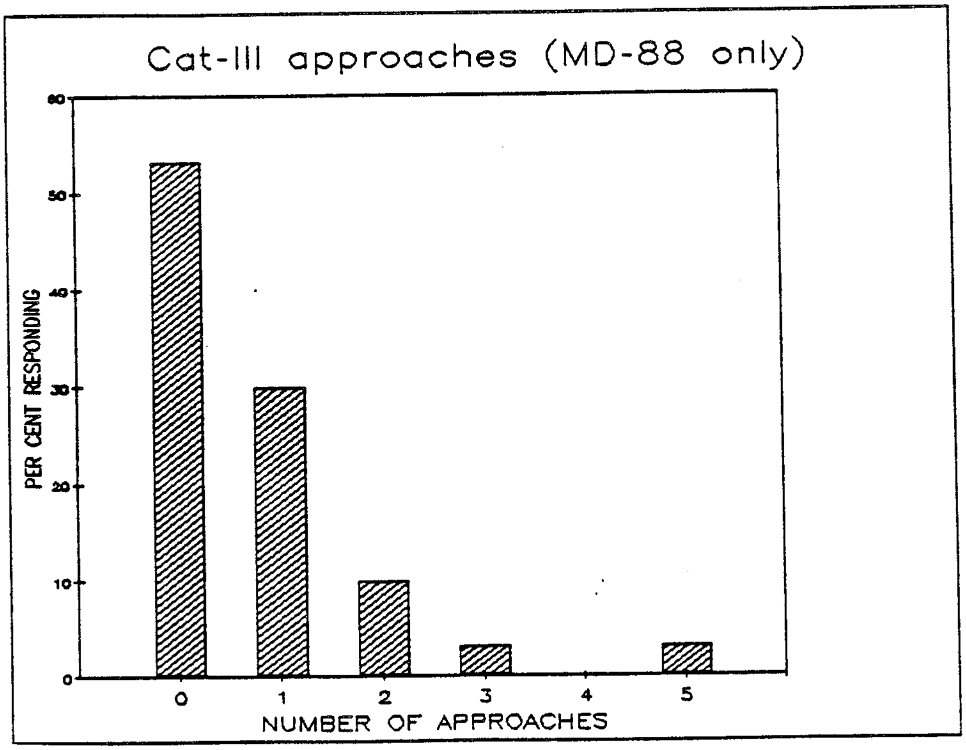


Figure V-4. Number of Category III ILS approaches. MD-88 only.

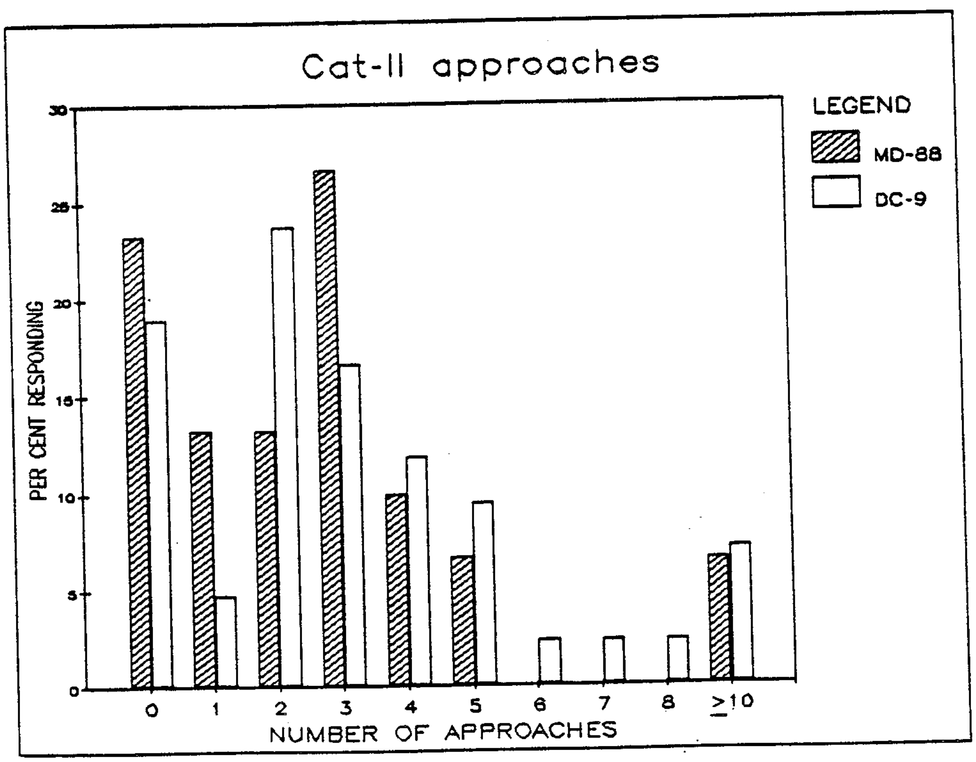


Figure V-5. Number of Category II approaches by aircraft type.

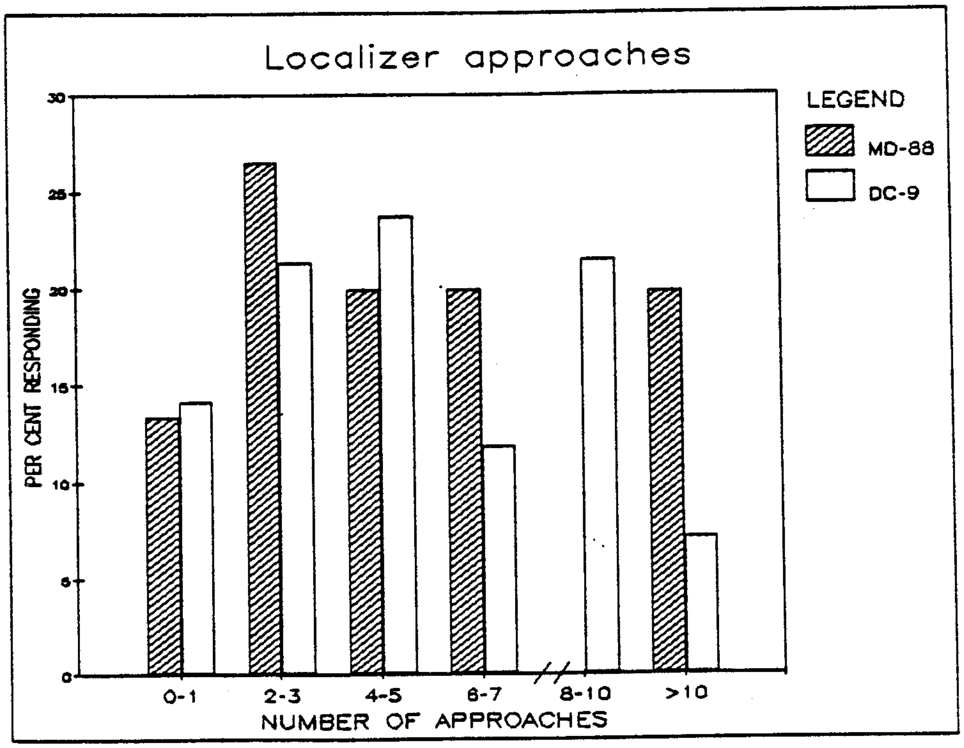


Figure V-6. Number of localizer approaches by aircraft type.

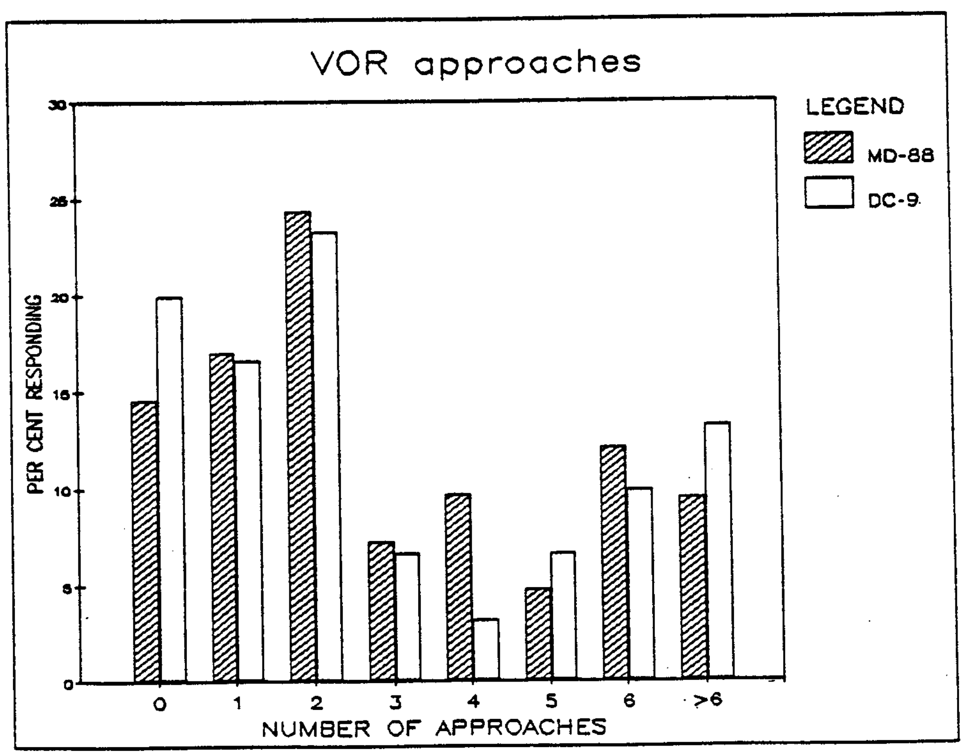


Figure V-7. Number of VOR approaches by aircraft type.

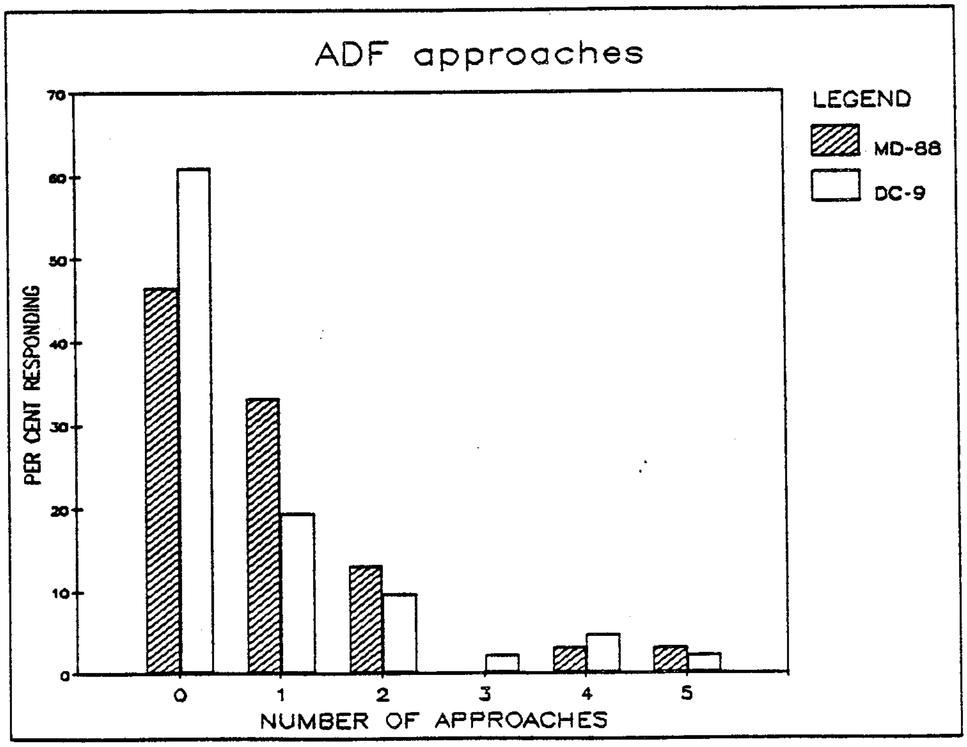


Figure V-8. Number of ADF approaches by aircraft type.

D. OPEN-ENDED COMMENTARIES

Data Handling of Open-Ended Questions

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 < >. On several questions, results were tabulated and presented prior to the body of direct quotations. The two-digit number at the end of each quotation is for cross-referencing.

We ask the reader to keep in mind that in interpreting the open-ended replies, most of the MD-88 pilots were new to the aircraft. This may explain some of the negativity, as it takes longer to be "comfortable" (word the pilots typically use) in these aircraft than in traditional aircraft (Wiener, 1985).

[1] Only answered by pilots who had flown both a traditional and a glass cockpit aircraft (MD-88 or 767/757)

1. Describe in detail an error which you made, or observed, in the DC-9/MD-88 that could have led to an incident or violation. How could it have been avoided? (equipment design? training? crew coordination?). Please describe specifically what occurred?

Responses to this question are listed below. To the greatest extent possible, they are verbatim from the volunteers' own words. In some cases minor editing was required.

Due to the prevalence of reports of altitude deviations ("busts") and other problems related to altitude acquisition and maintenance, the reports are divided into those that involve altitude, and all others.

The two-digit number at the end of each report is a questionnaire serial number, included for cross-referencing. In those cases where the respondent indicated that he was no longer occupying the seat which he held at the time of his volunteering for the study, the <u>new seat</u> is included in brackets.

The problem of "killing the capture" on the MD-88, which appears both in response to this question and to others, was first encountered by the first author in a previous field study, dealing with crew transition to the MD-80 (Wiener, 1985). The problem arises from the FMC logic when the pilots, intentionally or otherwise, change parameters while the aircraft is in the altitude capture mode, but has not completed the capture maneuver. A change in parameters, notably vertical speed or airspeed, may result in the aircraft departing from capture mode, and thereby failing to level off at the target altitude.

<u>MD-88 Reports - Altitude Deviations</u>

Climbing out of BHM we were cleared to FL 270. Before reaching altitude, we were cleared pilot's discretion down to FL 240. We rearmed the flight guidance system to FL 240, thinking that the airplane had already captured the FL 270 altitude. Actually we had disarmed the alt hold mode and the aircraft continued to climb to 28,500 before ATC and we caught the error simultaneously. We should have actually watched the aircraft level off and not assumed anything. Automation tends to lead to complacency which takes improved crew diligence and coordination to overcome. 09

Possible altitude deviation and accident. Climbing out set altitude window and observed it arm. Only due to other traffic were cleared only to FL XXX. We got busy with routing changes, and looked up and saw that we were going through our assigned altitude. I then noticed that the altitude window had changed to a new altitude which was not selected. Most people use the altitude window as the place where you ("symbolically") annotate your altitude. As a result of this incident and a few others, I now write down on a piece of paper the altitude assigned. So in this case, instead of decreasing workload, the result was the opposite. Another example -- all the automatic warning systems that are supposed to be there to catch the errors by the pilots such as take-off warning horn. I do not trust them to do their job, i.e. back me, the human, who is liable to make errors. 11 (L-1011 F/O)

The MD-88 has a unique altitude bust feature built into it, with the autopilot engaged, autothrottles engaged, and VNAV engaged. When the pitch window of the FMA is showing VNAV/LVL and you push the SPD/SEL button, the pitch window goes to VERT/SPD, not ALT/HLD and generally a 100 fpm climb or descent will develop. Most of us are aware of the problem and don't do that anymore, but design could prevent that. 12

Captain moved the IAS wheel while A/C was capturing altitude. It canceled the altitude hold and went 200 feet low before I called out altitude. 13

Level at FL 350, clearance to descend to FL 240 at 250 kts. IAS 250 was selected to descend instead of VNAV. Aircraft pitched up to get 250 kts. We busted through 35,400 before disconnecting the autopilot and then descended properly. Why not go into alt. hold or no climb until speed is dialed in and selected? The descent on the MD-88 still gets many new pilots in trouble, particularly those coming off the 767. 20

I failed to make a crossing restriction because I expected the aircraft (MD-88) to perform the descent. I had not programmed correctly and did not closely monitor because an F/A <flight attendant> offered us a meal. (There would be no opportunity to eat at the airport). Double problem: 1) scheduling (no provision for eating); 2) inappropriate monitoring of automated flight. 21

F/O climbing to 10,000 assigned altitude, VNAV and autothrottle on, autopilot off. He leveled at 10 without trimming nose down and immediately engaged the autopilot. As the A/P trim tried to trim nose down, the altitude increased a couple of feet, enough for the VNAV to sense above 10,000. This caused the autothrottle to advance to climb power, completely overpowering the ability of the slow autopilot trim to keep the nose down and hold altitude. The A/C pitched nose up and began a rapid climb. I caught it at 10,200 with the VSI indicated 1200 + fpm. Avoid by trimming before engaging the autopilot. 22

Captain's leg. Holding instructions given by ATC and captain decided to copy holding instructions as well as F/O. Aircraft was in a descent and when holding altitude given, nobody dialed it in and altitude bust occurred. Some has to "mind the store". If captain had been doing so or if he was hand flying the airplane, he would not have had the freedom to write instead of flying. 35

We were climbing out to cruise altitude and were given an intermediate altitude level off. We dialed in the new altitude. The plane was climbing rapidly, so the captain started to decrease the rate on the vertical window. This disarmed the altitude capture. I noticed it 200 feet below level off altitude, and the autopilot had to be disconnected so we didn't fly through the assigned altitude. <See also report No. 13 above, next report (62), and comment at the beginning of this section>. 58 (767 F/O)

Several altitude excursions due to manipulating vertical speed wheel on FGS panel after the altitude capture, which kicks A/P out of capture mode. 62

I feel that the biggest problem in the MD-88 is altitude excursions. I had three excursions and one fail-to-capture. Leveled off at 13,000 accelerating, F/O getting out an approach plate, and I was looking at radio panel when altitude alert went off. We were climbing through 13,300 when I disconnected and recovered. Second was in traffic pattern at BWI, downwind to base turn at 2000, and third was entering downwind leg at ATL. All three incidents traced to inadequate autopilot trim rate. 85 (727 captain)

