

1. The first step in the process is to identify the problem or issue that needs to be addressed. This involves gathering information and understanding the context of the problem.

2. Once the problem is identified, the next step is to define the objectives and goals of the project. This helps to clarify what needs to be achieved and provides a clear direction for the team.

3. The third step is to develop a plan or strategy to address the problem. This involves breaking down the problem into smaller, manageable tasks and determining the resources needed to complete each task.

4. The fourth step is to implement the plan. This involves putting the strategy into action and monitoring progress to ensure that the project is on track.

5. The final step is to evaluate the results of the project. This involves assessing the outcomes against the objectives and goals and identifying any areas for improvement.

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**COCKPIT RESOURCE MANAGEMENT: EFFECTS ON
BEHAVIORAL INTERACTIONS ACROSS AIRLINES
AND AIRCRAFT TYPES**



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Cathy Colebrook Clothier

1991

For My Husband and Best Friend,

Brian Lee Clothier

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BEHAVIORAL INTERACTIONS ACROSS AIRLINES
AND AIRCRAFT TYPES

by

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THESIS

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To the others on our research team I must say a hearty "Thank You!" John Wilhelm had the patience of a saint when he taught me not only how to turn the computer on but also how to make it work for me. Fellow students Cheryl Irwin, Sharon Jones, Terry McFadden, and Steve Predmore, in addition to helping me overcome my phobia of computers, were gentle critics and ardent supporters of my ideas. I count them among my closest friends.

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Finally, I must acknowledge the friend who stood by me for better or worse, just as he promised to do nine years ago. Brian Clothier was my anchor during this fast-paced tour. Without his support, I doubt that I would have achieved this milestone.

ABSTRACT

COCKPIT RESOURCE MANAGEMENT: EFFECTS ON BEHAVIORAL INTERACTIONS ACROSS AIRLINES AND AIRCRAFT TYPES

by

CATHY COLEBROOK CLOTHIER, B.S., M.A.

SUPERVISING PROFESSOR: ROBERT L. HELMREICH

Due to the growing concern over human errors playing an instrumental role in aircraft accidents, the Federal Aviation Administration encouraged airlines to develop Cockpit Resource Management (CRM) training programs to address that issue. Baseline data measured crew interactions before pilots were exposed to seminars and simulators. Longitudinal data described behavioral changes wrought by the intervention. Within airline and within fleet data clearly showed that crews were more effective after CRM training. Within airline and across fleet data verified fleet differences discovered by the first method. Technology level seemed to be a cause of the fleet differences for crews performing in simulators. Crew size affected

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performance both on the line and in the simulator. Finally, the across airline and across fleet data, in addition to describing fleet differences, highlighted differences between the behavioral effectiveness of crews in different airlines.

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CHAPTER ONE

Ivan Steiner in 1974 wrote "Whatever Happened to the Group in Social Psychology?" In this article, he identified the roots of social psychology as springing from the study of individuals in small groups. He also bemoaned the fact that the study of groups had fallen from favor at least in part because it is difficult to capture the intricacies of group interactions in an experimental setting. Steiner emphasized the need to study actual groups in realistic settings in order to capture valid, generalizable behavioral dynamics.

From the study of groups, social psychology has grown to encompass and emphasize other areas of work such as the self and attribution theory. Yet our discipline is a dynamic one that encourages applied and pure research to play off of each other. So today we are focusing on the study of small groups again. Thanks to knowledge gained in the experimental areas, applied research in small group interactions is once again in favor. William McGuire (1967) extolled the benefits of applied and pure research when he called for unity between theory oriented research and natural setting investigations. In keeping with what McGuire called 'the best of both worlds in social psychology', my work in the aviation field has involved applied research and an outcome of this study will be a template to use in experimental designs in the future.

More specifically, my work has investigated aircraft accidents. When airplanes crash we obviously want to know why. Was it due to weather? Or was the accident caused by catastrophic mechanical failure as in the case of United Flight 232 which crashed at Sioux City, Iowa without its hydraulic flight controls. Or was the accident due to human error? Government and civilian sources attribute 55% to 70% of all aircraft accidents to pilot error. A classic example of pilot error occurred in December 1972. After the pilots lowered the landing gear on their L-1011, they noticed that the green nose gear "down and locked" light was not illuminated. Though the red warning light in the gear handle itself was extinguished, indicating three locked gear, the crew elected to investigate further. While attempting to solve the problem, all three men focused on this one indicator bulb. No one noticed that the autopilot had become disengaged and that they were in a steady descent. They crashed in the Florida Everglades, killing 99 people. Did they have a malfunction? Most definitely. The Group Process malfunctioned.

What is the group process? It is a complex interaction between individuals who have joined forces in an attempt to reach a goal. To grasp the "group process" concept, these two words can be defined individually. First, a "group" is more than simply a collection of individuals. Fisher (1980) cites John K. Brillhart's (1978) five characteristics of a group:

1. A sufficiently small number of people so that each is aware of and can react to the others.

2. A mutually interdependent goal in which the success of each is dependent upon the success of others.
3. Sense of belonging.
4. Oral interaction.
5. Behavior based on norms and procedures.

The second word, "process", incorporates the dynamic relationships of events as they change in time. These events affect each other continuously. Through process, advancement toward a goal results. The group process, then, is the fluid, interdependent series of events that occur as the group moves toward its goal.