<u>MD-88</u> <u>Reports</u> - <u>Other</u>

Arriving into ATL, a line of severe CB's were depicted on the ND as just west of the runways. A/C were landing to the east. I stated to the captain about 10 minutes from landing that I thought we should hold in the clear to the west of ATL until the CBs moved across the field to the east. I was concerned about landing with a tailwind if not windshear. With the CBs east of the field, they would not be a factor in approach or landing. The weather depiction on the ND was invaluable in forming my opinion. The captain, however, pressed on with the approach, and just prior to entering the weather the wind were reported as 280 degrees at 13 kts. (exceeding our tailwind limit). We executed a missed approach into a CB and tried to coordinate a turn back to the west in moderate turbulence. 5-10 minutes later the storms moved off the field and a very easy visual approach was made. More training in windshear avoidance involving geographical relationships of A/C, airport, and CB would help. The MD-88 ND/weather feature is excellent in displaying realtime weather scenarios. 10

On ILS final encountered severe turb and rain, executed a missed approach. Map failed due to no VOR update. We were told to hold at intersection, but couldn't find it due to map failure. (Note: intersection we were to hold at was off of an inoperative VOR). Then autopilot began having trouble holding altitude (we are now unsure of where we are and had to hand fly or monitor A/P very closely. Now both of us are trying to find where to hold, monitor the A/P, and talk to company and passengers. (A real mess). Solution: one fly and one do the rest - <u>and</u> <u>have</u> <u>maps</u>

out; communicate; inertials would help (no map loss). 14

Set up at night to do an ADF approach. The FMS was not set up for that approach, so I tried to build it myself. The FMS called for a descent before the ADF for final approach. Going to MDA early could have been disastrous. We need IRUs <inertial reference units> and complete lists of available approaches to each airfield in FMS. 15 <Note: starting in the fall of 1991, all of the company's MD-88/90 series aircraft will be delivered IRU equipped.>

Landing at DCA, River Approach, F/O flying. As he called for before-landing C/L, I lowered gear, flaps, read C/L, then when I was able to look outside again he had flown past R/W 18. We could not get back to the runway, so we landed on 21 (with tower's OK). I would avoid this happening again by: 1) a good briefing; 2) I do not take my eyes off of runway during C/L (or any other time). Of course a three-man crew would have avoided this problem, but as I indicated earlier <attitude scale>, I am neutral on that subject. 18

We were cleared to hold at an intersection and the FMS depicted holding was similar, but not same as depicted on the hold depicted on the STAR. I let the FMS (LNAV) start the holding pattern before I caught the difference. Luckily the initial turn was in the same direction. I should have been more careful - the copilot too. I was flying but he was engrossed in the FMS hold as he had never used LNAV for a hold. Never trust automation without checking it out first. 19

We were approaching Austin from the east north east in absolutely clear and visibility unlimited weather at night. We were heading straight for the SPICE outer marker and were anticipating a visual approach to 13R. Both the F/O's and my radios were tuned to the 13R ILS frequency and our courses were set properly. Both of our nav displays were in the map mode. In other words we were doing everything right - ILS armed to capture. The controller cleared us for the visual approach and asked us to keep the speed up and keep it in tight as much as possible for spacing on other landing traffic approaching from the northwest. I complied with his request and turned base leg inside of SPICE OM. I started my turn to final, looked out of my window during the turn and runway lights and VASI-L and rolled out on that runway. The tower controller advised us that it appeared to him that we had rolled out aligned with R/W 17. A quick glance at the instruments and I knew he was correct, and immediately rolled to the right and back to the left and was in the slot for 13R and landed without incident. The controller had just saved me. Both runways have VASI-L but there are no approach lights to 17, something we both should have picked up immediately, but didn't. Also, there are usually some bright lights just south of and 1-2 miles west of the extended centerline of R/W 13R which illuminate a number of ball fields and some tennis courts. I usually look for them to assist me in finding the approach end of runway 13R. I don't recall seeing them that particular evening. I normally change my nav display to full compass rose when intercepting the localizer whether operating IFR or VFR. I did not get around to doing that this evening - probably because I was using the map to turn inside of SPICE. This could have been avoided had I refused to cooperate with the controller's request and flown an approach right over the SPICE OM. I don't allow controllers to talk me into doing anything I am not comfortable with and really had no particular concerns with this request. I later called for our next ATC clearance and asked that controller to pass along to the tower controller my gratitude for his actions. The F/O seemed a little surprised that I would do such a thing as admit to my error over the radio. I would like to think that either the F/O or I would have discovered the error before landing on the wrong runway, but since the controller was the first to catch it, thankfully we'll never know. 44

I programmed FMS with one piece of information (a holding pattern) but did not execute it since it was for my own information only. Captain at a later point programmed something on his FMS. The Execute button illuminated on both FMSs due to my arming the system, and he hit the button. It inserted my holding pattern into the flight path even though we were not cleared and aircraft started a turn. Easy catch, but other goof-ups wouldn't be as easy. Better CRM <cockpit resource management> would have cured this one. 55

Tuned wrong loc frequency for 8L in ATL. Did not identify the LOC due to conditions - VFR daytime. Armed ILS and assumed autoflight would capture localizer. I realized something wrong when A/C depiction on nav display showed us going through the localizer. This could have been avoided by: 1) have PNF verify the loc frequency; 2) identify the nav aid regardless of the weather; 3) ensure at least one pilot is in arc mode; 4) not relying on the autopilot to the place where you become complacent. 56

On approach to BHM R/W 5 with both radios tuned to the ILS, the F/O was navigating in the map mode. We were cleared for the VFR approach and the F/O continued for the runway displayed on the ND, which could have put us 1/2 mile south of the actual R/W 5. When NAV 1 and 2 are tuned to the ILS, the FMS no longer accurately updates its position and goes to dead reckoning when ILS's are selected, and the switch <ND display mode> should be in arc or compass rose, not map! This is one of several such incidents. The AHARS should be replaced with IRUs as in the 756/767. 59 (L-1011 F/O)

Slowing from 340 kts. at 11,000, then being cleared down to 8000. F/O began descent using IAS mode, selecting IAS 250. He did not notice that the trim rate was too slow to bring the A/C speed back to 250 below 10,000 until we could select alt hold and extend speed brakes to comply with speed restriction. I was distracted by complying with route changes issued along with altitude change - direct intercept input to FMS, and frequency change at the same time. Training to complete airspeed change prior to selecting lower altitude might have helped. 60

The captain loaded the flight plan into the FMS for a flight from HOU to CVG. The fix just prior to IIU (Louisville) was MYS (Mystic), but the captain saw the unfamiliar MYS on the flight plan and entered the familiar MSY (New Orleans) into the computer. I caught the error and pointed it out to the captain. 83

DC-9 Reports - Altitude Deviations

A very eager F/O took the initiative to set in assigned altitudes and even thought he was PF, and as PNF our procedures call for me to acknowledge on radio, then set the alt alerter. After several instances of this F/O quickly setting it himself, we were set up for me to assume he would set it the next time. He was busy and did not and we busted an altitude. These new F/Os should be told in training that their performance is not predicated on eagerly doing "extra" tasks. 7

The most common error is the failure to level off and maintain proper altitude. Too many times during the last 1000 feet of climb or descent distractions such as "heads down" in the charts, frequency changes, etc. cause altitude deviations. There always seems to be a frequency change or runway assignment given about level off time. 8

Altitude bust. Heard the AAD in my subconscious, however went 1000 feet below my assigned altitude. Copilot could have caught it. It should have a voice <alert> that says "Altitude, Altitude". 36

While cruising at 31,000 the autopilot was inadvertently turned off or kicked off by itself and the A/C began a slow descent. We noticed it at about 250 feet below our assigned altitude. 48

After takeoff the F/O hand flew the aircraft to 10,000 feet, leveled off and engaged the autopilot. There was turbulence, and scattered buildups in the area. We also received a frequency change while attempting to avoid the weather. I observed the airplane to be descending toward 9,500 feet and pointed this out. This is not an uncommon error. It could be prevented by an "altitude capture" mode. On the DC-9, when the A/P is engaged, the vertical speed existing at time of engagement is maintained. 67

Altitude excursion seems to be the problem on the DC-9. Fairly frequently the PNF prevents an altitude excursion and twice I had been involved in missing an altitude, once in climb and once in descent. The scenario seems to occur when the PF and PNF are distracted by separate events/problems and both lose altitude awareness. The autopilot is engaged and seems inadequate to capture the pilots' attention. The 1000 foot prior <to assigned altitude> call helps, but is not always made. Perhaps the PF should fly the A/C after the first AAD alert until level off; no looking at charts, talking on separate frequency from PNF, talking to flight attendants on the interphone, adjusting radar -- some of the common distractions. 82

Altitude bust descending on initial phase of descent during approach briefing. It was caught after we were 300 feet low. Better crew coordination and "flying the plane" would have helped. I suppose auto altitude capture would have caught it, but this is no substitute for staying heads up.

<u>DC-9</u> <u>Reports</u> - <u>Other</u>

During one of my first months on the line I aborted a takeoff just prior to V-1. The reason I aborted was because of an autothrust disengage light illuminating. This is a system rarely used on a DC-9 and turned out to be a nuisance light. Looking back it was an unnecessary abort, however at the time I was concentrating on the takeoff and waiting to hear the first officer call "V-1". The light in question is red and to me, red is bad. I gained view of the red light from my peripheral vision and executed an abort. I feel this is poor design. It may be necessary for the light to be red and the system is rendered inoperative on the ground by the ground shift, however the nose strut begins to decompress near V-1 and the aircraft goes to the flight mode thus enabling the system on the ground. Granted this was probably just a fluke, but it caused a high speed abort. 2

F/O didn't communicate during arrival STAR. He twice dialed in the wrong course or got distracted with speed control and didn't update or fly published course. Since I'm a fairly new captain (eight months), I've watched things very closely to make sure items are corrected before they cause a problem, and have had good luck so far. 3

Victor airway on arrival had large left turn to station (about 120 degrees). Clearance to cross intersection at 10,000, F/O read intersection at 67 DME when it was really 37. We had confirmed outbound course, and intersection at 10,000, but not the distance. If I had not questioned the descent point we would have busted the altitude at the intersection. A glass cockpit would have avoided this: distance to waypoint readout, visual display of waypoint, green arc <projection of point at which target altitude would be obtained>, and FMS display readout. 5

This occurs almost every flight into DFW or ATL when it is the F/O's leg. I try to get a gate and Approach or Tower will call and I'll miss their call. The company wants us to call about 10 minutes out in DFW and closer at ATL. I know how to avoid this: by calling for a gate when we are on the ground. I used to do this, but I was told, "Earlier." DFW will usually say "call when on the ground." This <early call> was one of the things the company said it would not require when we first started flying the DC-9. 6

Captain's leg on an early departure after a very short layover. No other traffic into ATL and 3 previous controllers told us to keep speed up. Neither of us noticed that we were indicating 340 knots at 8000 feet, until Approach called us and asked our speed. I was new to the F/O seat, and failed to notice that the captain didn't slow at 10,000. I was studying the approach. 24 [767 F/O]

> <Note: the following incident included on the questionnaire took place on an Air Force DC-9 (C-9), which is outside of the scope of this study. It is included in this report simply because it is an interesting, very critical incident.>

While in the Air Force, on the eighth leg of an eight-leg day I had a new copilot in the right seat. He was tired and overloaded, so he was sitting back sprawled out with his left hand resting on the flap/slat handle (fairly common position). We finished the checklist and took off on the roll. As I called for gear up, his left hand stayed on the flap/slat handle and he brought them up. Fortunately the DC-9's flaps and slats move slowly, and I reached over and extended them. The DC-9 family has a problem in its design when the copilot is seated comfortably usually rests his hand on the lever. In my opinion the design lets people get comfortable in a position that when they are tired they move the lever that is most convenient. Since then, when I am tired, I remind myself of what can happen. 28

We were on a standard arrival to IAH and were supposed to intercept a radial inbound to a VOR from an intersection. I, the F/O, set the inbound radial in my course select window and simultaneously told the captain what the inbound course was. He was still tracking the outbound radial from the last VOR. He acknowledged me, but did not set the new radial in his window. I failed to notice after about two minutes that we had passed the intersection and the captain was still tracking the outbound radial. I told him that we needed to turn back to intercept, just as ATC called us and asked if we had intercepted the inbound course yet. If the captain had put the new course in his window, or monitored my PDI, he would have noticed that we had passed the intersection. If I had watched him closer, we would not have flown past it so far. 29

Waiting to cross an active runway, Tower told us, "proceed straight ahead across runway at B, aircraft taking the active will hold for you, expedite across, contract Ground <121> .7 when clear." The captain pushed up the power, and I looked in my Jeps to see the Ground frequency. Well, Taxiway B split and we were expediting straight. The captain kept looking left at the aircraft holding for T/O, all lights on, and my initial call to stop was not heeded, and I ended up skidding us to a halt before we taxied onto the grass. We ended up less than five feet (more like three feet) from the grass. A happy ending, barely. How to avoid: 1) always look where you're going; 2) crew coordination - listen to your crew; 3) communication - better terminology from the tower (no "straight across"). 32

I was recently cleared HMV, FLM2 arrival to CVG. In error, I flew HMV direct FLM, CVG. Listening closer would have prevented this. However, if the DC-9 had a "glass cockpit", the proper routing would probably have been entered into the FMC, which would have prevented this kind of error. 39

Last leg of a long day - dark, tired, failed to notice on flight plan that we were tankering fuel to Daytona Beach. I knew that Daytona Beach was (at that time) a cutback runway, but didn't put two and two together until I was half way there. I looked at flight plan a saw a "do not tanker" message. I finally realized that I had missed some information. I checked with flight control and found they had erred by dispatching aircraft with extra fuel. Checked as to runway length vs. our weight (we were close to max landing weight). Flight control provided numbers as the book in our cockpit was so conservative that I would have been too heavy to land with zero fuel on board! Once we began thinking like pilots and not like bean counters I realized that we would have no trouble landing a DC-9 on the runway available. However, to cover ourselves we got all the exact figures and landed. Landing was uneventful, except I made the landing although it was F/O's leg. He was glad I did. This made me realize I could have pushed his limits if I had told him go ahead and land. So it worked out, but I check the figures now every time, tired or not. 40

In the DC-9, the crew inadvertently tuned the Falmouth VOR (117.0) instead of CVG VOR (117.3) and began tracking inbound. It occurred during a time of heavy workload during descent. A glass cockpit display and FMS would probably have prevented this event. A third cockpit member to handle ATIS, gate assignment, cabin PA's and checklist reading, might have also prevented this occurrence. 41

This error occurred at Hopkins International Airport in Cleveland. We were parked at Gate B-17 and pushed back at a very slow traffic period. We were the only aircraft moving on the field. The active runways for takeoff were 23 R/L. After we pushed back the captain started the first engine and left the second one for me to start while he taxied. The time it took to get to the runway was minimal. I coordinated ground clearance and takeoff clearance on the radio. I also accomplished the "after engine start", "taxi", "delayed engine start", and "before takeoff" checklists. It was my leg to fly. By the time I finished all of this and got my head out of the cockpit the captain stood up the throttles and gave me the aircraft for takeoff roll. As soon as I started to advance throttles

Cleveland Tower told us to abort takeoff because we were on runway 28 (of which 6000 feet remained). The Tower seemed ready for this mistake - I presume it had happened before. If you look at the runway layoff there's concrete everywhere. 46

Dialed in wrong course for LOC/ILS approach and unable to get flight director and autopilot to fly the same approach. F/O and myself visually cross-checked each other to make sure we had the same course set in. 49

1) Using autopilot turn knob to correct to a new radial, thought knob was in detent, but we were actually in a shallow turn. 2) Holding at marker awaiting ILS approach, strong winds, no DME, cleared for app and let down from 3000 to 1800. Asked to make 360 degree turn for spacing, then cleared for approach. A lot closer to marker than we thought, resulting in large angle of intercept inside marker. Times like that would be nice to have DME or FMS. 52

Failed to set brakes on engine start. A/C rolled toward terminal. Would be avoided by stricter adherence to checklists and crew coordination. 61

Copilot landed in ATL with 5-kt. tailwind and rain. Landed in landing zone on a speed runway, 8L. I told him, "you reverse and I'll brake (light rain)." Went to make high speed turn off and the aircraft started sliding sideways. I got in straight and stopped it on the high speed. Later I thought I should have gone to the end of the runway. Talked to a 767 captain that landed behind us and they actually had a 15-kt. tailwind at 20 feet. He called the Tower and told them to turn the airport around before someone got hurt. When I went back out the airport was turned around. 63

On a back course ILS into Columbus, Georgia, at night, IFR, weather at minimums. As a new F/O I forgot to put the proper course in the PDI prior to the approach. It was still set on the previous direct heading to the Columbus VOR. I was paired with a captain in his first month. When BL mode on the flight director was selected, steering was given to the course in my PDI instead of the correct back course. The captain was flying and followed the flight director. There wasn't any ADF available to back up the approach, so he descended on a course 50 degrees off of the proper one, centering the flight director steering. It was some time later that the discrepancy was noted. Had there been terrain or traffic and the error not detected, an accident or incident could have resulted. This could be avoided by approach checklist emphasizing placing the proper course in the PDI. 69

Misread the outbound heading on a jet airway where two jet routes converged over a fix. The wrong heading was taken. 72

Autopilot engaged, instructions to slow below clean speed. When we lowered slats autopilot did not retrim rapidly enough and A/C lost 100 feet with continued descent. Deactivated autopilot and recovered manually. 86

We were filed over two VORs and then out a specific radial from the second VOR. The two VORs are less than 30 miles apart, and differ by only 1 digit <.2 mhz.> (116.7 vs. 116.5). The captain was flying and had switched my nav radio to a separate VOR at the destination field for another reference. We started out the radial from the first rather than the second VOR as filed. Pertinent factors included a short (pushed) flight, the close proximity of the two VORs, and the similarity in frequencies. I would recommend that if a crew member is going to change the other crew member's nav radio, that he should tell him. I would also recommend that VOR stations so close should differ in frequency by more than one digit. If this is not possible, then I would recommend that the first digit <1 mhz.> be varied, e.g. 115.7 vs. 116.7, instead of 116.5 vs. 116.7. <No serial number - this report submitted after database was completed>

2. What can you say about crew coordination on the DC-9/MD-88? What areas of crew coordination/communication need improvement?