Within that group context, two dimensions exist--the social dimension and the task dimension. The social dimension refers to the relationships between group members. Feelings toward others, membership satisfaction, and group identification fall under the social dimension. The task dimension, on the other hand, refers to the work to be performed. Defining the job and how it will be completed are part of the task dimension.

Since the task dimension holds the key to what takes place in the cockpit, a closer look is needed at this dimension. The task dimension can be thought of as a system containing three major divisions--Inputs, Process, and Outcomes.

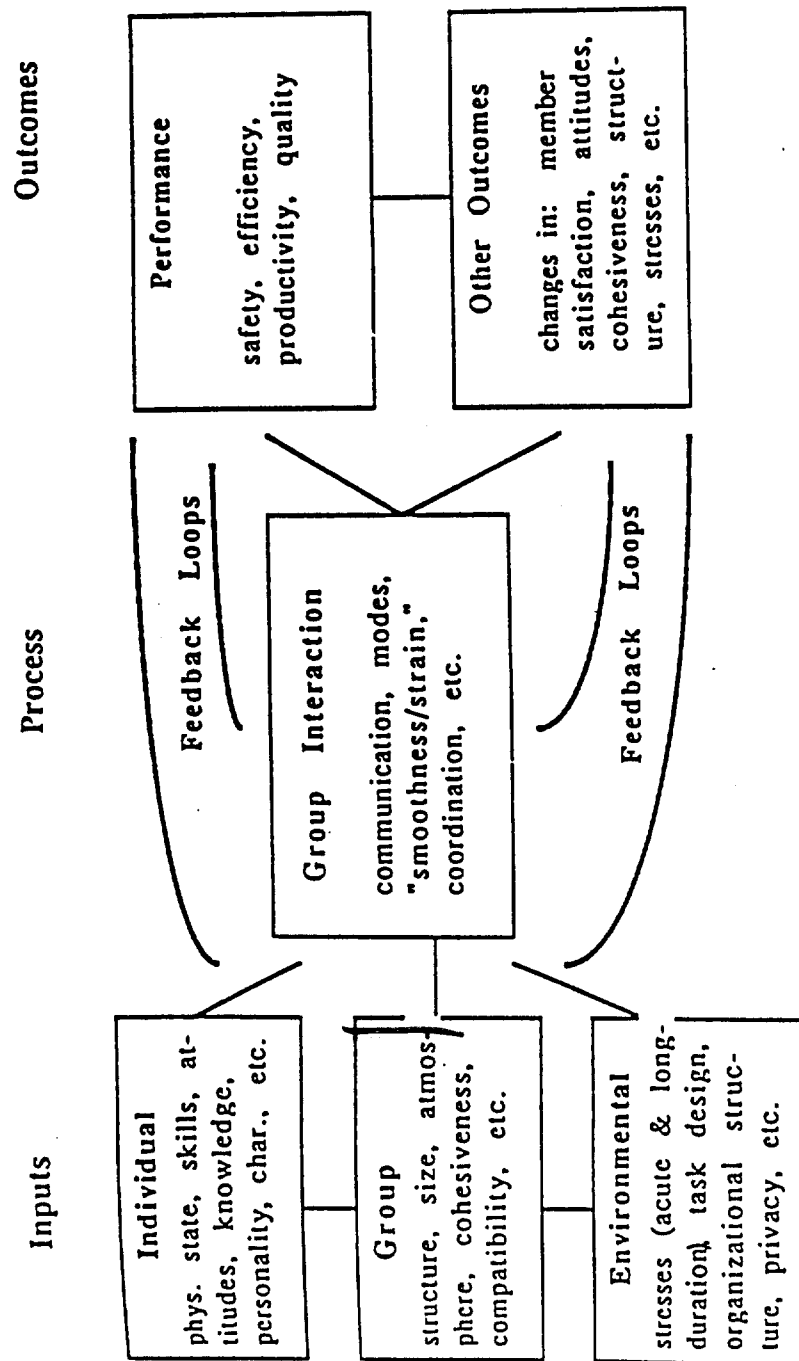


Figure 1

McGrath's model in Figure 1 illustrates factors affecting group performance within these divisions. Input variables concern the personal characteristics members bring to the group, the composition of the group itself, and the environment in which the group is functioning. Process variables refer to the group interaction itself--how individuals coordinate their actions. Finally, outcome variables describe how well the group performed the task. This division also includes changes in attitude and cohesiveness.

As mentioned above, the three types of input variables concern the individual, group, and environmental factors. Within the individual factor rests skills, attitudes, and personality characteristics that each member brings to the interaction. Individual skills determine the level of expertise and resources available to the group. Attitude and personality affect how the group members actually interact.

The group factor includes size, prior history, and structure. Size of the group affects workload distributions. Prior history can either enhance or inhibit the functioning of the interaction. Structure refers to the rights and responsibilities of each member in their group role.

Environmental factors refer to the characteristics of the task itself, level of stress, and organizational structure. The task design can be highly automated or primarily manual. Stress fluctuates depending on environmental changes such as severe weather in the aviation field. Finally, organizational structure shapes the environment and goal the group must achieve.

Input variables in McGrath's model flow into the process area. Within the process division lie factors describing the actual mechanics of group interaction. This interaction in the cockpit context can be described by communication factors and leadership characteristics. One important communication factor is the preflight briefing. Ginnett (1988) studied airline crews in their formation phase and determined that the initial briefing was critical to the performance of the crew. If that briefing, which was generally conducted by the captain, established an interactive environment, contained "we" language, and defined guidelines for crew actions, crew performance was consistently higher. Other communication markers were identified by Foushee and Manos (1981) in their analysis of cockpit voice recordings from the Ruffell Smith (1979) simulation study of airline crews. Foushee and Manos found that crews who accomplished fewer errors during the flight exhibited certain types of communication styles. These styles fell into the areas of decision-making, assertion, and workload distributions. In decision-making, a low-error crew shared the "big picture" within the team. Assertion behavior described crewmembers who stated their information, asked questions regarding crew actions, and advocated a plan of action. The effective crews also reported excessive workloads when they occurred and expressed work priorities to the rest of the crew. Another communication determinant of crew coordination was self-critique. Irving Janis (1972) emphasized feedback as a critical component in the decision-making process. Without self-critique, learning and evaluation does not take place.

Leadership characteristics also describe the group interaction.

Fiedler (1967) identified two basic leadership profiles as task-oriented and group-oriented. These correspond nicely to the Spence and Helmreich (1978) instrumentality and expressivity profiles of behavior. On the flight deck, these profiles are manifested in a concern for tasks and in the group climate. A crew high in task concern will use all available resources to reach a goal. They will act decisively when the situation requires. A crew with a positive group climate will ensure the "tone" is relaxed and supportive. They will check in with each other to provide support.

In McGrath's model, inputs set the stage for the group process. What takes place in the interaction determines the outcome. In the aviation arena, the outcome hopefully is a safe and efficient flight. Crews which exhibit the communication and leadership skills necessary in the interaction phase should produce fewer errors and be characterized by cohesiveness.

The FAA realizes that pilots are technically proficient as individuals. However, since 55% to 70% of all aircraft accidents are due to human error, the FAA asked if pilots can be made proficient as a crew. To emphasize its concern, the FAA said in a circular:

"In recent years a growing consensus has occurred in industry and government that training should emphasize crew coordination and the management of crew resources."

Due to this pressure, several airlines instituted their own Cockpit Resource Management (CRM) programs. CRM is the "effective utilization of all

available resources--hardware, software and liveware--to achieve safe, efficient flight operations" (Lauber, 1987). The question now is "Are these programs producing positive group behavior changes among airline crews?"

CHAPTER TWO

The first question that must be answered is "How do we measure the effectiveness of behavioral interactions?" A common airline yardstick is the accident and incident rate. But these are poor indices for our purposes because, thankfully, they are few and far between. We need a method to capture the day-to-day activities of crews on the line and in LOFT (Line Oriented Flight Training). The instrument developed in response to this need was the NASA/UT Line/LOFT Worksheet.

Three versions of the worksheet have been used. The first was developed in March 1987. It asked for evaluations of each crewmember separately. Analysis showed that evaluators were scoring the individual crewmembers nearly identically, and only occasionally mentioning significant actions by a pilot. Therefore, one year later in April 1988, the second version was put into use. It asked for *crew*, as opposed to individual, evaluations. To capture individuality, the second version of the worksheet provided space for evaluators to record significant behavior items of specific crewmembers. Finally, an even more refined version of the worksheet was developed in January 1991. The 15 behaviors listed on the two previous versions were consolidated into ten behaviors. The remainder of the worksheet remained the same. Examples of the three versions of the NASA/UT Line/LOFT Worksheet are shown in Appendix A.

Items to be scored on the worksheet came primarily from two sources. The first source was a NASA investigation (Cooper, White, and Lauber, 1980) in which 60 accidents occurring during 1968 - 1976 were studied. These accidents, in which crew coordination problems had been cited as playing a significant role, displayed common themes. Among them were:

- Preoccupation with minor technical problems
- Inadequate leadership
- Failure to delegate tasks and assign responsibilities
- Failure to set priorities
- Inadequate monitoring
- Failure to utilize available data
- Failure to communicate intent and plans

The second source was the Cockpit Management Attitudes Questionnaire (CMAQ) (Helmreich, 1984). This 25-item instrument taps crewmember attitudes on three factors:

1. **Communication and Coordination** defines a belief in shared information and teamwork in the cockpit.
2. **Command Responsibility** reflects agreement with the appropriateness of the shared responsibility of crewmembers for the flight.
3. **Recognition of Stressor Effects** pertains to

consideration and possible compensation for performance degradation due to stress. (Gregorich, Helmreich, and Wilhelm, 1990).

From the NASA investigation and the CMAQ the NASA/UT Line/LOFT Worksheet was born. Here I will discuss only the latest version with its ten items since it is the most current and encompasses constructs tapped by the first two versions. In it, three clusters hold different behaviors. The first cluster describes Communication Processes and Decision Behavior. In it are four scored behaviors:

-Briefing (conduct and quality). The effective briefing will be operationally thorough, interesting, and will address coordination, planning, and problems. Although primarily a Captain responsibility, other crewmembers may add significantly to planning and definition of potential problem areas.

-Inquiry/Advocacy/Assertion. This rating assesses the extent to which crewmembers advocate the course of action they feel best, even if it involves conflict and disagreements with other.

-Crew Self-Critique (decisions and actions). This item evaluates the extent to which crewmembers conduct and participate in a debriefing, operational review, and critique of activities. This includes the product, the process, and the people involved.

-Communication/Decisions. This rating reflects the extent to which free and open communication is practiced. It includes initiating

checklists and alerting others to developing problems. Active participation in the decision-making process is encouraged and practiced. Decisions are clearly communicated and acknowledged.