MD-88 Crews

With the many options available as to how you want to use the different gadgets, it's important to tell the other guy what method you are using and what you are planning to do. F/O 9

I like the policy of "my leg I'll do the FMS, your leg you do the FMS." With the autopilot off, then the PNF programs the FMS/FGS. However, this policy is only moderately followed. If I am flying and the captain programs the FMS, I am not always positive what mode of operation exists (i.e. crossing speeds and restrictions, etc.). If the captain updates something for me, I appreciate it if he verbally tells me what he did, at the least. F/O 10

MD-88 crew coordination - the pilots are usually too busy if anything comes up from the cabin during climb and descent. Any call in a terminal area can be a real distraction or possible problem. We also have a hard time building crew rapport due to switching flight attendants so much. We need to improve communication between cabin and cockpit crew. Adding much more information to the required briefing is not the answer. Already the captains are spending time <with flight attendants> that should be used to help in the preparation of the cockpit, to the point where the F/O has to do everything if you are to leave on time. You need to keep the entire crew together and have a briefing when you check in for the rotation. Another factor is that some captains who come off three-man crews don't realize that you have to operate as equals when it comes to workload. During emergencies crew coordination is imperative. You are constantly on the edge of the abyss of task saturation in a busy terminal area. In most cases the F/O cannot go back to check on the problem, and must take the word of a person who may not have the training to give a good assessment of the nature of the problem. It's very easy to have both <pilots> working on the problem and not have one guy maintaining aircraft control. F/O 11

I think it's improving, but there is significant room for more improvement. Sometimes I (as F/O) feel a real need to drag game plans (for abnormals) out of the captain. He should be telling, not me asking. Also many captains have their own set of procedures which tend to impede communication until you have customized yourself to him. Sometimes communication can be impeded by concern for FAA and company procedures. More concern for covering your rear than the big picture. F/O 14

Coordination is good, CRM training is making it better. What is good for the goose is good for the gander. Captains are not God. If an F/O must do certain duties a particular way, then all crew members should do it the same way. I see too many captains who believe "do as I say and not as I do." They will enhance communication, respect, and a better cockpit working environment if they adhere to procedures. F/O 15

I think the captain sets the pace. I try to maintain an environment that is open and free to communicate. Judging (albeit subjectively) from the results of recent trips, it appears than open communications pay off in smooth and hassle-free trips. F/O 17

Coordination is good. But there is too much talking (climb power, VNAV, flaps up, slats up, bank angle 25, etc.). Reduce some of the requirements that must be said out loud. Capt. 20

Crew coordination is this aircraft depends on each crew member advising the other continuously of what they're doing. It is so easy to say "just do it" yourself because the other person is busy on the radio, etc. I don't always verbalize all my actions. As captain, I find that I can't watch all that the F/O does because of my own workload. Capt. 21

I've seen too many occurrences of both sets of eyes glued on the FMS computer, when one set should have been monitoring the flight and airspace. F/O 42

Crew coordination on the 2-man crew is excellent -- far better than the 3-man crew. There is less coordinating to do. As far as the rest of the crew - flight attendants - are concerned, elimination of this ridiculous "sterile cockpit" rule would be a big step forward. We often hear the flight attendants talking to each other over the interphone system about some problem they have and they are trying to decide whether or not they should call us to advise for fear that we will get angry with them for violating the sterile cockpit. Capt. 44

Coordination is normally good, however, when one pilot is occupied with one duty (e.g. making a PA to passengers, obtaining ATIS on arrival, talking to company ramp to find out gate) the other pilot is unmonitored. Thus if he initiates an action or copies a clearance incorrectly the "out of the loop" pilot will never catch it. All the automation in the world won't catch that. Main area of crew coordination that needs improvement is one pilot verbalizing his future intentions or plans to the other so any errors in the plan can be caught quickly. F/O 55

Overall I feel that coordination is good on the MD-88. I feel that coordination is a lot better when both pilots have been on the 88 for a while and fully understand the full capabilities and limitations of the FMS/autopilot. F/O 56

Greater standardization is needed. The complexity of the autoflight system means an endless variety of techniques are used. Pilot disagreement on methods used is a constant problem. CRM doesn't really address the problems we have. Capt. 57

You need to assign jobs so both don't get tangled up trying to do different things on the FMC. F/O 58

Having flown both the DC-9 and the MD-88, I realize a great deal more communications is necessary on the MD-88. More attention has to be paid to the details of operating this aircraft. There are too many ways this aircraft can turn around and bite you. Never alienate your help: he may not be there when you need him. On the DC-9 you could be a one-man show if it were necessary. Capt. 59

I think crew coordination in the MD-88 is good. Following company procedures, common sense, and common courtesy, when combined allow for good coordination in the cockpit. Bringing coordination with the flight attendants in better focus by better briefing and better understanding of what services are being offered on a particular flight could stand improvement. Capt. 60

Too much talking is required when hand flying, since all manipulation of the nav and FGS panel is supposed to be done by PNF. F/O 62

Briefings are important, particularly in bad weather. You need to communicate what automation you intend to use, and when you go to manual control. Further, when ATC changes a route or instruction, the PF should command how to reset the computer, or if to use it at all. Capt. 77

DC-9 Crews

F/Os need to talk more about what they are going to do next, i.e. "...at 14 DME I am descending to 10,000 feet and turning right to 296 degrees outbound." They are slow and tend not to communicate their intentions as much as I would like. Capt. 3

On the whole crew coordination is excellent. If there should be any areas of improvement, it would be the standardization of procedures and information in line flying; and more emphasis on the F/Os input being desirable, even required as part of the communication loop. Capt. 4

There has been great improvement on the DC-9 in the past year in crew coordination. The CRM program has put in place the idea of the open cockpit. Capt. 5

Crew coordination is OK, but not great, but OK. I don't like having the PNF moving the gear and flaps for me. Some times he doesn't hear me or sometimes I want them now and not later. If I say what I'm going to do and then do it, it seems OK to me. To retract the gear for the F/O, I have to reach all the way across the throttle quadrant and block <the view of> the instruments as a critical time. Capt. 6

The DC-9 is very straightforward with little/no automation, so crew coordination goes to basics...more a matter of personalities than equipment-related tasks. These new/inexperienced F/Os should have it stressed to them that extra eagerness is not necessary to prove their worth (see above) <See comment No. 7, Question 1>. The importance of PF/PNF duty assignments is no less in this cockpit than in the 757. More is not better for an eager F/O. Capt. 7

Generally DC-9 crew coordination/interaction is excellent. Although I was a skeptic at first, the use of earpieces/headsets has greatly improved crew-crew and crew-ground communications, but reducing the "was that for us?" by about 90%. Capt. 8

Crew coordination on the DC-9 is generally pretty good because the cockpit is small and it's easy to monitor each other. Company procedures are adequate. Each captain needs to specifically brief each F/O he flies with on his individual techniques. F/O 29

Generally speaking crew coordination is satisfactory. This is one area that could be improved. The PNF should not change the nav radio frequencies without notifying the PF. The PF, whether he is captain or F/O, should be in charge of the nav radios. F/O 30

MD-88 crew coordination is more critical due to the higher workload than on the DC-9. Trying to hand fly an MD-88 while telling the other crew members how to program the DFGC/FMS is particularly labor intensive and clearly diverts both crew members' attention away from maintaining a safe lookout. F/O 33 [F/O MD-88]

I think it is basically good. Improvement could be made though, by each crew member flying verbally informing the PNF of his actions. This should be done on a continuing basis. I am referring to such things as heading being turned for navigation, altitudes being vacated, crossing restrictions which are being flown. This is not something that should be put on a required checklist, but rather an attitude and standard operating philosophy. Capt. 39

I have not had a single incident or problem on the DC-9 (since I began flying captain). DC-9 operation lends itself to good crew coordination. If I have a guy who might be new, or a little weak, I slow things down and help him keep up with the aircraft. F/Os all try hard to please the captain. Actually they tend to be too hard on themselves, i.e. get down on themselves if landing isn't perfect in every detail. The biggest problem in crew work is with flight attendants. We sometimes change girls five times a day. This makes it tough to even know who is back there and if they know what to do in case of emergency. I feel same crew of F/As should fly the whole rotation (as American does). This way you can get around personalities and not be put off by a possible bad first impression. Note: 99% of F/As are outstanding. They do a very hard job extremely well. Capt. 40

Our present approach to CRM seems to be leading to more confrontation in the cockpit. between me and the copilots. I welcome suggestions and constructive criticism in the cockpit, but I see more of a challenge to my authority. At times the cooperation and assistance of my copilots seems to be less than prior to the days of CRM. The captain's authority as final decision maker must not be diminished. Especially in the case of new hire F/Os I have seen an increase in insubordination. Again, I welcome an open flow of cockpit constructive criticism in both directions. But what I am seeing is more of a "this is the way we used to do it in the Air Force" mentality and less of a willingness to conform to the company's way of doing things. Crew members are encouraged in CRM to draw upon their previous experiences. However, this must be kept in proper perspective. The captain still must have the authority to "set the tone" in the cockpit, and expect the F/O to carry out his assigned duties without having to give a long dissertation justifying each decision. Perhaps part of the problem is that our company is hiring some older pilots with higher experience levels resulting in a captain/copilot team with both pilots closer to the same age and experience level. A more likely explanation, however, is starting to hire more assertive types. The "B scale" issue no doubt adds to friction in the cockpit. Capt. 41

Overall coordination is excellent. The DC-9 is so simple and its systems are so well organized. Each crew member functions well with the company's current guidelines. Occasionally I work with captains who do not comply with certain operational procedures, but these have been few. Usually these same captains are the ones who don't communicate as well as they should. But I adjust. F/O 46

Crew coordination is generally very good on the DC-9, especially with the new captains. When procedures are accomplished in the "flow" or order like we were trained to do them, crew coordination is good. Some of the older captains that have been on the DC-9 for years and still somewhat set in their "old ways", which can cause a breakdown in crew coordination and communication. F/O 48

Things are improving after exposure to CRM. We need to pay more attention to details of what person (PF or PNF talking on the radio) is doing. In good weather we tend to get lax and drift off into other thoughts rather than the apparent uneventful job at hand. Capt. 49

Crew coordination is good on the DC-9. You have to work together on a two-man crew, especially in bad weather or an abnormal situation. Sometimes there is much too much chatter when you taxi, especially at the big airports. Many times copilots try to read the checklist when I am busy figuring out where we are going. I just tell them to hold on a second. Training pounds into them the checklist and the dual response. That is great in the simulator, but in the real world you have to teach the copilot how you want to do it. Capt. 63

Our recent changes have been an improvement. The sterile cockpit concept has some merit, but it is a classic case of "them that no playa the game maka the rules". The captain is responsible for safely completing the flight and having a relaxed cockpit environment has been one of the reasons our company has had the best safety record of all airlines in the past 35 years. Capt. 67

I don't have any concerns in this area. I think the operation is smooth and safe. Dual head com radios would help. Also the ability to receive messages (ATIS, and eventually ATC instructions) via datalink would allow both pilots to monitor ATC at all times. Capt. 74

Crew coordination overall is very good and improving, particularly with the cabin crew. The biggest difficulty is communicating with the F/As. Some captains will not let me talk to the F/A when I ask to in a low workload time frame. 95% of the trips, by the end of the first day, I know what a captain expects and feel we work together well. By the end of the first trip I feel like there is a very good foundation for working together. It's the few guys who 1) insist on doing just about everything their own way; 2) feel threatened by any suggestion, question or initiative, that cause the problems. The impact seems to be that I, personally and together as a crew, see performance drop dramatically. It frustrates me that in those situations I try harder to be even better and usually perform worse. I feel sure it is because the captain and I are not supporting each other. CRM sounds great during training, but it's not reaching these guys and I have yet to find anyone who has been able to effectively deal with these individuals. Their personalities which make them difficult to get along with also makes them CRM-illiterate. F/O 82

In general coordination is very good. The only time I experience much of a problem is when the captain "mumbles", or repeatedly does not speak loudly enough to be heard and/or understood (due to cockpit noise, radios, headsets, etc.) Eventually you get tired to asking him to repeat himself and just assume what you thought he said. F/O 90

3. What did you think of your training for the DC-9/MD-88? What topics should receive more/less emphasis? Any comments on training aids and devices that were used, or needed?

MD-88 Crews

TABLE V-1. Listed below are replies made by two or more respondents (MD-88).

Need live instructors	6
Systems training too shallow	3
Long Beach training inadequate, used MD-82 materials with MD-88 differences	5
Need more hands-on training devices	4
Should have more FMS in ground school	8
Course is too intense, concentrated	4
CPT was excellent device	2
Training devices were out of date	3
Need ground school instructors with line experience	3

There was a lack of personal instruction. The whole ground training program was done by video tape and because the plane is so new there were many questions and no experienced instructors with answers. The video tapes were good, but I believe an instructor should teach systems and be able to lead in-depth discussions on each system and their quirks. There is always the way a system is designed to work on paper and then how it actually works in real life. 9

I was trained in Long Beach <Douglas>. Systems needed more depth and the program should have been MD-88, not MD-82 with differences training. Systems on 727 S/O were taught in adequate depth and this is how we should be taught. Interactive computers are very good. We should head in that direction. But do not eliminate the teacher/student classes where questions can be asked. 10

I thought MD-88 training was great. The only room for improvement would be to have a flight training instructor or a better trained ground training instructor to run the FMS/autoflight and system CPTs. The ground training instructors just can't answer line-related questions. 12

There should be more emphasis on systems and how they work. Much more emphasis on the things that can bite you: not capturing altitude; how you can <inadvertently> negate captures; map failures; going into D/R and drifting; when to turn it

<automation> off because your are overloaded. 14

Training in both aircraft was very good. In the full-time F/D aircraft, I feel that it is important to fly without the F/D (autopilot on or off) so that the pilot can become aware of the pitch attitudes required for various regimes of flight. This pertains to the first few days in the simulator before too many abnormals are introduced. 16 [Capt. DC-9]

I feel that the training was excellent on all aspects of the plane except the FMS. I was expected to learn the FMS on the line and in fact that's where I learned the system. This definitely needs more emphasis. An FMS trainer was not available when I went through training and it is needed. 19

Good training, but we need more emphasis on MCP, and less on ram air etc. Best training I have received at our airline. 20

Not enough time. Full day in class plus necessary study time for very long days. After a week at this pace, I found myself saturated and my learning curve for new material peaked. I really felt pressured because it was also my initial captain upgrade. 21

Training was excellent except for one thing. DC-9 to MD-88 conversions were given only four legs as an IOE. This is inadequate since the 88 presents a radically different approach toward flying. 35

I was pleased with the concept of the MD-88 ground school - slide tape presentation. I do think, however, that in the future the person who narrates the tape should be a pilot. I found myself becoming aggravated at the reader of the text for several reasons that had an overall negative effect on my learning. It was obvious that he did not have a flying background because he either mispronounced words or put accent on wrong syllable. For example, engine pressure ratio - we call it "E-per", he referred to it as "E.P.R." As far as the training aids, I found them to be the best yet. As for the simulator, I think it is an absolute waste of time to sit in a simulator and before each period give the instructor a flight attendant briefing. I feel the same way about a departure briefing. Fine, if you have an unusual departure, but otherwise we all know who is going to do what, when, and how. Let's <u>fly</u> the simulator. We can talk during briefing and debriefing. Like a fellow pilot said, "We are sitting in Atlanta in the middle of the summer with OAT of 95 degrees. If the F/O is so stupid that I have to tell him we'll not have to use engine anti-ice today, he doesn't belong in that cockpit. 44

Training was basically good. I had real problems with the autoflight system. It didn't make sense to me. I kept thinking of the 757/767 system. A pitch wheel for vertical speed only. After training I went back to the DC-9 for two months. On my first MD-88 approach, into DCA, my F/O asked me if I was a little high. Then Approach Control came in with, "Do you think you can make it?" We made a 360 degree turn. I was at least 10 miles behind the aircraft, trying to use the autoflight system. Too much time between training and flying the aircraft. 59 [L-1011 F/O]

There are some areas of the FMS that after a year are still poorly understood or uncomfortable to use. Discussion with other MD-88 pilots reveals same feelings. HLD and DES pages seem to be particularly troublesome. 71

It was good overall, but to much drills on V-1 cuts, missed approach, etc. This is necessary to meet the FAA criteria which are totally unrealistic. We are losing sight of the big picture. If I lose an engine, I want speed and altitude and to get back down, but I am not going to fly +/- 5 kts. and +/- 50 feet as in simulator drills. More time should be spend on real world problems rather than imaginary so-called critical situations. Have we ever lost an airplane due to losing an engine at V-1? I doubt it. 77 [Capt. 767]

<u>DC-9</u> <u>Crews</u>

TABLE V-2. Listed below are replies made by two or more respondents (DC-9).