The second cluster of behaviors have the heading Team Building and Maintenance. Two behaviors are in this cluster:

-Leadership, Followership, and Concern for Tasks. This rating evaluates the extent to which appropriate leadership and followership is practiced. It also reflects the extent to which the crew is concerned with the effective accomplishment of necessary tasks.

-Interpersonal Relationships/Group Climate. This evaluation captures the quality of observed interpersonal relationships among crewmembers and the overall climate on the flight deck.

The third cluster contains two behaviors that describe Workload Management and Situational Awareness. They are:

-Preparation/Planning/Vigilance. This rating indicates the extent to which crews anticipate contingencies and actions that may be required. Vigilant crew devote appropriate attention to required tasks and respond immediately to new information. *A crew indulging in casual social conversation during periods of low workload is not lacking in vigilance if flight duties are being discharged properly and the operational environment monitored.*

-Workload Distribution/Distracton Avoidance. Time and workload management is scored here. It reflects how well the crew

distributed the tasks to be accomplished. It also measures the ability of the crew to avoid distractions and to prioritize activities.

The final two items are more global in nature:

-Overall Technician Proficiency. This score depicts how well a crew discharges the technical aspects of the flight. Demonstrated mastery of CRM concepts cannot overcome a lack of proficiency. Similarly, highly proficient technical skills cannot guarantee safe operations in the absence of effective crew coordination.

-Overall Crew Effectiveness. This item is a composite judgment of the crew's performance. It takes technical and CRM behaviors into account.

These Line/LOFT Worksheet behaviors tap directly into the process division of McGrath's model. That process was the focus of this three-phased study. The first phase took place within airline and within fleet. Two major domestic airlines allowed their own check airmen and instructors to gather data on crews. These raters only observed crews in the type of aircraft in which the raters were qualified. Deidentified data from the Line/LOFT Worksheet were sent to The University of Texas at Austin. The purpose of this phase of the study was to determine if, and how, the introduction of CRM training affected the interactions of crews on the line and in LOFT. A secondary purpose was to investigate the possibility that crews perform differently as a function of the type of aircraft flown. Two

reasons for potential fleet differences, technology level and crew size, were to be analyzed.

Based on results from the first phase which revealed improvement in crew effectiveness and differences in behavior among various fleets, the second phase was planned. In this phase, one of the original airlines conducted a one-month audit. Eight evaluators observed crews within their own airline, but across different aircraft types. The purpose of this phase was to verify that fleet differences do indeed exist, and were not simply artifacts of the method of taking data used in the first phase.

The third phase of this study used a different set of evaluators. Eleven researchers from the University of Texas at Austin accomplished the same training on the use of the Line/LOFT Worksheet as did the check airmen and instructors in the two airlines. These researchers observed crews in five airlines. Four of these were major domestic airlines and one was a foreign carrier. This expanded phase sought to identify differences between the behavioral interactions of crews flying for different airlines. It also targeted fleet differences and the reasons for those differences.

This study is important both for present and future implications. By verifying that crews perform more effectively after CRM training, the great economic cost of these programs is justified. The discovery of differences in interaction patterns based on aircraft type fuels a deeper look into the reasons for those differences. By identifying technology level and crew size effects, training programs can be designed to enhance performance despite

obstacles caused by aircraft type. With a look the future, aircraft can be designed with the optimal crew size and technology level in mind.

CHAPTER THREE

This thesis addresses data gathered by three different methods. The first method took place within airline and within fleet. This means that observers in Airline A and Airline B obtained data only from crews within their respective airline. Also, each observer watched crews only within the type of aircraft for which the observer was qualified. The second method was within airline and across fleet. Airline A accomplished a one month audit during October 1990. Eight observers received additional training to increase their interrater reliability. Then each observer flew with crews in several different types of aircraft. The final method of observation, across airline and across fleet, was done by the research team at the University of Texas at Austin. This team headed by Dr. Robert Helmreich, was comprised of social psychology graduate students, research staff, and retired Check Airman. Six of the eleven members were rated pilots whose experience ranged from small aircraft to airlines to military flying. This research team accomplished the same training as did the airline observers.

Observers

Each of two airlines supplied volunteer Check Airmen and Line Oriented Flight Training instructors to act as expert observers. These pilots were trained in the basics of Cockpit Resource Management and then spent an additional day receiving evaluator training. They were first taught to

recognize behavioral markers of effective group interaction. Using several videotaped vignettes, these pilots scored the behavior of crews flying simulator missions. Discussion and comparison after each vignette increased interrater reliability.

Airline A trained 707 observers in 1989. Airline B trained a total of 290 observers. Approximately one-third of these were trained in 1987. In both 1988 and 1989, roughly 100 Airline B observers began taking data.

Subjects

All pilots in each airline were subject to this anonymous no-jeopardy evaluation. Crews were given no notice of an impending CRM evaluation in either the simulator or on the line. Crews ranged in expertise from having absolutely no CRM training to being fully trained.

Procedures

Each airline conducted interactive three-day CRM seminars for groups of approximately 24 pilots. These pilots were divided into four groups which accomplished activities designed to build cohesiveness. As a team, these groups accomplished tasks centered on briefing skills, communication loops, conflict resolution, and the effective use of all resources available to a flight crew faced with difficult decisions.

Within six months of the seminar training, pilots at each airline put their skills to use in a full-mission LOFT. These scenarios were conducted in high fidelity full-motion simulators. Full color visuals enhanced the realism of the flight. These LOFT scenarios were designed to present the crew with a

problem that could be successfully solved if CRM were employed. After the mission, crews reviewed their videotaped performance with the LOFT instructor and were encouraged to debrief themselves. Crews erased their own tapes after the feedback session.

Airline A trained its entire pilot force in 1989. This company is now doing recurrent CRM training for all crews. Both seminar and simulator training is refreshed. Airline B began their program in late 1987. Pilots for this company also receive yearly recurrent training.

Response Measure

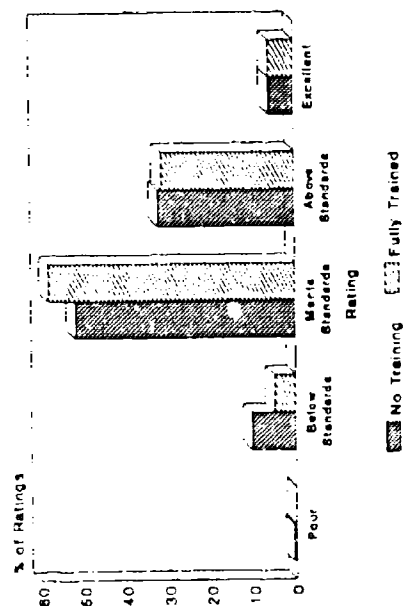
The UT/NASA Line/LOFT Worksheet provides a five-point Likert scale rating for interactive behaviors which contribute to two global measures--Overall Technical Proficiency and Overall Crew Effectiveness. These behaviors, which depict effective crew coordination, are rated from Poor to Excellent. The worksheet also provides space for the evaluator's comments about significant behavior or circumstances.

CHAPTER FOUR

Within Airline and Within Fleet

My first question concerned behavior changes within Airline A. Airline A is unique in that all pilots were introduced to CRM concepts in a seminar and applied these concepts in LOFT scenarios within a 12 month period. Therefore, evaluators had the opportunity to observe, in a short period of time, the behaviors of pilots, both trained and untrained. I asked, "Do crews exhibit changed behavior as a result of CRM training?" The results were positive in both LOFT and line observations. Figures 2 through 5 display changes seen in LOFT evaluations between crews without exposure to CRM and crews who had completed both the seminar and LOFT training. Over 1625 crews comprise the untrained category and over 485 crews were in the fully trained group. In each of the 14 areas of behavior on the Line/LOFT Worksheet, a statistically significant difference existed between these untrained and trained crews. ($F(2, 3379) = 4.37, p < .012$). In all cases, fewer crews were performing at a substandard level after training. At the highest end of the scale, fully trained crews generally earned more '5' ratings than untrained counterparts. However, the percentage of fully trained crews receiving a rating of '4', dropped in comparison to untrained crews.

BRIEFING



COMMUNICATION

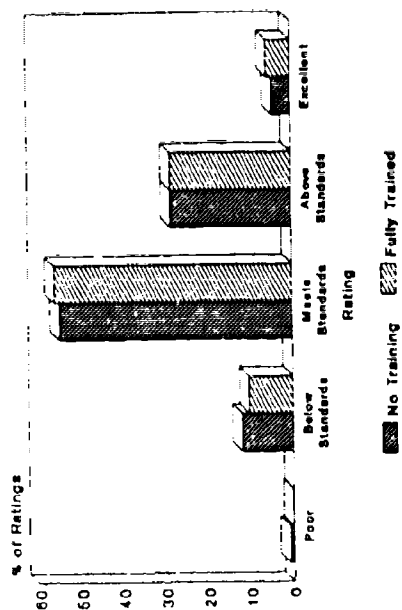
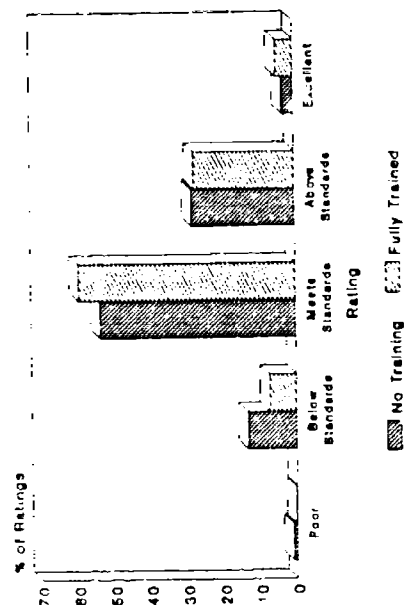
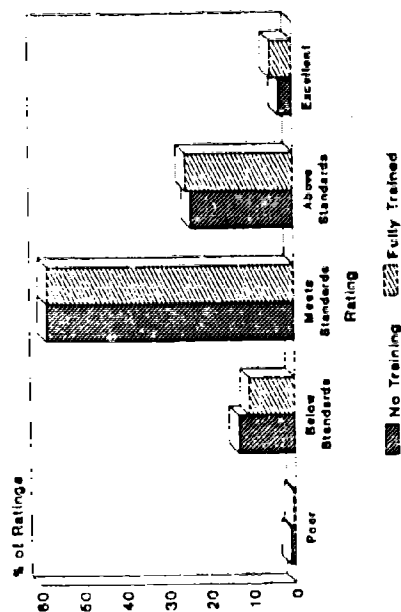