Need better CPT	3
More systems training	2
Better incorporation of CRM into training	2
More training on Jeps	2
Simulators and CPTs not reliable, out of date	4
Too much emphasis on non-precision approaches	2
Need instruction on ops specs, FARs, AIM	2

I feel that the DC-9 school is a good school and always has been. One area that could be addressed more is performance. I can't comment on the training aids as they have been completely redone since my training. I have heard favorable comments about the new ones. 2

The DC-9 training (ground) was excellent, but <u>only</u> due to the instructors. Flight training initially was not on company equipment, creating concern and some confusion for first-time checkouts. Line training was adequate. Recurrent training has too many complex systems on the same day due to (I am told) FAA requirements for so much time to arbitrary subjects. 4

Early training (sim 1-3) was poor. Training in a simulator with entirely different cockpit from our DC-9s is poor, especially for two pilots new to the DC-9, e.g. HSI vs. no HSI. Obvious lack of ATC experience of my F/O partner (six months as 727 S/O) greatly impacted my training as I spent a great deal of time carrying his ATC load and/or actually training him on the spot on how to be an F/O in ATC environment. Half-day on introduction to Jeps was obviously inadequate, especially from a non-pilot instructor. The F/O playing catch-up during the simulators changed the whole emphasis of these periods from role-playing and habit pattern setting in routine ops to OJT in radio and instrument procedures. 7

I thought the initial training was fine, except for the simulator. I could have used more training on the Jep manuals and approach procedures. I was stuck as an S/O for six and a half years because of no hiring, and I had not flown all that long. 24

We need more emphasis on crew coordination for people like me coming from the single seat community in the military, especially with little S/O time on the 727. 26

The big item here is LOFT. LOFT helps a lot, but it takes a while for a new guy to figure out what to do and when. 28

The training was excellent in all respects except one. I think a better, more sophisticated CPT would have been helpful. The ground school instructor and simulator instructor were superb. 30

I was quite satisfied with my DC-9 training. Simulators in general, though, need great improvement in the feel of the controls and the visual presentations. Both features, on every simulator I have flown, are over-sensitive when compared to the actual aircraft. A pilot has to develop two sets of flying skills, one for the real aircraft, another to satisfy the computers in the simulator. 39

I enjoyed DC-9 training. I flew it a long while as an F/O, so it was like putting on a really great old pair of shoes. More emphasis may be put on less flying by the book in certain instances. New copilots will often try to be configured and on-speed at the marker, which really plays havoc with the people behind you, and makes the controller's job much harder. You can still fly smoothly and fast and get everything done by 1000 feet on a nice VFR day when you're cleared for a visual approach. They <F/Os> don't look out of the window nearly enough. (Nor do I, probably, but I try). 40

Excellent! All my ground school, simulator, and aircraft instructors were highly knowledgeable and helpful. I would like to see a more thorough review of Ops Specs material and perhaps some of the FARs. A periodic review of material in the AIM would be helpful. 41

I thought the DC-9 systems and simulator training was adequate (not good, but adequate). Flying training (2 rides) was almost marginal. Every landing was a new adventure. I had only flown fighter-type aircraft prior to the DC-9. This put a lot of pressure on the line check captains that flew my IOEs. Most of my learning was accomplished on my IOE. 46

For the most part the training was good. I don't think the ground school portion can be any shorter. A lot of material is covered in a very short time, requiring a great deal of study time prior to classes in order to keep up. The cockpit trainer (DC-9) in ground school is helpful, but needs an overhaul badly. The flight training syllabus is very good. It does a good job of preparing you for the evaluation. I felt that one of my instructors could have been a bit more prepared when it came to briefing some of the pre-mission topics. 48

More attention should be paid in ground school to flight instruments/autopilot/flight director. The instructors do a good job on mechanical parts, but tend not to understand the actual operation of the flying part or the actual uses of the automatic phases. 49

The training was adequate. The major problem was in ground school: dated slides, systems comments by the instructor that were not covered in the manuals, the only reference now, after 20 months since transition, is in my written notes. The slide-tape training environment (e.g. 767/757) is a better way to ensure that all info is properly documented and passed along to us. We shouldn't have to rely on the capability and quality of the individual instructor for the complete dissemination of the material. 74

The training was great. I felt very confident after coming out of training. The training aids were poor or non-existent. We certainly need more and better CPTs. 80

4. Do you like the way the DC-9/MD-88 operates in the ATC environment? Please mention things you have trouble with, and things that work well, in dealing with ATC.

<u>MD-88 Crews</u>

TABLE V-3. Listed below are replies to Question 4 by two or more respondents (MD-88).

Map display (HSI) a real asset; aids situational awareness	7
Too much time is spent programming in high workload periods; MD-88 is "too busy"	6
Excellent at cruise; LNAV excellent; doesn't depend on VORs	5
To much head-down time	4
Difficult to descend; gets behind descent	3
ATC changes, crossing restrictions add too much workload	3
VNAV level-off at 10,000 not smooth	3
Holding page (capability) helpful	3
Automation is unpredictable	3
Too many brief descents, interruptions from ATC	2
DFW ATC operates poorly	2
Controllers don't understand our "magic"	2
Speed changes under autothrottle too abrupt	2
Radar superimposed on HSI map excellent feature	2
Problem of killing capture with V/S wheel	2

The MD-88 works well, but when things get busy it takes too much time to program the computer. It's just easier to hand fly some times. The autothrottles are the best part of the automation. They are extremely reliable, and free your attention to fly the approach more carefully. 9

I like the way the MD-88 works with ATC, but I have trouble with:

1) Shallow descent rate, 15 flaps, idle power, 180 kts. yields less than 1500 fpm <descent rate>. Sometimes this is not adequate at big airports.
2) VNAV is a nuisance below 12,000 since <u>it</u> decides when to slow to 240 kits. (10,000 foot transition). FMS OVRD is good in theory, but the desired speed is not maintained in descent, the path is.
3) Updating continuously the heading bug in Map mode - busywork!

Things I like:

1) Nav display with weather projection capability. This is a great safety enhancement.
2) Nav display during vectoring for ILS approach. Situational awareness vastly increased.

3) Fuel calculations in FMS - a safety backup. 10

Cruise portion of flight is great - you don't have to constantly be following VORs, correcting for wind manually like in the DC-9. Descent profile helps in seeing if you will make <crossing> restrictions. Entering holding patterns with plenty of lead time is nice, however you still need to manually (mentally) figure these out. In a non-ATC environment, i.e. tower closed, call when you are on the ground, the CRTs are a must. They give you a great bird's eye view of where you are and where you want to go, and save you from landing at the wrong place. 11

There are usually too many small descents, instead of 1-2 large descents. It usually requires too much work to allow the FMS to really be useful. Even if we do get the large descent, very often we will get airspeed changes in the descent, which are too much work to change in the FMS. 12

ATC at DFW is very bad. They say keep speed up and then clear you for visuals from 11,000. MD-88 does not descend very well. ATL ATC keeps you informed about what to expect. DFW ATC is dangerous. Also have had them give crossing restrictions the A/C cannot make; then they get mad. 13

Sometimes restrictions are given in a way that are not very efficient. This causes you to reprogram FMS (heads down mode in cockpit). Also, not as much direct <clearance> as could be. I suspect that the controllers are not aware of the magic on board. For example, "fly heading 200 when receiving proceed direct." They are unaware that we can go FMS direct. Also, FMS system does not level and accelerate well at 10,000. It captures at 10,000 feet, when levels off and then goes to climb power to get the 335 kts. 14

Basically I like the operation. You <u>must</u> stay ahead of the magic, or it will lead you astray. You must be sure it is doing what you think it is doing. I have had several aircraft go from Nav Track to Hdg Hold for no apparent reason, and the only way to know is to constantly monitor the FMA. 18

The MD-88 works well except for the descent phase. The FMS (VNAV) often gets behind in the descent. It is usually easier to adjust the descent using the autopilot. ATC changes speeds on us so often that the profiles are not workable and we lose the efficiency of the FMS programmed descent. The LNAV function is great. It allows ATC and the pilot great flexibility, especially when VORs are out of service.

I particularly like the map display for maintaining <u>situational awareness</u>. I feel concern when the A/C automation does not respond (like engaging VNAV) only to find out that it did not take, yet I had anticipated that mode was engaged. Trying to translate ATC instructions directly into the computer and not getting expected responses (granted often operator error), causes a lot of head-down computer work. Altitude select knob set for 100 foot increments a real poor arrangement. 21

Generally speaking I like the way the MD-88 operates in the ATC environment. There is a problem on all automated aircraft when your departure includes a hold-down at 10,000. Once your autopilot goes into the altitude capture mode and begins to level off, and event which occurs at various altitudes depending on your rate of climb, the autothrottles start to retard to keep the speed at 250 kts. Once you level off at 10,000 the command airspeed bug jumps to 320-330 knots range and up come the throttles. If you were hand flying the airplane you would not have done this. Some pilots overcome this by going to FMS override and selecting a speed of 320-330 as the capture begins. The throttles then remain at climb power; however the airspeed does exceed the 250 kt. limit and the FAA has violated pilots for doing this. I think it is time for a regulatory change that would allow climbing aircraft that are cleared to 10,000 feet to utilize this procedure (or speed intervention on the 767 or 737) or anything that will allow the throttles to stay at climb power during this phase of flight. It would be a much smoother operation. Would it really be careless and reckless to operate at 300-350 kts. at some point below the magical 10,000 foot level? Another solution: don't clear us to 10,000 climbing. 44

The -88 is a hand full. Digital programming takes a lot of time. Analog operation (DC-9) autopilot with basic throttles is a good deal easier to use in a fast-changing environment, and in fact is the method used on the MD-88 when things get busy. Below 10,000 feet one pilot is almost <u>completely</u> occupied working the radio with the other flying the airplane. 57

I like the hold page. Gets you into holds easily. I also like the green descent arc in the map mode. No more mental gymnastics on crossing restrictions. I don't like a V/S wheel that controls both the V/S and the IAS, which when touched in the capturing of an altitude disarms the capture and selects a new pitch mode. Provides a lot of excitement. <See Question No. 1> 59 [L-1011 F/O]

FMS requires too much heads-down operation in terminal environment. Lack of tight integration in cockpit systems and automation increases workload. 62

Things go well once you get the feel for the modes, and don't try to set up the FMC below say 10,000 feet. ATC should avoid last minutes runway changes. New pilots get behind very easily in the automated cockpits. During parallel approaches ATC vectors you toward the localizer. They should always clear you to intercept it because often they get busy and run you across it, and legally you must just continue on their vector. 77

I like the ability of the Nav display (ND) of the MD-88 to show the relationship of the aircraft, nav aids, airports, and weather. This is a major step forward is safety. When ATC gives vectors in the terminal area for weather, the ND is invaluable. 83

The MD-88 is difficult to slow down, especially if required to descend at the same time. Autothrottle response is not smooth enough. If you are a little slow in a turn in the traffic pattern, or if ATC asks you to increase A/S by 20-30 kts., the autothrottles will jam on too much power -- very uncomfortable for the passengers. 85

DC-9 Crews

TABLE V-4. Listed below are replies to Question 4 by two or more respondents (DC-9).

Need dual head radios	4
DC-9 can do anything required	4
Good radio practices are essential	3
Low-tech works better than automation	3
Precise navigation difficult; hard to track airways	3
Poor trim adjustment in autopilot mode	2
Controllers talk too fast	2
Need independent flight directors on each side	2
Airspace is saturated	2
Flight directors are antiquated	2
ATC controllers are highly cooperative	2
DC-9 very maneuverable, responsive to flaps/slats	2
RNAV is needed	2

The DC9 works well except for being unable to get much point-to-point or direct clearances. If you are not RNAV equipped, you don't get the shortcut routes as often as RNAV aircraft. ATC provides headings depending on their workload. 3

Troubles: holddowns, slowdowns, delays, saturated frequencies, less than capable controllers/equipment, less than capable pilots, inadequate separation, untrained radio voices. Works well: flexibility, permitting deviations <route>, mostly sharp, clear, concise instructions or calls, forwarding weather information from previous flights, general courtesy. 4

DC-9 works well in ATC environment, but will not come down like a 727 and won't go up like a 767. I have never before seen or used an flight director that doesn't have an altitude hold bar. I can fly the airplane better than the autopilot on a coupled approach. The autopilot has a hard time with gear/flap/slat movement. I always thought the machine should be able to do better than me. I have to get everything stable so I can take over. All in all, it's a fairly versatile airplane. 6

The DC-9 works well in the ATC environment specifically because it lacks the automation I loved so well in the 767. ATC is not geared toward RNAV/VNAV capabilities, so these features can range from useless to handicap. The DC-9 is low-tech in a low-tech ATC environment. The most serious fault is the lack of positional awareness that could be greatly improved, not with a 767 map display, but with such simple additions as an HSI, and DME on all ILS frequencies. Having had DME to the runway in the 767 really emphasizes what a safety factor this is in the terminal area. There is occasional difficulty with ATC forgetting how busy a two-man crew can be. They always want us to understand that they were "on the land line", but often forget that we have an airplane to fly first, talk second. 7

Yes, the DC-9 does a good job. It's a 1955 technology aircraft operating in a 1955 ATC environment. Please have controllers talk a little slower in the DFW and NYC areas. The faster they talk, the behinder they get. The system is getting overloaded. 8

The DC-9 is underpowered compared with other, newer jets. Often ATC will ask for unrealistic climbs. When we tell them that we cannot make it that high, that soon, we get vectored all over the place. Avionics are adequate for today's environment, although two independent flight directors would be helpful. Simplicity makes the airplane easy and fun to fly. No FMS to babysit. 29

The DC-9 is OK. Our navigation ability is very limited as to its precision and overall capability. Numerous corrections are required to stay on course. We are rarely dead on an airway centerline. Much mental arithmetic and "how goes it" checks are needed to satisfy crossing restrictions. We cannot go directly to a VOR much more than 200 miles away. VOR needle indications often waver back and forth making precise navigation difficult. 39

Yes, I like the way it operates, but if you have a problem, either in the aircraft or in the cabin in the terminal area - with bad weather and lots of traffic - you can really get behind trying to deal with everything at once. The DC-9 systems are simple enough that problems can easily be handled. Listening up before speaking; using your call sign always; don't get mad - people are probably trying as hard as they can to do right. If you have a delay or a go-around, so what? Come back and do it again. You can build situational awareness by listening to the radio and getting everything done before you get down into the terminal area. 40

I am content with the way the DC-9 operates under normal conditions. However, during times of heavy workload, one additional factor such as an aircraft malfunction or passenger problem can tax the crew to the limit. An ACARS system would be useful in the DC-9. The flight director in the DC-9 is antiquated and "sloppy" compared to later generations. 41

The DC-9 works well in the environments that the company sends us into. We do not go into LAX, DCA, or NYC. This relieves us of some of the more unpopular cities to fly into. I also get the feeling that the ATC controllers are aware of our capabilities. They seem to issue clearances that are usually easy to accommodate. 46

I think ATC must have been designed around controlling the DC-9. On other airplanes, they frequently set you up high. The unique problem of the DC-9 is tracking the airways. The controllers seem to be much more aware of the lack of precise adherence to airway centerlines. This of course is the result of our not having computer-generated displays in our cockpit. 67

VOR/DME navigation is archaic. Point-to-point inertial through the FMS is more accurate and would (does) provide both ATC and the flight crews with better and simpler tools. The problem is with the mix of the two. If the ATC system were designed for RNAV, we could take full advantage of the current technology and simplify the entire system. How about requiring RNAV in the high route system? 74

I like the fact that low automation keeps me involved with the flight, but automation would be nice to reduce the workload occasionally and reduce fatigue during long days. The most frustrating items in the DC-9 are: 1) flight director; 2) the PDI and RMI needles are all +/- 2 to 4 degrees, sometimes more. Some Centers are accustomed to and insist on all aircraft tracking a radial precisely. In the DC-9, there is no such precision. I think common sense, courtesy, and empathy go a long way in dealing with anyone. On thing that perhaps controllers could be aware of, particularly approach controllers, is that they sometimes ask us to maneuver in such a way that is uncomfortable to passengers. We tend to comply, partly due to vanity, and partly because we don't want to be "punished" with a delay due to failure to comply. 82

5. What can you say about overall workload of the DC-9/MD-88 compared to other aircraft you have flown? Include mental workload, monitoring, etc.

<u>MD-88 Crews</u>

TABLE V-5. Listed below are replies to Question 5 by two or more MD-88 respondents.

Great amount of monitoring required, increases workload	10
High workload; highest of any plane I've been on; higher than the DC-9	8
No problem once you're experienced on aircraft; initially difficult	4
Mental workload higher	2
Mental workload is less	2
Checklist is too long, creates workload	2
FMC must be watched	2
757 is a superior airplane	2
Workload the same as other aircraft; no problem	2

There are more things to watch over than in a traditional plane. If you could trust everything to work as advertised, the only concern would be programming ("typing") on the computer. Unfortunately when you least expect it, something goes wrong and you have to both fix the mistake or problem and also get the aircraft going where it should be. If you just had the normal scan and flew the airplane it would be simpler which of course you can always revert to if you want. 9

Checklist is too long. Initial setup at the gate is relatively long (i.e. entering fuel into ACARS, enter ZFW twice, entering CG <u>and</u> ZFW CG). However, many other chores are eliminated (EPR <u>calculations</u>, gross weight). In flight the workload is lightened except for the checklist length. The revision of our checklists (12-15-89) is a big improvement. Mental workload is greatly reduced thanks to the FMS. However, the FMS does occasionally miscalculate and it needs to be watched fairly closely. 10

The highest workload of any (transport) aircraft I have flown. The workload on the ground is heavier than any aircraft I have flown. Monitoring can be a pain. There are too many combinations of switches that can get you in trouble. 11

From T/O to landing the workload on the -88 is less. If feel that in the terminal area, the use of the FMS with the autopilot is too much work. It is far easier to manually control the autopilot or hand fly. 12

You can't take your eye off for a second. I enjoy the workload. Otherwise I would get bored. 13

Harder to stay in the loop - no need to get chart out and check radials. This can cause boredom, causing pilot to be out of the loop. It is harder to be a passive monitor than an active one. I try to check radials and use charts to prevent this. 14

In the MD-88 you can do much more, but automation increases your workload due to the increase in monitoring duties and FMS programming. 15

Under normal circumstances the MD-88 workload is equal <to the DC-9>. But, at time of high stress, if you try to stay up with what is going on and keep using the magic, the workload is much higher. In other words, the magic relieves workload only if it is set up ahead of time. I am not sure it really reduces mental workload because you cannot sit and allow it to function without close monitoring. 18

The MD-88 has a high workload. The FMS is a great tool but demands a great deal of attention. You have to constantly be aware of the mode it is in, and it often will switch modes on you, LNAV to Heading Hold, for example. With the influx of new copilots it is an added task to teach the FMS and how you want it used. There seem to be different attitudes (both in training and among other captains) on how to use the system. The automated MD-88 definitely increased my workload compared to the DC-9. 19

Compared to the 767/757, I feel that the MD-88 has to be watched carefully. I feel that the two-man crew (any two-man crew) creates anxiety in that we're often both busy and not able to monitor each other. On the three-man crew, I felt that there was better cross checking of the other pilot. 21

The workload on the MD-88 is a factor of 2 to 3 times great than the DC-9 on the ground (preflight, taxi-out, checklists). Once airborne, workload may be slightly less if little programming is required, or maybe more if changes come up which require programming. 34

Workload is no problem. I have to admit, when I was flying on a three-man crew during the initial discussion about glass cockpits and two-man crews I was skeptical. I became a believer about half way to Los Angeles on first leg of my IOE as a 767 F/O. I have since had to fly technologically disadvantaged three-man crew aircraft, and I did not enjoy it at all. 44

During smooth, normal operations the workload is less <in the MD-88> since less "thought" (e.g. tracking radials, working out drift corrections, etc.) is required. During emergencies/system problems a two-man aircraft involves more work and crew members are unable to effectively monitor each other since one person must fly and the other work the problem. In the MD-88, preoccupation with programming the FMS during these emergencies can lead to task saturation, even though FMS programming is only slightly helpful. 55

Overall the workload seems to be greatly reduced. In the departure and terminal stages, this is essentially true when the full capabilities of the FMS are understood and utilized. During the first several months on the MD-88, though, the FMS can be overwhelming and greatly <u>increase</u> workload.