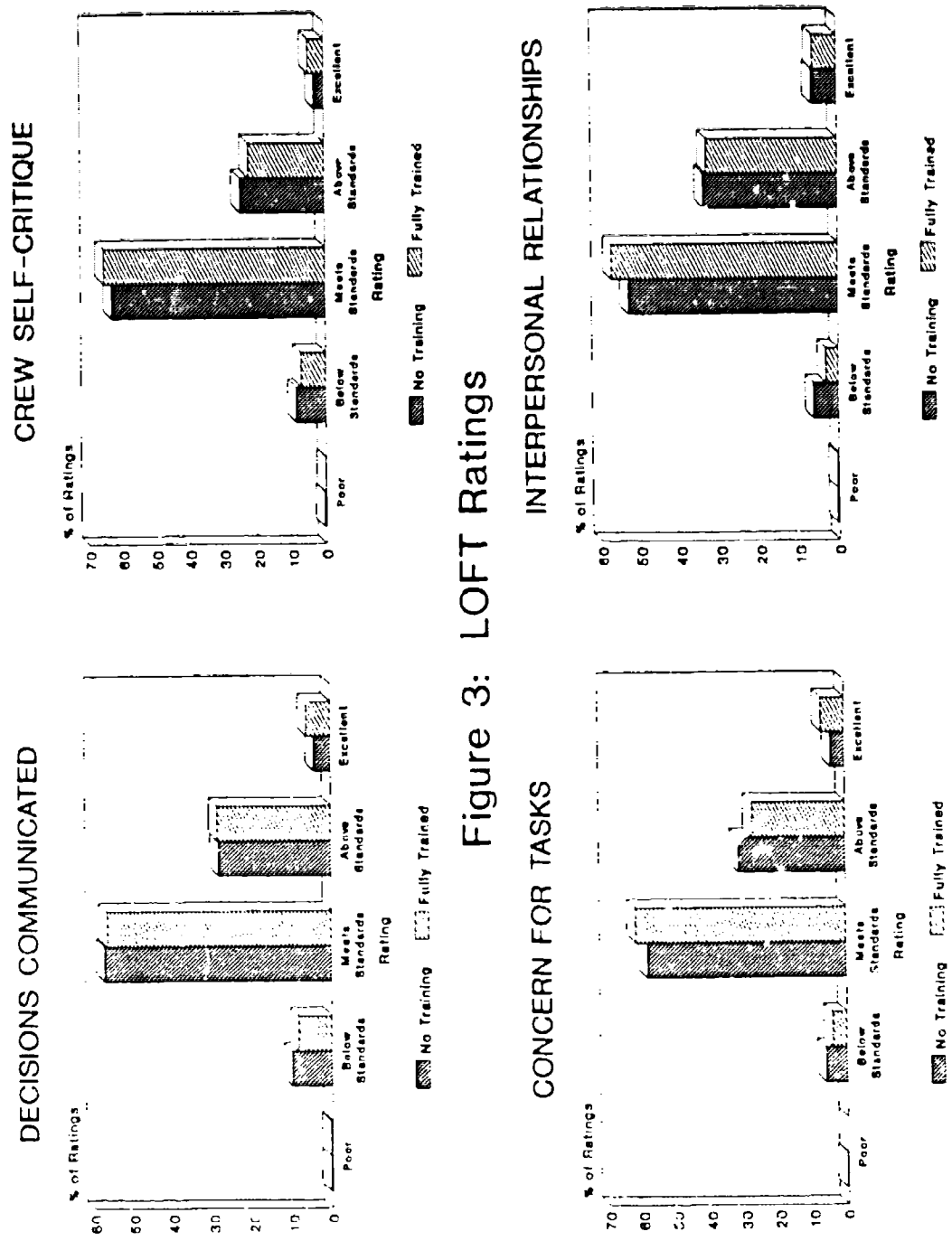
Figure 2: LOFT Ratings

INQUIRY

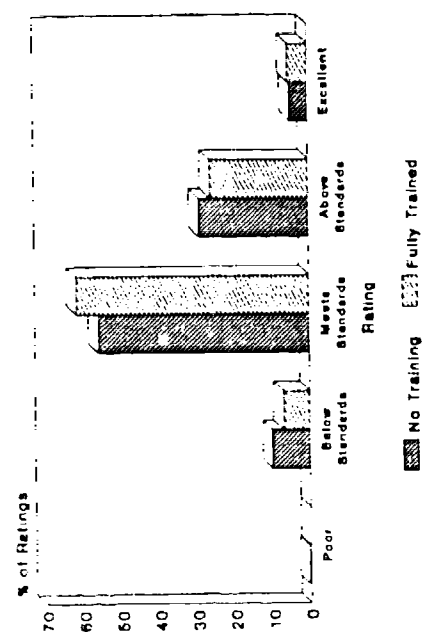


ADVOCACY

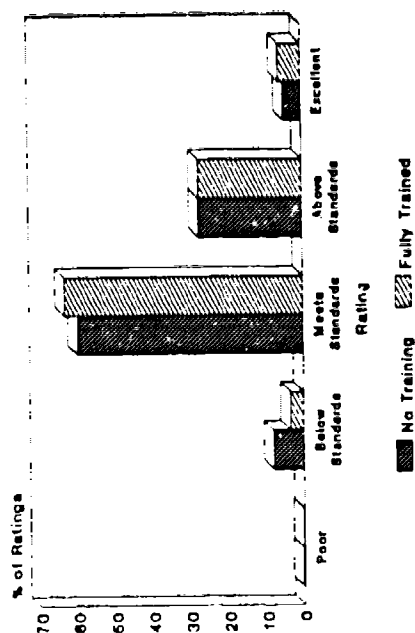




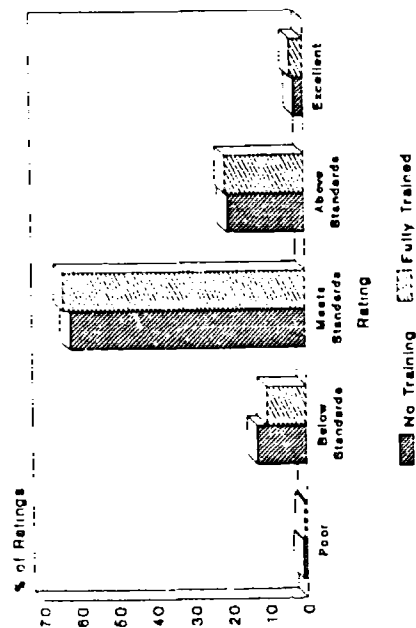
OVERALL VIGILANCE