Flying the DC-9 was a lot simpler, but required a lot of head work. You were more involved with the flying. Your brain was the computer, for better or for worse. In the MD-88 you do a lot more monitoring, and do it rather poorly. I would always want to be looking at an approach plate when we didn't capture an altitude. 59

The autopilot/flight guidance system is poorly integrated on the MD-88. The older B-737 SP-177 autopilot/flight director is much easier to use and much more reliable. The workload in the terminal environment and during preflight is high <MD-88>. The overall cockpit layout is poor - the hazards of derivative aircraft. 62

Initially the workload is quite difficult. After about 50-100 hours workload becomes better and at the 200-300 hour point workload will decrease. Monitoring is <u>very</u> important and you must train yourself to continue to monitor, especially when you think all is well. Remember, in God we trust, everything else we check. In an automated airplane, I recommend check twice! 77

<u>DC-9 Crews</u>

TABLE V-6. Listed below are replies to Question 5 by two of more DC-9 respondents.

Workload moderate, manageable, same as other aircraft, no problem as long as conditions normal	17
Workload is higher, or excessively high in DC-9	7
Workload is excessive below 10,000 feet	7
Third man is needed during abnormals; workload higher in any two-man plane	5
Workload is fatiguing	4
No "magic" - less to worry about	4
First officer is overworked	3
Monitoring load is high	3
Mental workload is high	3

DC-9 workload is as much as any aircraft in our fleet. With new copilots it increases the captain's monitoring workload. New copilots should have more company experience before checking out as initial F/O. 1

When everything is going well, the workload is fine. It's just when outside factors such as weather, maintenance problems, or passenger problems enter the picture that it can create stress. The DC-9 is a hands-on operation, so you don't have the computer to worry about. I find that when the workload gets hectic, actually hand flying the aircraft helps me deal with the situation better. 2

Man is better at working than monitoring. To me, the new generation of aircraft should advise the pilot of possible errors in a passive manner, and possibly provide guidelines for action. Computers are better at monitoring, and should be utilized to assist the pilot in his decision making. Monitoring can be very boring work and even a distraction. Remember, "quiet and dark" are ideal for sleeping, too. As to below Cat II approaches, why deliver people to a destination where they can't see to get home? 4

Much of the DC-9 workload in arrival/departure area is a very high mental workload. In the 1950 cockpit and the 1990 environment, we must do most of our decision making without information that the glass cockpits have. No wind information, no visual picture of the airport and our position. CRTs show far more information than we have in the DC-9 cockpit. Autopilot, autothrottles, and altitude capture are sure a help in arrival and departures. 5

On every airplane I have flown, one crew member does more work than all the others. The F/O on the DC-9 does all the engineer's work, all the F/O's work, and half the captain's. I try to help as much as I can, but sometimes get loaded down and I can't watch him <F/O> as much as I'd like to. I like to fly the airplane to cruise altitude, then hook up the autopilot, and later fly the plane from 10,000 to landing. I think this lessens my workload. 6

Stick and rudder and navigation workload is higher, but button pushing workload is lower, than automated aircraft. Overall workload on the DC-9 is lower than the 757, but the tasks that remain are not as much fun because they include the menial tasks, such as chart study, course setting, etc. It is too simplistic to stack up tasks on each side of a scale. Higher workload on a 757 can be more relaxing and enjoyable if the tasks themselves are less tedious and repetitive. Comprehensive warning systems greatly reduce the mental workload because a pilot does not feel the need to constantly recheck routine items. Energy can be directed toward flying the aircraft. 7

The workload of the DC-9 is similar to the 727 and DC-8, very manageable until an abnormal situation occurs. Then the 2-man versus 3-man crew differences become obvious. With a 3-man crew there is always someone who can devote full time to flying the aircraft. In a 2-man crew, in an abnormal situation (mechanical, passenger, etc.) generally 1 1/2 men are dealing with the problem and 1/2 man is flying the aircraft. 8

<The DC-9 has> fewer magic components to babysit. This makes things simple. It forces you to stay involved with the airplane. If too many things were automated, you would become detached and miss things. Overall the workload is moderate, depending on the terminal environment. I enjoyed "flying the airplane with my mind" and figuring out climbs/descents etc. 29

The workload on the DC-9 is greater than it was on the L-1011. This is partially caused by the fact that the DC-9 is two man crew (vs. 3 for the L-1011) and normally flies more legs per duty period. But the DC-9 also has a higher mental workload than the L-1011 due to the lack of automation on the DC-9. The DC-9 requires constant attention to navigation. There are no computers to automatically fly a programmed route. Much mental arithmetic is needed in the approach phase to compute start-down points, and to satisfy altitude crossing restrictions. On a 10 to 12 hour day involving six-plus legs, it definitely affects the fatigue factor. 39

DC-9 - higher workload due to shorter hops. More stops equals more dealings with ATC, passengers, fuelers, etc. More time down in light plane country. I get pretty tired after a bad day (weather, all instrument approaches to minimums, etc.). The four-day trips we have are notorious. You really have to watch it on the fourth day. You can easily make errors. 40

I don't find the workload a burden. Naturally a new copilot has his hands full and it takes a while for him to feel comfortable. The workload is higher in any two-man plane than the 3-man. With the DC-9 being a manual aircraft, once you have everything done, you just fly it. The automated aircraft takes more work reprogramming. Once you are flying, unless you get ATC changes, the automatic aircraft will do everything for you. My friends on the MD-88 say that because the computer says it's right, many people don't cross check the automation to see if the information is correct (for example, are they really going to make a speed and crossing restriction). 63

There's no doubt that the DC-9 is tough duty compared to other airplanes. Lots of legs, lots of small, poorly equipped airports, lots of new employees, limited avionics and airplane-related equipment. The good part is that it's really flying. Lots of challenges with proven, albeit old, equipment, and eager, young co-workers. What could be better? 67

I believe for the workload for the captain is a lot less than other aircraft, but for the F/O it is a lot more. 80

6. <u>List</u> the features or modes of your aircraft flight guidance, instrumentation, and avionics that you like and dislike.

The results of this question are given in Table V-7 below. Following the tabulated responses are verbatim responses where these were included by the volunteers.

TABLE V-7. Likes and dislikes in cockpit equipment.

LIKES: MD-88 Crews

Item	Times Mentioned
Map mode of HSI	13
HSI map and weather radar on one display	9
Airports and nav aids on HSI map	3
Flight path on HSI map	1
Map plus DME	1
Flight Management System (FMS) in general [1]	10
Information available from FMS	4
Hold page	6
Autoland Cat II and III capability	5
Autothrottle (esp. T/O and cruise)	4
LNAV (NAV)	3
VNAV	4
FMS override button	2
Auto go-around	1
Direct intercept page	1
VOR designator (3 letters) to establish waypoint	1
Various levels of automation available	1
NAV-autopilot-autothrottle relationship	1
Vertical speed mode to climb in turbulence	1
Reliable autopilot	1
Glass cockpit in general; EFIS displays	5
FMA panel	4
EPR calculation regardless of anti-ice use	1
Color radar	3
ACARS	2
Fast/slow bug on PFD	1
ILS display	1
ADF display	1
ETA to fixes	1
Dual head radios	2
Engine power	2
Automatic strobe light	1
Autobrakes	2
Transponder auto shutoff after takeoff	1
Pressurization	1

DISLIKES: MD-88 CREWS

Item	Times Mentioned
AHARS (unreliable; not up to IRU)	7
VNAV descent (rough; unable to maintain airspeed)	9
VNAV level off at 10,000 feet (power surges)	5
ND obscured by yoke	4
Altitude select knob (100 foot adjustments)	4
Mysterious loss of alt hold and alt capture	3
Altitude control in level-off	1
Altitude alert window (numbers change)	1
Map failures due to navaid loss	1
FMS hard to get used to	2
DFGS in general	1
FMS too complex (e.g. hold page)	1
Autopilot-FMS interlink cumbersome	1
FMA info should be on ADI (like 757)	1
Can't auto tune VORs	2
Autothrottle response	3
A/T slow to respond to level off	1
Speed modes awkward	1
Autopilot	1
A/T on landing	1
Assigned airspeed doesn't go into profile calculation	1
Difficult to transition to IAS mode smoothly	2
Vertical speed wheel	1
Too many FMC (and map) failures	3
Computer slow to respond	1
Burned out lights in engine display, FGS panel	1
Lack of logic in switch patterns and movements	1
MCP design	1
ADI screen in fuzzy	1
Air conditioning system	1
Flat plate digital instruments for engine parameters	1
MCP design	1
DFGS should have self-illuminating buttons	1
Time spent programming (head in cockpit)	2
Updating heading bug (company policy)	2
Too many ways to do the same thing	1
Too many buttons to press to do some things	1
Too many repeated inputs (e.g. ZFW)	1
VNAV below 12,000	1

LIKES: DC-9 CREWS

Item	Times Mentioned
Simple operation; basic airplane; easy to understand	8
"Everything" - good generic airplane	3
Basic airplane - allows you to keep up skill level	1
Avionics in general	3
Reliability	2
Flight director ("simple")	8
Autopilot ("simple", "predictable")	6
PDI reciprocal heading feature	6
SCAT	3
ILS - A/P mode	1
Heading select	1
Approach coupler	1
Engine instruments	1
VOR/DME	1
Manual throttles	1
"steam gauge" <traditional dial> instruments	1
Heading bug on flight director	1
ILS ("straight-forward")	1
Hand flying	1
Smooth roll control	1
Landing characteristics	1

<u>Comments</u>

The DC-9 works fine if you understand its limits. 37

All facets of the avionics, instrumentation, and guidance are SIMPLE! The autopilot doesn't fly the pilot: the pilot has to fly the autopilot. VOR/DME information seems to be enough to get around in our domestic U.S. system. I'm not interested in INS or ground track information. I really like flying the DC-9.

The DC-9 is a good basic aircraft that will do anything but autoland. Because it is a basic airplane, it keeps your flying skills up. 63

The good thing about the DC-9 is its simplicity. Once you've made the trip back down memory land and gotten comfortable again, it's really a remarkably reliable, simple airplane. And best of all, it flies great. 67

DISLIKES: DC-9 CREWS

<Note: most of the "dislikes" listed by DC-9 crews were items or features that are not present in their aircraft. These are listed in the first segment of the table below>.

Item	Times Mentioned
Lacking, or would like to have:	
HSI (in place of RMI and PDI)	11
Autoland	2
Pitch reference on F/D	1
Altitude hold bar on F/D	1
VOR annunciation in F/D mode	1
Light test feature in F/D mode	1
Altitude capture on A/P	1
Pitch command on F/D in level flight	1
Wind or TAS readout	1
Go-around mode on A/P	1
RNAV ("for fuel savings")	1
Angle of attack indexer ("for windshear escape")	1
Third VHF com to monitor company radio	1
Dual DME displays for each pilot	1
ADF (non-digital)	4
Weather radar (need color; antiquated; erratic)	3
Flight director	3
Cockpit antiquated in general	3
Autopilot ("sloppy", unresponsive in some modes)	2
Autothrottles	1
ADI (too small)	1
VOR mode on A/P	1
Engine instruments	1
Gear horn cutout only on F/O's side	1
Hard to equilibrate VHF volume esp. over 10,000	1
Can't hear bell when F/A calls	1
Would like redundant and independent A/P and F/Ds	1
Pitch control too sensitive on descent	1
Sometimes skids when A/P engaged in level flight	1
Instrument lighting	1
Can't engage A/P in a turn	1
ATC demands more than a DC-9 can do	1
ILS needles are in poor position	1
Too many lights are illuminated on the ground - hard to catch important one	1
Altitude alert	1
Hard to remember which compass inputs to what	1
Lacks the basic "T" arrangement due to PDI	1
F/D and A/P don't always agree on coupled approach	1
Approach coupler is not smooth	1

Pressurization is a problem is not set correctly	1
Can't see VHF No. 1 freq. when captain uses A/P turn knob	1
No. 1 DME and altimeter hidden by yoke	1
Slat extend light hidden from view [1]	1

[1] Doesn't say by what.

Comments

1950's cockpit in a 1990 environment.

The whole cockpit of the DC-9 with respect to flight guidance, instrumentation etc. is marginal. The reliability of our DC-9s is superb. While I may not like some of the instrumentation, at least they always work.

7. If you have flown both a traditional and a glass cockpit aircraft (MD-88 or 757/767), please give us your insights into the differences between operations in the traditional and the glass cockpit. (If not, please leave blank).

MD-88 Crews

I have flown traditional aircraft (KC-135, T-37) in the Air Force and now the MD-88. The biggest advantage to the glass cockpit is the amount of information available to the pilot from the FMS, and the autothrottle and autoland capabilities. The disadvantage is the time spent inside the cockpit trying to program the FMS, when often times it would be easier to fly the whole plane by hand without the neat gadgets. My biggest concern with the glass cockpit is the erosion of basic flying skills in instrument conditions. We rely so much on autopilot (because we are encouraged to give a smooth ride to the passengers) that the basic crosscheck of flying instruments, and eye-hand coordination skills, become rusty along with the confidence to fly an instrument approach down to minimums. 9

I rely on the FMS map without cross-checking the charts. Every now and then the map will be off by up to 1/2 mile, as verified by the outer marker. Situational awareness is much better in a glass cockpit. 10

I like the glass cockpit. The CRT is tremendous in helping us know exactly where we are and how much we really need to deviate in weather. The bird's eye view it gives us is fantastic. The flight guidance system and FMS still increase rather than decrease workloads at the times you need their help the most. I liked flying the glass cockpit because it was a challenge, but it definitely is not a workload reducer in its present format. You also have to work at keeping up your basic flying skills or you lose them. I still back up everything with VORs and radial selections. If in doubt, I still believe the VORs. 11 (L-1011 F/O)

The glass cockpit aids the pilot in finding a field he is unfamiliar with at night. I would never go back to traditional cockpits if I can help it. 13

I flew both the DC-9 and the MD-88. You can do much more with the FMS and the DFGS and autothrottles. But there are moments when you workload is actually increased on the MD-88. Also, FMS/autothrottle responses are sometimes very slow or abrupt. They need to be updated to smooth, reasonable response times. 15

The glass cockpit has significantly more information available to the pilot on few instruments. The glass cockpit or advance automation is hard to use or program when unusual situations come up, such as holding at a different fix, or routing changes once the computer has been programmed. 16 (DC-9 Captain)

The glass cockpit has some very, very nice features, such as the nav display, which makes route planning, weather avoidance, and ever to some extent route changes easier to visualize and complete. I particularly like the nav display during an ILS approach when the whole picture is being displayed and your exact position is easily determined. I do not like the fact that the same nav display with go D/R and then "nav fail" at the worst moment. Then the workload required to recover the N/D is usually too high and the rose or arc displays must be selected. In the terminal area, the workload can be very high if you try to keep up with the FMS. Usually it is better to set it up for the final approach and use the "straight" autopilot until then. I also do not like the fact that at least half the nav display is hidden by the yoke. I cannot emphasize enough the absolute necessity as captain of being certain that the FMS is doing what you think it is doing. 18

In the traditional aircraft, all attention in the critical areas of flight are on the primary flight instruments, and if it's VFR, the outside environment. To use the automated cockpit, a certain amount of the attention is diverted. It has to be, in order to run the automated cockpit. On takeoff the PNF has to look in the cockpit to push climb power, VNAV, and to run the flaps up at 1000 feet. In the traditional cockpit, the PNF can do his duties and still look outside. In the approach environment the PNF has to have his head in the cockpit much more in the automated cockpit. I feel that the automated cockpit is not designed for VFR. Your outside awareness is much better in the traditional cockpit. 19

I believe I maintained a better situational awareness in the traditional cockpit. I find that I frequently expect the magic to take care of me and I allow myself to be distracted from flying the airplane. 21

Traditional is much easier and simpler to operate...few system require "programming." Set VOR course and frequency - what else is there? It requires you to stay in the loop and do more head work (updating frequency and course, planning descents, visualizing a holding pattern or best headings to go around a storm. On the negative side, if you get out of the loop, there is no pre-programmed course or descent to back you up. The basic difference is that a glass cockpit provides a tremendous amount of information, some of it useful, some of it distracting. However, in order to get the useful information, the system has to be programmed en route. This takes time (workload) when time may be of the essence. The interface between crew members and the systems is a major factor in how the system will be used. The interface on the MD-88 has not been designed as well as it could be (767 guys can't wait to get back to that aircraft). 34

From an operational point of view, there are few if any real differences with the exception of the map <HSI map mode>. While this is very useful, it promotes a loss of ability to "visualize" the aircraft position. With respect to the FMS, I strongly believe that a solid foundation is needed in terms of basic flying skills. This is difficult, if not impossible, to get by initially flying an aircraft like the MD-88. 35