PREPARATION FOR ACTIVITIES



DISTRACTIONS PRIORITIZED



WORKLOAD DISTRIBUTED

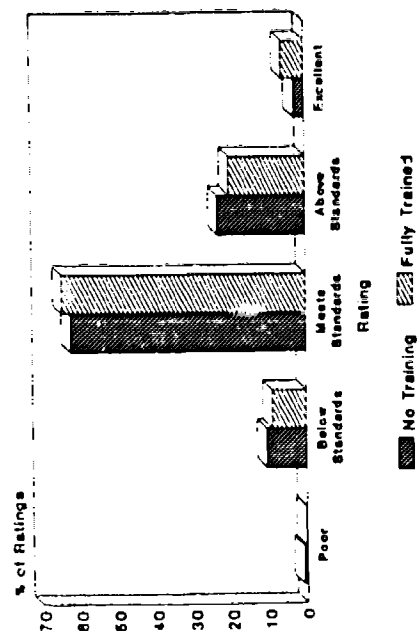


Figure 4: LOFT Ratings

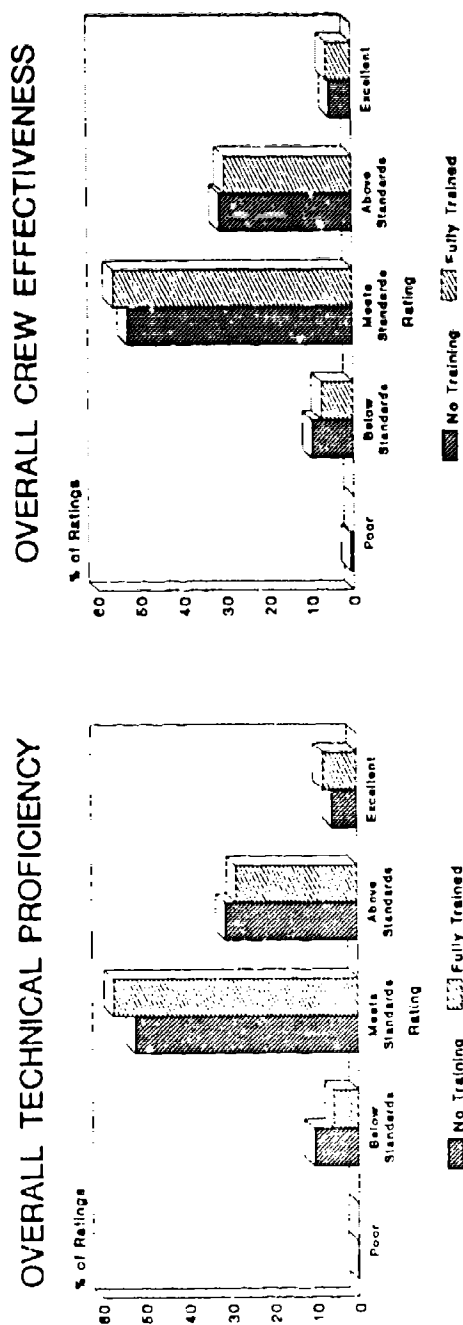
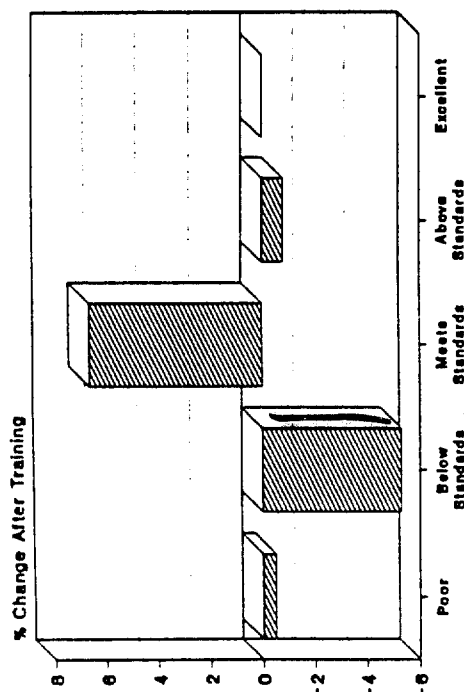