1) Glass cockpit is always 2-man. In weather with an emergency you approach (sometimes exceed) task saturation. 2) High level of automation can leave pilot out of the loop since humans are not good at just monitoring (without coupling monitoring to action), and you get bored and distracted. That's fine as long as the system is working properly, and it's been programmed properly. But if these two prerequisites are not met, it'll bite you. 3) Glass cockpit - a pre-condition exists (I know cause I've done it) with analyzing why the aircraft isn't doing what you thought you told it to do. So you try to reprogram it. All the while the error is uncorrected; e.g. it does not intercept the ILS, so you check that it is armed, that the correct freq is in, etc. Meanwhile you are shooting through the localizer or getting high on the glide slope. 4) Traditional cockpit - much less flexibility than glass cockpit, e.g. lacks RNAV, more difficult to remain position oriented, requires more attention. 55

The workload of the PNF is greatly reduced in the glass cockpit due to the fact that he doesn't have to look up freqs/courses, etc. The ability to know your exact position is definitely comforting. This is useful during visual approaches into unfamiliar fields. 56

Glass cockpit are definitely higher workload environments. I like them for a perverse reason - I like gadgets, as I suppose most pilots do. Crew coordination gets to be a problem on an aircraft with a DFGC because of the many different ways to operate that accomplish essentially the same thing. This presents more areas of disagreement between crew members as to which technique is better. I frankly think that the traditional cockpit is a far safer operation, but the glass cockpit is the future because CRTs are cheaper to maintain than conventional instruments, and this is a "bottom line" driven industry. 57

In the glass cockpit you rely more on the computer, and the company pushes you to do it that way. They say you should back everything up manually, but if you did you couldn't handle the workload. I felt that my flying skills were better than flying the traditional planes, but now I make an effort to turn off the magic every once in a while to remain proficient. 58 [767 F/O]

DC-9 Crews

<Note: Most DC-9 crews had not flown glass cockpit aircraft, and hence could not answer this question. Only ten replies were given. Nine of these are reproduced below; the tenth was incomplete. Of the ten replies, eight had previously served as

first officer on the 767, one was now flying as first officer of a 767, and one captain had just completed 767 school. None of the DC-9 pilots in the study had MD-88 experience (see Figure II-2 and II-3). The past or present 767 experience is noted in brackets at the end of the comment.>

The traditional A/C can be set up for departure and changed much easier and quicker than the glass A/C. Once we are out and on our way, the glass cockpit provides much more information and closer tracking tolerances than traditional A/C. It's harder to change route in the glass cockpit. I prefer the large HSI of the 767/757 over the smaller one on the MD-88. Approaches are easier with the extended runway centerline and less chance for wrong airport landing under visual approaches with the glass cockpit. 3 [former 767 F/O]

You stay more on top of situations and airspace around you in the traditional cockpit. Glass cockpits are fine if all goes as planned, and the programmed information is correct. It is disconcerting to have your head down reprogramming when you're descending into busy airspace. Likewise, to delay departure because you are re- or re-reprogramming your magic for ATC changes, or disagreement with its internal workings. Glass cockpits can be very boring - to distraction - when you're cleared direct in the dead of night. But they can ease the workload when you know what lies ahead. I prefer doing instead of watching, yet I do appreciate the split-second support the magic can provide. 4 [former 767 F/O]

The glass cockpit gives one so much more information in one picture that mental time can be used on the big picture. In a conventional cockpit much of the time is spent visualizing where you are and where you will be. The glass cockpit gives you the entire picture, as well as wind vectors, climb and descent crossings. Automation in glass cockpit allows you to manage the aircraft and spend time planning. Traditional is more hands-on, so while you are trying to stay ahead, you must spend quite a lot of time monitoring what is happening now. 5 [former 767 F/O]

The glass cockpit has a much lower workload en route. The tedium of frequency changing, course setting, estimate making, etc. is all gone. The downside is that the pilot can drop out of the loop mentally. This is not so much a problem at cruise, but finding yourself out of the loop on an approach when computer dumps can be disastrous. The temptation to re-program at this point can be overwhelming and also very dangerous. (We don't emphasize enough the choice of switching to manual nav at this point.) In the traditional cockpit, there is less automation, and thus less risk of finding yourself lost. One must stay in the loop just to get the basic job done...but overall capability is decreased at a price. On balance, the glass cockpit is highly desirable and a great safety advance, if training emphasizes the dangers of over-dependence on the displays. 7 [Former 767 F/O]

I just checked out on the 757/767 in February <questionnaire received March>. I have to qualify my answer with the fact that I only have one month line experience on the 767 and things are still new to me. The FMC programming is not as compatible with the ATC system as it should be. Too many times ATC clearances are not as exact as FMC programming. Rather than giving a direct clearance, ATC gives you an airway intercept. It takes more steps to program - it's easier to pick up a map. The FMC is great for en route clearances and low density areas. There are too many changes to make in high density arrivals and departures. The VNAV is not very smooth in making crossing restrictions. 24 [New 767 F/O] <Note: prior to the completion of this study, the company recognized this problem and put more emphasis on choice of automation level in the training program>.

I have just finished training on the B-767, but have not yet started flying it on the line. I do have some observations though. I like very much the technology of the 767. However, I think an error has been made in the philosophy of flight training's approach to the use of that technology. We are basically instructed to use the auto systems all of the time. Here I disagree. While we need to be thoroughly familiar with the use of all the systems on the glass cockpit, we should also be encouraged to often fly the aircraft using only raw data (DC-9 type) instrumentation. I think with all the emphasis on automation there is a subconscious tendency for all pilots to feel somewhat removed from the operation of the aircraft as the "computer system" takes over. Complacency could be a result. For sure greatly degraded basic instrument flying skills are a result. 39 [767 captain just out of training]

The single largest drawback to the glass cockpit is the amount of time required to feel comfortable and proficient with the systems. Once you learn to scan and assimilate all the wealth of information supplied by the glass cockpit, it becomes highly beneficial. The autoland capability of the 767/757 is truly an asset (likewise the L-1011 autoland). I miss not having such a system on the DC-9. 41 [Former 767 F/O]

For the first 20 years of my flying career my experience was restricted solely to traditional cockpits. I felt comfortable knowing that whatever needed to be done would only be done if I did it. It was easy to understand the concepts and equipment and the major challenge was to develop your own physical skills to a point where they measured up to your own lofty expectations. Now that I'm a captain, I am primarily focused on the safe completion of a flight, rather than impressing myself or someone else with finesse and perfection in physical flying skills.

From this vantage, I like the assistance that the automation gives in that it allows more attention to be given to the "big picture", rather than concentrating on physical details.

The problem obviously is that on rare occasions, there is an equipment malfunction, off-route clearance in a busy ATC environment, or weather problem that necessitates reversion to a manual mode. This gives you a great deal of simpatico for a fish suddenly hauled out of water. Charts fly, blood pressure rises, and confusion reigns supreme. With 20 years of experience flying manually, I was able to cope with the occasional misfire. My concern is with people who in the future will have less and less of a reservoir of experience to fall back on.

My other concern is with the transition period into the glass cockpit. Six months and 300 hours into the transition period, I felt extremely comfortable with and confident in the new technology. In fact, I would still go back to the 767 in a minute if seniority allowed it. The first six months was a period of slow assimilating the new way of flying. I felt like a world class marathoner trying to ride around on a bike and getting tired. Different skills were required to do the same task, and it seemed quite frustrating and confusing.

Another concern is that making the airplane do what you want it to do by pushing buttons becomes almost an end in itself. You have some difficulty ascertaining that line where you need to give up on controlling the magic and concentrate on controlling the airplane by whatever means necessary. This is also a concern below 10,000 feet where you can easily become enthralled with pushing buttons and monitoring the magic and forget to concentrate on such real hazards as uncontrolled aircraft and flocks of birds.

I only flew the 767 for one year, but toward the end of that time, after 600-700 hours, another potential problem became apparent. After you spend six months figuring out how to efficiently operate this marvelous machine, you start developing a deep appreciation and respect...almost awe...of it. You monitor it hour after hour and it functions perfectly and you soon realize that it can fly longer and more perfectly than you will ever be able to do. After a while it's difficult, bordering on the impossible, to monitor it the way you would a fellow crew member. After all, you know that a fellow crew member is going to foul something up once in a while, so you keep alert knowing that you may need it for ammunition for the times when he catches you in a foul-up. It makes a nice little mental game and keeps you both sharp. With the computer, there's so few glitches that the mind finally just gets overwhelmed with monitoring and goes into the ignore mode in spite of all your best efforts to the contrary. 67 [former 767 F/O]

By far the biggest advantage of the glass cockpit lies in the HSI map mode. The ability to orient ones self at a glance instead of relying on the mental gymnastics of bearing and DME, which requires constant updating (and the added burden if the VOR is co-located with the airport) frees one to concentrate on other aspects in the approach environment. I think the company should emphasize (encourage) the importance of each pilot hand flying a raw data approach at least once during every rotation--especially on the 767/757. In my three years on the 767, I was amazed at how few pilots went back to the old compass rose and flew raw data. It was a humbling experience every time I did it, but it was a good reminder that the "old ways" are still there as a backup. I had one experience with a bad DME signal in Boston that skewed our map by over 15 miles on an approach to R/W 4R in

low weather conditions. Otherwise, the system worked flawlessly.
74 [Former 767 F/O]

8. Please feel free to add anything else that you think we should know about the human factors of your flying job.

MD-88 Crews

Overall, the MD-88 is a big improvement over older generation concepts. If the pilots are not prone to complacency, it is much safer in the MD-88, as well as more efficient. It is up to the pilots, however, not to let their attention lapse to a point where they let the A/C do things that are not intended. It is easier to stay ahead of the MD-88 than on other A/C, but it is not automatic. 10

Stress keeps going up. I am afraid of making any kind of mistake for fear of losing my livelihood. I am human and we humans are not error free, yet we keep going with the opposite assumption, and when we do make an error, we are therefore punished even though there may be a reason for us doing this. We look at what error was done instead of trying to understand why it was that we were placed in a situation where the likelihood of an error being committed was greater. Radios are the weakest link in our system, yet we run our operation as if they will always work. When you really need the readback procedure to work on ATC, which is when you are busy, it's a joke. When you are busy the controller will usually miss a wrong readback. He too is task-saturated and is no longer listening -- he is thinking of the next command he must issue. 11

I would like to see a study of the duty day, including: 1) the number of legs per duty period; 2) rest breaks during a duty period. Some of our trips have 12-hour days with at most a one-hour break between legs with an A/C change. This leaves no time to eat during a long duty period, especially in bad weather; 3) rest breaks between duty periods. 18

I feel that there is a definite difference in the copilots that have flown copilot on traditional cockpits and then moved to the automated; as opposed to copilots that have just flown the automated cockpit. The former are more aware of the outside environment and flying the airplane. The latter are much more concerned with using the automation efficiently, but forget that we don't fly by ourselves. I also feel that we need to constantly practice flying airplanes. We need to make raw data approaches and takeoffs. That is how we get our feel for the airplane. I hope that the new automation does not become a crutch rather than a tool> 19

I strongly believe that the 3-man crew was lost to purely economic considerations, at a real safety loss. We gave up the redundancy of human factors. When the "going gets tough" for 2-man crews, the pilots often operate almost independently, unable to monitor each other. On three-man crews, I always felt that one pilot could concentrate on "aviating" and the other two pilots could run the appropriate checklists, trouble-shoot, etc., while double-checking on one another! The MBAs have won again! 21

With the advent of more complicated electronics and nav aids, we are advocating that the pilot not flying make all changes on the flight guidance control panel, flap position, radio frequencies, lights, ignition, anti-ice, etc. This further complicates matters for the pilot flying (hand flying) in that it takes time (albeit a short time) for the brain to put a name on a particular control to be moved, verbalize the control and movement. Then reception, processing, and reaction time of the pilot not flying come into play. The comment from above is "think ahead". If we could always foresee the future, instantaneous reaction of the pilots would not be necessary. 22

Pilots need to remain proficient in all levels of automation with respect to the aircraft. A pilot needs the ability to go to "Plan B" in the event of any kind of automation failure. Company policy should promote this philosophy of periodically using no autothrottles, no flight director. This would help keep those skills in tune when the automation fails. 35

The absolutely worst human factors problem in our business today is the continued scheduling of crews with late night and early morning duty periods within the same rotation, as well as the month's schedule. For example, I had one trip when I arrived in California at 1:00 a.m. (4:00 a.m. EST). Then a day later I had to get up in CVG at 4:15 a.m. for a 6 a.m. departure. No matter how automated we get the cockpit, until these scheduled duty times are addressed then there will always be stress and mistakes created by factors that only managers have control to change. We as pilots have tried for many years to correct this and still see it in the 90's. 53

Fatigue is a problem in flight crews of any aircraft type. The problem with automated cockpit crews is that they tend to rely too much on the aircraft when fatigued. For example, when I am tired I don't monitor altitudes in climbs and descents as closely as I should to ensure altitude captures. The point I am trying to make is that will all the technology available today, I feel that more emphasis should be put on ways to provide safeguards in cockpit automation to assist fatigued crews. The MD-88 is definitely a step in that direction, but more should be done to increase its reliability. 56

I retire in nine years. If the glass cockpits are the future, I'm glad to be retiring. Continuous automation does result in a deterioration of flying skills, and the big problem is what do you do when the electrons quit? Will a pilot still remember basic flying skills? I fly with copilots now who get upset and have difficulty handling the A/C if the flight director is off. They're hooked on the steering bars. Without them, they're lost. ATC is also a problem. A lot of new hire controllers know nothing about airplanes, and especially do not realize that 250 kts. at 28,000 feet is not the same as 250 kts. at 10,000. I am also receiving a lot of ambiguous clearances from controllers these days. I'm not sure what their standards are, but I know they need to be raised. The quality of new hire pilots is still good, owing to my company's preference for ex-military types. Experience is still very important in this business, and it's the real reason the system isn't more dangerous than it is. 57

The current training policy when switching aircraft is ridiculous. I was trained for the 767 from October 8 to November 15, then I went back to the MD-88 from them till December 31. Then on January 7 I am on the 767 again. With the complex cockpits and systems of today's planes, do they really expect me to stay proficient in one plane while training in another? 58

I feel increasing mental strain due to the legalistic climate today. Though I do my best personally and attempt to foster good communications and coordination with my fellow crew members and other company employees who are part of this team, it seems that this may not be enough to satisfy the FAA or the press should a decision of mine be questioned. For example, taxiing at BHM for flight to ATL, "autospoiler inop" messages is displayed on OAP. We stop, check the POM, reset the C/Bs as directed, but the message is still displayed. Next we check the MEL as directed for landing weight penalty and description of items to comply with in order to fly the aircraft with this message displayed. Requirements include: A) Do not arm autospoilers for T/O or landing; B) Do not arm autobrakes for T/O; C) Autobrakes must be placarded (MCO sticker applied). Do we: 1) Return to the gate to have MTC apply placard? 2) Comply with A and B and write up malfunction, continue to ATL, and have MTC apply placard there? I feel that option 2 is no less safe than option 1, but in today's climate I chose to return to the gate. This all took place in a recent LOFT, so it didn't cost the company any money or inconvenience any passengers, but my concern is the effect on the system this sort of thing is going to have. 60

The job today is not what it was 20 years ago when I was hired. Today there are many factors combining together to erode the satisfaction and esteem we once enjoyed in this career. Sometimes we pilots have been our own worst enemies. I've never heard a doctor tell people that open-heart surgery is a piece of cake. Yet pilots routinely play down the demanding tasks that we are called upon to perform. A Cat II approach in a blizzard with cross winds, snow and ice covering the runway, and a generator inop - "Aw shucks, Miss, there ain't nothing to it. Any monkey could learn this." In my career I've been through a fuel crisis, controller strike, two recessions, and deregulation. That was nothing compared to the current frenzy over drug testing, security screening, leveraged buyouts, and checklist changes. We at this airline are fortunate that we have such a strong company. Yet we feel the trickle-down effects of these things none-the-less. The more automated the A/C becomes, the more my role changes from <u>pilot</u> to <u>flight manager</u>. The best system I've heard of is at Air Alaska. The bought head-up displays (HUD) for their 727's which allows pilots to <u>hand fly</u> a Cat III approach! In summary, the airline pilot job is not what it used to be. But we all go through changes in life, so what's the big deal? Well, when frustration levels are increased at what point is job performance adversely affected? 85

DC-9 Crews

You should have done this <experiment> prior to the manufacturers and airlines dumping millions into the development and purchase of all this fancy stuff. I prefer the close coordination of the 2-man crew. However, in emergency situations I would prefer three men (hijackings, emergency descent for structural problems, any type of situation that may require one person out of the cockpit). Having one person left to work radios and possibly operate systems (especially abnormal systems) is too much for a safe operation. 4

Look into the scheduling practices of various airlines. It seems that everyone wants to get his pound of flesh out of the crew: the company, the passengers, the news media, the FAA, the NTSB, the courts, the taxing authorities, airport security, and DOT (with the drug testing). Pilots have to overlook all this pressure and still do a safe and professional job. All of this takes is toll mentally and physically. 6

Scheduling trips with long days and short layovers and back side of the clock <night flights> that include landing in the early morning and flying another leg do not lead to a very safe operation. Too much time is being taken away from aircraft training and used for CRM and security training. 24

Pilots and flight attendants should be scheduled together. At least all day, but entire rotations or even an entire line for a month would help team building and allow the entire crew to work together much better. Sometimes we'll see five crews a day. this does not make our job any easier. It would be nice to know the people we work with long enough to know their names. Another airline schedules crews together, so the "inefficiencies" argument doesn't hold a lot of weight. Without exception all of the F/As and pilots I have talked to agree with me. 26

I feel that now the most irritating part of my job is the ATC environment. Specifically the lack of coordination that goes on between controllers. It seems that each controller sequences his traffic according to a letter of agreement rather than the next controller's ability to handle the aircraft. This is evident when you are switched to a new controller and he/she asks why you are going so slow/fast. 28

F/Os need to realize that they have a ticket that can be taken away and a job that can be lost. If they are too meek to criticize me when I am screwing up, they will have to pay the consequences. I try to point out that I'll be making mistakes and they must call them to my attention. No one pilot can do it all by himself. 38

Why are we so tired after a three or four day trip? The day after a hard trip you feel almost poisoned. It's not a "good tired", such as results from hard manual work. Rather it is a harsh feeling that seems to go all the way to the bone marrow. I've never understood this. Our work is not hard physically and it's not all that stressful mentally. Find a cure for this and you can retire early. 39

I think that more emphasis needs to be placed on studying the physiological effects of poorly conceived flight rotations with continually changing sleep cycles, inadequate rest periods, and lack of opportunities for proper nourishment. Being tired, dehydrated and hungry probably plays a much larger role in crew effectiveness than the type of automation we employ. 41

1) Lack of food on some flights with long duty days, or early/late flights when food service is closed. 2) Work days - early one day, late the next. More attention should be paid to diurnal cycle by scheduling. 3) Get the reporters (news) and lawyers out of the cockpit. Flight recorders (cockpit) are 100% off limits until after all investigation is over and finalized. 4) Spend FAA money to upgrade all runways used for commercial aviation, with a minimum of: VASI, R/W markers with 1000 foot length remaining, ILS, VOR/DME on all airports. The money held by the government in the Airport Fund <Aviation Trust Fund> to help balance the budget figures doesn't do much to help safety. 49

There has to be some way to improve communications between ATC and the airplane. A voiceless system using an up/down link with visual screen and printout (if desired) would be great. Don't overload pilots with senseless, repetitious checklist items, briefings which are often not listened to. Callouts are for the benefit of the CVRs. All in all, we're a more standardized pilot group which is good. However, let's not cross over a common sense line and run a SAC <Strategic Air Command> type operation. It's still a fun job - let's keep it that way. 51

In the Marine Corps in Viet Nam I sometimes flew over 90 hours per month. As a commuter airline pilot and flight instructor I flew nearly 100 hours some months. As a corporate pilot I flew about 35 hours a month. With this company I have flown all full contractual months with few exceptions for 14 years. My conclusion? 35 hours is about minimum for staying sharp, more than 80 is too much. Additionally, I believe that rotating shifts, disrupted sleep patterns, back side of the clock flying, etc. is highly deleterious and should be treated as such for scheduling purposes. 67

In today's flying you almost need a lawyer in the jumpseat. Any mistake (including the wrong foods for a positive drug result) can cause a loss of license. Flying is not so hard, but keeping up with all the rules and being afraid to make a "mistake" can cause an upset stomach. I've never known of a pilot who deliberately made an error. Yet there is a feeling of having the screws tightened more and more, so no possible human error can occur. That is a wrong assumption the on the part of the public, press, FAA, and the government. Working in a hostile environment is not all that much fun, and it's very tiring, leading to possible "errors" on the pilot's part. It is tough to keep awareness at 100% while always looking over your shoulder and being second guessed. 80

VI. DISCUSSION AND CONCLUSIONS

A. INTRODUCTION

This volume outlines the purpose, rationale, and methodology of this study, and reports some of the data collected in a simulator experiment, as well as from a questionnaire. At this writing the analysis of most of the data generated by the simulator experiment has not been completed, and will be reported in subsequent volumes of this report. Accordingly, the experimental data reported here do not allow the authors to draft conclusive results: this will have to await the analyses which will be reported in Volumes II and III, and summarized in Volume IV. Indeed, the primary questions which prompted this study, a need to understand differences between traditional and advanced technology cockpits with respect to crew coordination and communication, will not be addressed in this volume.

Nonetheless we shall summarize and comment on the information reported here, as we believe that even in its incomplete state, the data reflect on the basic questions and hypotheses that motivated this study.

B. SIMULATOR (LOFT) RESULTS

In this section we shall discuss the results of the LOFT experiment covered in detail in Chapter IV. The reader should keep in mind that the purpose of the LOFT experiment was not to pit one aircraft model against another and declare a winner. It would better be described as an opportunity to determine the relative strengths and weaknesses of a traditional and a high technology version of the same basic aircraft. In short, it should be regarded as an exploration, not a contest.

Had it been a contest, it would have been a somewhat unbalanced one, for as we have pointed out in Chapter II, the DC-9 crews were considerably more experienced in their aircraft than those in the MD-88. Although the DC-9 pilots had more flying time in their aircraft, both with respect to hours in type and months in type (see Chapter II), their total flying time was actually slightly less than the MD-88 crews (the difference being statistically non-significant). Also, statistical analyses within fleets found no correlation between performance measures and time-in-type.

The LOFT scenario described in Chapter III was designed to be both realistic and fair to all crews. That is, we attempted to construct a LOFT that would not, in any way that we could predict, favor either the traditional or the high-technology aircraft. The electrical systems that were failed and the abnormal procedures for combating the failures were virtually identical in the two aircraft; the other problems dealt with weather and decision-making, which was essentially aircraft type-independent.

If there was one factor we attempted to build in, it was that the LOFT be communication-intensive. We believe that we accomplished this. The LOFT was highly demanding of the crews, but within the bounds of realism, and appeared to meet the goal of requiring a highly coordinated effort between the two pilots. The combination of the electrical problems, deteriorating weather both at the destination and potential alternates, and clearance into a somewhat irregular unpublished holding pattern created a high workload atmosphere throughout the flight, and the need for a well coordinated cockpit. A "one-man show" probably could not have completed the LOFT successfully.

The fact that the LOFT scenario was communication-intensive provided those crew members who had been through the company's new CRM program the opportunity to practice what they had learned. Even those who had not yet taken the course were certainly aware of it, and mindful of the lessons that they would soon learn. We will have to await the publication of Volume III to gain insight into how the crews of the two very different aircraft handled their cockpit communications demands.

Workload

One of the significant differences produced by the LOFT data was that MD-88 pilots, using the NASA Task Load Index (TLX) rated their own workload as higher than did the DC-9 pilots. This finding is somewhat consistent with the information obtained on the questionnaire (see Chapter V, Section D, particularly open-ended question No. 5 on workload. See also open-ended question No. 7, for pilots who have flown both a traditional and a glass cockpit aircraft.) Although there was great diversity of opinion, it was generally felt that in spite of some of the obvious advantages of the glass cockpit (e.g. the HSI map mode display, the superior autothrottle, etc.), the workload in the MD-88 could become excessive.

This was also consistent with the findings of previous field studies in automation (Curry, 1985; Wiener, 1985, 1989), where pilots of the advanced technology aircraft expressed the feeling that during periods where the workload was high, the automation increased the workload, and where it was low, it tended to reduce workload.

The concern over workload in the modern cockpit was also consistent with opinions of crew members in the host airline's 757/767 and MD-88 fleets whom the first author spoke with during jumpseat observations. The typical comment, heard repeatedly during interviews, almost to the word, was "I love this airplane, love the power and the wing, and I love this stuff (pointing toward the mode control panel and CDU), but I've never been so busy in my life." At this point they often add, "But some day it (automation) is going to bite me." The word "busy" and the sentiments just quoted appear over and over in the lexicon of the glass cockpit pilots, even though as seen above, their overall view of the aircraft is highly favorable.

Just as the word "busy" appeared so often in the conversations and open-ended questionnaires of MD-88 pilots, the word heard and seen over and over in the opinions of DC-9 crews was "simple" (and "simplicity"). The DC-9 pilots repeatedly described their aircraft, its systems and operations, as "simple." (Note: many of the attitude items reported in Chapter IV address the question of workload and automation.)

The reasons for the subjective feeling of excessive workload in the modern technology aircraft has been explored in the previous field studies (see references above), and need not be repeated here. We would mention that the LOFT portion of this study essentially validated both the problems and strengths of cockpit automation reported in previous NASA research, and gave emphasis to the words of previous authors (Wiener and Curry, 1980) regarding the necessity to allow pilots to work out their own solutions to problems, within reason, employing automation, or turning it off, as they see fit.

An interesting example was the entry into the holding pattern at Columbia. This was a demanding procedure, which was required by ATC due to the presence of a no-radio (NORDO) aircraft in the vicinity of Columbia VOR (CAE). The crews were just coming off of a missed Category II approach, and had to copy their clearance and plan their entry and holding pattern. For the DC-9 crews, there seem to be few alternatives and little trouble. They simply dialed the radial on their VOR course selector and with this and DME flew by basic airmanship into the holding pattern.

For the MD-88 crews, there were alternatives. They could fly the entry using basic airmanship and VOR navigation, much as the DC-9 pilots had done, or they could turn to the CDU holding page, set up a waypoint to be used as the holding fix, and fly via direct intercept to the holding fix, then allowing the FMC to establish their holding pattern, and hold automatically. Many of the MD-88 crews that attempted this did so correctly, and exploited the full benefits of automatic holding. However, several crews had difficulty entering the unpublished holding pattern into the CDU, or got "behind the airplane" and could not catch up, and got lost on the entry.

Perhaps the smoothest and safest performance of this task came from those MD-88 crews who combined basic airmanship with automation. These crews elected to ignore the hold page and FMC-based navigation in general, and manually selected the VOR and radial much the way the DC-9 pilots had done it. They then flew manually or at a lower level of automation (e.g. autopilot, heading select, and altitude hold). Upon crossing the holding fix and establishing their inbound leg, they then turned to the hold page and assigned the FMC the task of establishing and maintaining the holding pattern.

This type of performance, with a crew (presumably the pilot flying) deciding when to use automation and when not to, has been an issue in management and training in the last decade. One extreme policy has been to require that the crews utilize the automation. Pilots in previous field studies have referred to this management policy as "We bought it, you use it." Many pilots in this and previous automation studies have been critical of their transition training for an alleged over-emphasis on automation, on teaching only how to use, rather than whether to use, various features of the available automation (see open-ended question No. 3).

Curry (1985) urged training departments to offer what he called "turn-it-off training." It would appear to the authors that this particular portion of the LOFT experiment, and the various solutions attempted by the crews, brings this problem into focus, and validates the recommendations of Wiener and Curry. About a year after the LOFT study, two airlines, Delta and Federal Express, promulgated their own "Philosophy of Automation" (see Appendix 4). Delta's philosophy is clearly consistent with the view that flight crews should have discretion, within the bounds of reason, to use or not use automation, consistent with their views of the best and safest way to perform a maneuver.

Perhaps out of these studies and the examination of the question by Delta, Federal Express, and other airlines will emerge a new doctrine: "We bought it, you decide if and when you wish to use it." We would endorse such a management policy.

Crew Performance Ratings

The three measures of crew performance as judged by the expert raters, the LOFT instructor and the NASA observer, produced few statistically significant contrasts. Where significant results were found, they again favored the DC-9 crews over the MD-88 crews. The crew composite ratings from the Overall Rating Form filled out by the NASA observer revealed significantly higher (18 per cent) ratings for the DC-9 crews. On the Detailed Rating Form the DC-9 crews again were seen as superior, though the difference (about 8 per cent) fell just short of statistical significance. On the CRM Evaluation form (sometimes called "Line/LOFT" form) no differences between aircraft models were detected. The interpretation of these between-model differences will be discussed later in this chapter.

It is interesting that so few contrasts produced significant differences on the crew rating scales. It is not easy to interpret the failure of the captain versus first officer as pilot flying to produce differences. There was in our LOFT plan a defect that may have diminished somewhat the potential of this variable. At this airline the first officers are not permitted to perform the duties of PF on Category II approaches. As a result, at the point in the flight to Columbia where it was ascertained that the weather required a Category II approach, in those crews in which the first officer had been the PF, the captain had to take back the PF role for the approach. Following the missed approach, some captains gave it back to the first officer, but most elected to remain as PF for the holding pattern and the diversion to Charlotte.

As a result of this transfer of duties, our ability to assess differences in crews with the duties were assigned to captain or first officer suffered during one of the critical points of the flight. Differences between these conditions may emerge from our analyses of crew coordination and communication (CRM), which will be covered in Volume III.

In an analysis of reports to NASA's Aviation Safety Reporting System (ASRS), Orlady (1982) found not a superiority in one or the other conditions, but the fact that certain types of errors prevailed under each condition. For example, when the captain was the PF, there was a greater number of reports of near mid-air collisions (NMACs), takeoff anomalies, and crossing altitude deviations. When the first officer served as PF, there were more altitude deviations, NMACs during approaches, and landing incidents. Orlady's study was completed before the appearance of the current generation of high-technology aircraft, and we do not know of any study of the combined effects of PF/PNF duty assignment and cockpit automation.

Crew Errors

In spite of the higher performance ratings of the DC-9 crews, no such differences could be found in our analyses of error data. Our experimental hypothesis, based on the field studies of Wiener and Curry, including interviews and questionnaires by pilots of advanced technology aircraft, was that cockpit automation generates more serious errors than traditional technology. Thus we expected to see, among crews flying the same LOFT scenario, not necessarily a difference in the number of errors, but a different error distribution, namely for the MD-88 crews a higher frequency of the more serious errors in our three-way categorization of error severity. The reasons for this hypothesis are discussed in Wiener and Curry (1980), and Wiener (1988, 1989). To put it very briefly, it is in the nature of digital systems to invite more serious errors, due primarily to the opportunity to make blunders in digital input, but due also to the relative lack of "coupling" of the pilot to the machine in the highly automated models, and the lack of feedback inherent in many automated systems in aviation and elsewhere.

While Wiener and Curry felt that they had some basis for such a prediction, still there had not been an experimental evaluation of the types and severity of errors that would be produced by the two levels of technology. We believe that this is the first attempt to verify experimentally the automation-severity of error hypothesis. As the data reported in Chapter IV indicates, we failed to find support for the hypothesis in this experiment. Table IV-4 and the analysis of variance of these data reveal no differences in mean number of errors between DC-9 and MD-88 flights, nor is there a significant difference in the distribution across the three severity classifications. Likewise the error analysis performed by the NASA observer, who rank-ordered the severity of the errors committed by DC-9 and MD-88 crews, showed that the mean error severity of the two aircraft to be essentially equal.

It is true that we found no support for our hypothesis that the more automated aircraft would generate more severe errors. However, it is equally important to take note of the fact that the opposite hypothesis, that automation eliminates human errors by eliminating their source, oft stated by the producers and supporters of automation, found no support from this experiment. It is long been the dream of traditional engineers to "automate human error out of the system." To the degree that this experiment represents a realistic simulation of a highly demanding airline flight segment, we find little to comfort those who see automation as a cure for human error.

C. CONCLUSIONS

What does this say for automation? Granted that the MD-88 crews were less experienced in their aircraft, it appears that where differences exist, they favor the performance of the traditional technology air crews. As to the difference in experience levels, our sample of pilots actually represent the real world of line flying, in that for at least the next few years, the pilots of advanced technology aircraft will have less time in type than those flying traditional aircraft. The MD-88 crews did, however, have equal (actually slightly higher) total flying time than the DC-9 pilots. In the years to come, these differences will be less apparent: the advanced technology aircraft will no longer be the "odd balls" of the fleet, but will be the mainstay. And accordingly, their crews will have time in type approaching that of the pilots in the older aircraft. We say "approaching" because for several years, until the traditional planes are retired, the phenomenon of DC-9, B-737-100 and -200, and particularly B-727 pilots, who spend many years in the same cockpit and accrue a vast amount of time in type, will remain. The 20-year B-727 veteran can be found at almost any airline.

Setting aside the differences in experience in type, we ask why advanced technology has not served its pilots better?

The pattern of results provide only weak evidence of either higher workload or poorer performance among the MD-88 crews. The statistical contrasts critical to our experimental hypothesis failed to provide statistically significant differences. Analysis of the observer's detailed ratings only approach traditional statistical significance criteria, while instructor ratings and errors are in the same general direction but are nonsignificant. We have identified either an overall effect of substantially lower magnitude than those seen in previous investigations or a problem that occurs only in narrowly defined situations.

We would have to conclude that, with the exception of the overall ratings of crew proficiency, we have failed to find reportable difference between the performance of DC-9 and MD-88 crews, and thus at this point cannot draw any inferences about the effect of cockpit automation on the ability of qualified crews to fly a difficult mission. We have failed to produce evidence to support our hypothesis that automation would generate more serious errors. Clearly one may also conclude that we have not produced a case in favor of high technology cockpits --- that the crews of the DC-9, a product of mid-1960 decade technology, performed just as well as those flying a very advanced, very expensive, modern technology aircraft.

D. EPILOGUE

Aviation safety is a living, growing, constantly changing enterprise. Times change, new problems emerge, new equipment appears, and the industry enjoys a steady improvement in machines, materials, training methods and devices, maintenance, information, procedures, supervision, and management. Many of the problems pointed out in this report and in subsequent volumes in this series have already been remedied.

Certain portions of this report, mainly the discussion of errors made both on line flights and in our simulation experiment, involve self-criticism. It is a testimonial to the dedication of the management of the cooperating airline and the professionalism of the volunteer pilot group that they would share their experiences and opinions with the authors, and hence with the aviation community at large.

The errors and weaknesses reported here should not be viewed as criticism of the host airline and its pilots, but as an example to others of the unselfish efforts on the part of a company and its employees to understand and improve the human factors of airline flight. The willingness to examine, recognize, and report conditions that require remedy is the foundation of flight safety.

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VIII. NOTES AND ACKNOWLEDGMENTS

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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 approximately equals 300 meters, and one mile approximately equals 1600 meters. The male gender has been used throughout this report, as all of the pilot volunteers and LOFT instructors were males.

3. It is assumed that the reader is familiar with aviation terminology and abbreviations.

4. Figure III-3 was reproduced with the kind permission of Jeppesen-Sanderson, Inc.

5. The first author was assisted at the University of Miami by Vincent Chen, Jose Pena, Vanessa Donahue, and Lynn Russell. We also acknowledge the assistance of the following persons at NASA Ames: Michael Smiley, Don Bryant, Mark Allard, Patti Bergin, Asaf Degani, and Elizabeth Veinott.

6. The authors gratefully acknowledge the support of the host airline, which unfortunately must remain anonymous. We acknowledge as well the cooperation of the Safety Committee of the Air Line Pilots Association (ALPA) at that airline. The study would have been impossible without the support of the DC-9 and MD-88 pilots who volunteered to participate. Unfortunately they must also remain anonymous.

7. It was not practical to publish all of the statistical output from this study (e.g. intercorrelation matrices from the attitude questionnaire). Qualified persons may request additional data from the first author: Box 248237, University of Miami, Coral Gables, FL 33124.

8. The opinions expressed in this report are those of the authors, and not of any institution, organization, or agency.

IX. APPENDICES

APPENDIX 1 - RATING FORMS

Form	Filled out by
Participant Survey	Each pilot
Overall Rating Form	NASA observer
Detailed Rating Form	NASA observer
CRM Evaluation Sheet	LOFT instructor

ID Number___________

Participant Survey

Please fill out this short survey to give us your opinion about the LOFT scenario you have just completed.

Crew Position (circle one) **CAPT** **FO**

1. Were you aware of the events and problems presented in this LOFT prior to participating today?

____ No information about any aspect of it.

____ Slight familiarity with problems and events.

____ Considerable familiarity with problems and events.

____ Detailed information on problems and events.

Please evaluate the work or effort required by the scenario using the scales below. A general definition is provided for each scale.

2. **Mental Demand:** How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Low 1 2 3 4 5 6 7 High

3. **Physical Demand:** How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low 1 2 3 4 5 6 7 High

4. **Temporal Demand:** How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Low 1 2 3 4 5 6 7 High

5. **Performance:** How successful do you think you were in accomplishing the goals of the task provided by the LOFT? How satisfied were you with your performance in accomplishing these goals?

Perfect 1 2 3 4 5 6 7 **Failure**

6. **Effort:** How hard did you have to work to accomplish your level of performance?

Low 1 2 3 4 5 6 7 High

7. **Frustration Level:** How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

Low 1 2 3 4 5 6 7 High

OVERALL RATING FORM

Crew Number/Date ________/________

Aircraft DC-9 MD-88 (circle one)

Evaluate the crew as a team on each of the following items:

CREW COMMUNICATIONS AND DECISION MAKING

1. Communications were thorough, addressing coordination, planning, and problems anticipated	Not at all	1	2	3	4	5	Very much
2. Open communications were established among crewmembers.	Not at all	1	2	3	4	5	Very much
3. Timing of communications was proper.	Not at all	1	2	3	4	5	Very much
4. Communications were relevant, complete, and verified.	Not at all	1	2	3	4	5	Very much
5. Active participation in decision making process was encouraged and practiced.	Not at all	1	2	3	4	5	Very much
6. Alternatives were weighed before decisions were made final.	Not at all	1	2	3	4	5	Very much
7. Appropriate **immediate** actions were taken when time was not available for **crew** decision making.	Not at all	1	2	3	4	5	Very much

INTERPERSONAL (MANAGEMENT) STYLES AND ACTIONS

8. Crewmembers showed concern with accomplishment of tasks at hand.	Not at all	1	2	3	4	5	Very much
9. Crewmembers showed concern for the quality of interpersonal relationships in the cockpit.	Not at all	1	2	3	4	5	Very much

WORKLOAD AND PLANNING

10. Overall workload	**Low**	1	2	3	4	5	**High**
11. Work overloads were reported and work prioritized or redistributed.	Not at all	1	2	3	4	5	Very much
12. Crewmembers planned ahead for high workload situations.	Not at all	1	2	3	4	5	Very much
13. Appropriate resources were used in planning.	Not at all	1	2	3	4	5	Very much

CREW ATMOSPHERE AND COORDINATION

14. Overall vigilance	Inattentive	1	2	3	4	5	Alert
15. Interpersonal climate	Hostile	1	2	3	4	5	Friendly
16. Preparation and planning.	Late	1	2	3	4	5	Well in Advance
17. Distractions avoided or prioritized	Poor	1	2	3	4	5	Excellent
18. Workload Distributed and communicated	Poor	1	2	3	4	5	Excellent
19. Conflict resolution	Poor	1	2	3	4	5	Excellent
20. Overall technical proficiency	Poor	1	2	3	4	5	Excellent
21. Overall crew effectiveness	Poor	1	2	3	4	5	Excellent

Items 4, 7, 10, 19 and 20 excluded from analyses

DETAILED RATING FORM

Crew Number/Date ________/__________

Aircraft DC-9 MD-88 (circle one)

Evaluate each crewmember. Use the following ratings for all categories:

1 - below average
2 - slightly below average
3 - average
4 - slightly above average
5 - above average
n/a - not observed or not applicable

Items specific to a phase are indicated in **bold**.

PRESTART

	Captain	First Officer	Notes
APU Problem Resolution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC & Ground Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

TAXI/TAKEOFF

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

CLIMB

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

CRUISE

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Descent Planning	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

DESCENT AND INITIAL CSD PROBLEM

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Failure detection	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Workload Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

APPROACH/MISSED APPROACH AND CSD FAILURE

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Altitude Vigilance (Decision Height)	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Workload Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Holding planning and "set-up"	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Failure detection	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Workload Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

HOLDING/CRUISE TO ALTERNATE

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC/Company Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Holding "Maintenance"	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Diversion decision	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Workload Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

APPROACH & LANDING

	Captain	First Officer	Notes
Crew Coordination/Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
ATC Communications	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Plan. & Sit. Awareness	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Procedures, Checklists, Callouts	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
PA & PAX Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Workload Management	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Aircraft Handling	1 2 3 4 5 n/a	1 2 3 4 5 n/a	
Overall Performance & Execution	1 2 3 4 5 n/a	1 2 3 4 5 n/a	

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DELTA AIR LINES CRM EVALUATION SHEET

DELTA AIR LINES

SECTION I: PERSONNEL DATA:

Rater ID # ____________________ Rater yr. of birth ________

Date: Month __________ Year __________ (Do NOT enter the day)

Number of previous CRM seminars? Capt. _____ F/O _____ S/O _____

Number of previous LOFTs? Capt. _____ F/O _____ S/O _____

Base: Capt. _____ F/O _____ S/O _____ Equipment ____________

Please place a checkmark to identify the crew member(s) and type(s) of training or checking being evaluated.

_____ Line Check for Capt. __________ F/O __________ S/O __________ or Crew Audit ________

Number of Takeoffs and Landings observed __________ (Line Check Only)
Total Amount of time observed __________ (Line Check Only)

_____ LOFT (2 hr 30 min) followed by training. **LOFT #** __________

_____ Captain PC + 45 min. CRM LOFT with special crew training. **LOFT #** __________

_____ Other training (specify type and position) ______________________________

SECTION II: CREW RESOURCE MANAGEMENT EVALUATION

			(CIRCLE)					
1.	Briefing: Thorough, establishes open communications, addresses coordination, planning, team creation, and anticipates problems	Poor	1	2	3	4	5	Excellent
2.	Communications: timely, relevant, complete, and verified	Poor	1	2	3	4	5	Excellent
3.	Inquiry/questioning practiced	Poor	1	2	3	4	5	Excellent
4.	Assertion/advocacy practiced	Poor	1	2	3	4	5	Excellent
5.	Decisions communicated and acknowledged	Poor	1	2	3	4	5	Excellent
6.	Crew self-critique of decisions and actions	Poor	1	2	3	4	5	Excellent
7.	Concern for accomplishment of tasks at hand	Poor	1	2	3	4	5	Excellent
8.	Interpersonal relationships/group climate	Poor	1	2	3	4	5	Excellent
9.	Overall vigilance	Poor	1	2	3	4	5	Excellent
10.	Preparation and planning for inflight activities	Poor	1	2	3	4	5	Excellent
11.	Distractions avoided or prioritized	Poor	1	2	3	4	5	Excellent
12.	Workload distributed and communicated	Poor	1	2	3	4	5	Excellent
13.	Overall workload	Low	1	2	3	4	5	High
14.	Overall TECHNICAL proficiency	Poor	1	2	3	4	5	Excellent
15.	Overall CREW effectiveness	Poor	1	2	3	4	5	Excellent
	If Observed:							
16.	Management of abnormal or emergency situation	Poor	1	2	3	4	5	Excellent
17.	Conflict resolution	Poor	1	2	3	4	5	Excellent

APPENDIX 2 - ATTITUDE QUESTIONNAIRE

ID Code: ___ ___ ___ ___ ___ ___ ___ ___

Please place your self-assigned NASA ID code above. If you do not know your code, just attach a piece of paper with your name. We will replace your name with the code and destroy the paper. Once all the questionnaires are in, we will destroy the only ID-to-name list once and for all. Where we use the shorthand DC-9/MD-88, take that to mean whichever model you currently fly.

If your aircraft or seat assignment changed since you joined the study last summer, what is your current aircraft and seat? Reply only if there has been a change.

aircraft ___________ seat ___________

I. AIRCRAFT EXPERIENCE

We would like to know your past experience in your company's turbojet aircraft. Please consider your experience <u>only at this company</u>. Place an "X" in the box for each seat on each aircraft that you have ever occupied. Do not put flying time.

	SEAT		
	Captain	F/O	S/O
DC-9			XXXXXXXX
MD-88			XXXXXXXX
B-737			XXXXXXXX
B-757/756			XXXXXXXX
B-727			
DC-8			
L-1011			
DC-10			
B-747			

1. Which seat in which aircraft did you occupy immediately before going to DC-9/MD-88 school?

Aircraft ___________ Seat ___________

2. Approximate total flying hours at this company (include S/O)

_______________ hours

3. Approximate hours DC-9 __________ MD-88 ____________

3a. How many months has it been since your DC-9/MD-88 transition to your present seat?

______________ months

4. What do you consider the most advanced aircraft (with respect to instrumentation, avionics, automation etc. that you have flown? Include military or other employers:

ans: _____________________

5. Do you own a home computer? (Y/N) ans: ________

6 If yes, what type? _____________________

7. MD-88 ONLY: Please indicate the approximate number of autolands you have made (either as PF or PNF) in the last year (1989).

Number __________

8. Approximately how many actual Cat II or III approaches have you made (as PF or PNF) in the last year (1989)?

Cat II ______ ; Cat III ______ (MD-88 only)

9. Approximately how many non-precision approaches (as PF or PNF) have you made in the last year (1989)?

VOR ________ LOC __________ ADF __________

10. If the money and quality of trips were all the same, what would be your first choice of plane to fly in company's <u>present fleet?</u>

Aircraft: ______________

II. ATTITUDE-TOWARD-AUTOMATION SCALE

This is a 28-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."

Answer all questions based on your present aircraft. That is, if you now fly the MD-88, but once flew the DC-9, answer as an MD-88 pilot. Where we use the shorthand "DC-9/MD-88", we mean whichever one you are currently flying.

For the purpose of these questions, consider the word "automation" to mean autopilots, autothrottles, flight directors etc. in the DC-9; and in the MD-88, the more advanced flight guidance and controls as well.

1. Flying today is more challenging than ever.
2. I take active measures to prevent a loss of my flying skills due to too much automation.
3. The DC-9/MD-88 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. As I look at aircraft today, I think they've gone too far with automation.
6. I always know what mode the automation is in.
7. I use the automation mainly because my company wants me to.
8. In a highly automated plane, you run the risk of loss of basic flying skills.
9. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "managing" the flight.
10. I am not concerned about making errors, as long as we follow procedures and checklists.
11. I look forward to more automation - the more the better.
12. I have no trouble staying "ahead of the plane".
13. CRM training is more important for two-pilot than three-pilot crews.
14. Automation does not reduce total workload.

15. It is easy to bust an altitude in today's environment.

16. Flying the DC-9/MD-88 in congested terminal areas such as Washington and New York is not particularly difficult.

17. Training for the DC-9/MD-88 was as adequate as any training that I have had.

18. I am concerned about the reliability of some of the automation equipment.

19. I prefer the two-pilot cockpit to the three-pilot operation.

20. I am concerned about the lack of time to look outside the cockpit for other aircraft.

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

22. Our CRM training has been helpful to me.

23. Some times I feel more like a "button pusher" than a pilot.

24. There are still modes and features of the DC-9/MD-88 automation that I don't understand.

25. There is too much workload below 10,000 feet and in the terminal areas.

26. In the DC-9/MD-88, it is easy for the captain to supervise the first officer.

27. Autoland capability enhances safety.

28. Electronic flight instruments ("glass cockpits") are a big advance in safety.

ATTITUDES-TOWARD-AUTOMATION ANSWER FORM

Referring to the 28 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 28 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					

(Identical response form for questions 14-28 not shown here)

III. OPEN-ENDED QUESTIONS

Note: In the original forms sent to the volunteers, space was allowed between the questions. For brevity this page of the form has been condensed in this report.

Please answer the following questions in your own words.

1. Describe in detail a error which you made, or observed, in the DC-9/MD-88 that could have led to an incident or violation. How could it have been avoided? (equipment design? training? crew coordination?). Please describe specifically what occurred.

2. What can you say about crew coordination on the DC-9/MD-88? What areas of crew coordination/communication need improvement?

3. What did you think of your training for the DC-9/MD-88? What topics should receive more/less emphasis? Any comments on training aids and devices that were used, or needed?

4. Do you like the way the DC-9/MD-88 operates in the ATC environment? Please mention things you have trouble with, and things that work well, in dealing with ATC.

5. What can you say about the overall workload of the DC-9/MD-88 compared to other aircraft you have flown? Include mental workload, monitoring etc.

6. Please list the features of modes of your aircraft flight guidance, instrumentation, and avionics that you like and dislike.

Like	Dislike

7. If you have flown both a traditional and a glass cockpit aircraft (MD-88 or 757/767), please give us your insights into the differences between operations in the traditional and the glass cockpit. (If not, please leave blank).

8 Please feel free to add anything else that you think we should know about the human factors of your flying job.

APPENDIX 3 - SIGN-UP FORM FOR VOLUNTEERS

Name ______________________________ Capt. or F/O? __________

Address ____

City ____

State ____________ ZIP ______________

Home Phone: Area Code (   ) Number ______________

Are you presently an instructor or check airman? ________

How long have you been flying the MD-88 ? ________ months

Total MD-88 flying time __________ hours

Total flying time (including flight engineer), all company aircraft: __________ hours

Make up an ID code for yourself and enter it below. Use any combination of letters and numbers (up to a max of 6). Do not use your Social Security or company pay number, birth date, etc. Insert it in the blank below. The last two positions are for our use. The last indicates aircraft type (DC-9 vs. MD-88). In the next-to-last, insert "1" if you are a captain, "2" if you are a first officer.

The red sticker is for you. Please enter your full eight-character ID and keep it some place convenient. We suggest a log book or Jep manual. If you have questions, please call the Project Director or your Safety Committee.

Your ID code:

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APPENDIX 4 - DELTA AIR LINES AUTOMATION PHILOSOPHY STATEMENT

The word "Automation", where it appears in this statement, shall mean the replacement of human function, either manual or cognitive, with a machine function. This definition applies to all levels of automation in all airplanes flown by this airline. The purpose of automation is to aid the pilot is doing his or her job.

The pilot is the most complex, capable and flexible component of the air transport system, and as such is best suited to determine the optimal use of resources in any given situation.

Pilots must be proficient in operating their airplanes in all levels of automation. They must be knowledgeable in the selection of the appropriate degree of automation, and must have the skills needed to move from one level of automation to another.

Automation should be used at the level most appropriate to enhance the priorities of Safety, Passenger Comfort, Public Relations, Schedule, and Economy, as stated in the Flight Operations Policy Manual.

In order to achieve the above priorities, all Delta Air Lines training programs, training devices, procedures, checklists, aircraft and equipment acquisitions, manuals, quality control programs, standardization, supporting documents, and the day-to-day operations of Delta aircraft shall be in accordance with this statement of philosophy.

APPENDIX 5 - PREVIEW OF VOLUMES II, III AND IV

Listed below is a brief descriptions of forthcoming volumes of this project. Expected publication date is mid to late 1992.

VOLUME II (Everett Palmer, Editor)

This volume will consist of two parts:

1. An extension of the analyses of crew error made during the LOFT flights.

2. An examination of the procedures as carried out by the LOFT crews, and an analysis of workload peaks.

VOLUME III (Barbara G. Kanki, Editor)

Volumes I and II are concerned with flight crew performance, and the relationship between performance and level of automation. In contrast, Volume III deals with group processes, or the means by which flight crew performance is achieved. We may think of level of automation as an input variable, and crew performance as an output variable; Volumes I and II attempt to express output as a function of input. Group process variables may be thought of as mediators between input and output. Mediating processes describe the strategies or behavior styles which differentiate among performances and typically involve communication patterns which are analyzed as dynamic, interacting sequences of behavior of flight crew member. Volume III will chart this mediation activity by a detailed analysis of crew communications from the LOFT exercises. It will explore other group processes related to communication skills, decision making, problem solving, and training countermeasures associated with effective crew performance.

VOLUME IV (Earl L. Wiener, Editor)

Volume IV will be an executive summary of the three previous volumes. It will highlight the findings, implications, and applications of the study. It will be relatively brief, and will be able to serve as a stand-alone summary of the study.

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this study was to examine jointly cockpit automation and social processes. Automation was varied by the choice of two radically different versions of the DC-9 series aircraft, the traditional DC-9-30, and the glass cockpit derivative, the MD-88. Airline pilot volunteers flew a mission in the simulator for these aircraft. Results show that the performance differences between the crews of the two aircraft were generally small, but where there were differences, they favored the DC-9. There were no criteria on which the MD-88 crews performed better than the DC-9 crews. Furthermore, DC-9 crews rated their own workload as lower than did the MD-88 pilots. There were no significant differences between the two aircraft types with respect to the severity of errors committed during the LOFT flight. The attitude questionnaires provided some interesting insights, but failed to distinguish between DC-9 and MD-88 crews. Further information follows in Vols. II and III.

14. SUBJECT TERMS
Automation, Human Factors, Crew Coordination, Cockpit, Crew Communication, Human Error, Workload

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