Figure 5: LOFT Ratings

BRIEFING



COMMUNICATION

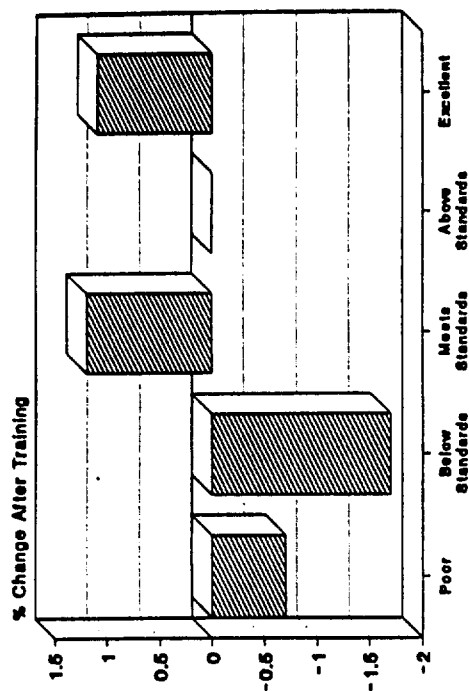
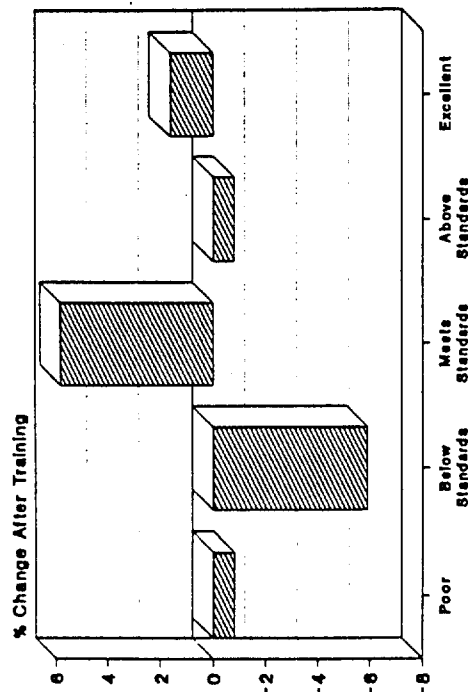
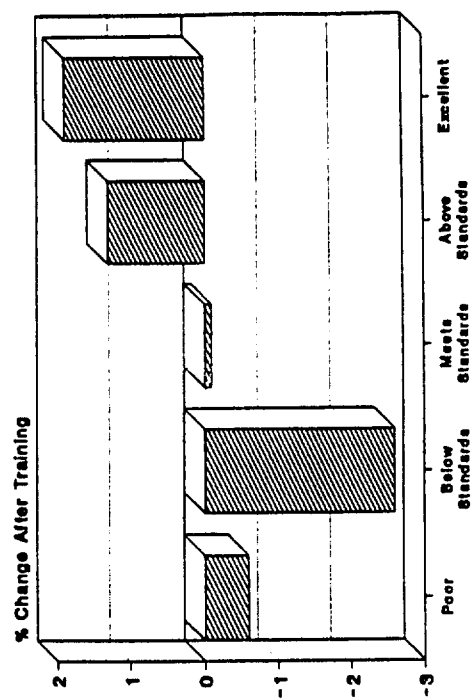


Figure 6: LOFT Differences After Training

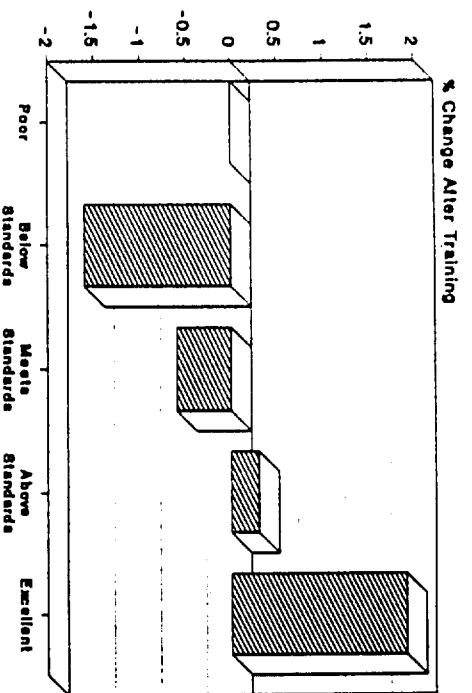
INQUIRY



ADVOCACY



DECISIONS COMMUNICATED



CREW SELF-CRITIQUE

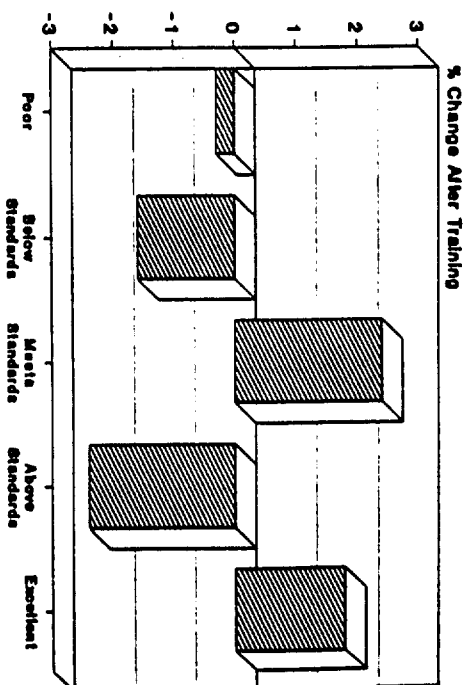
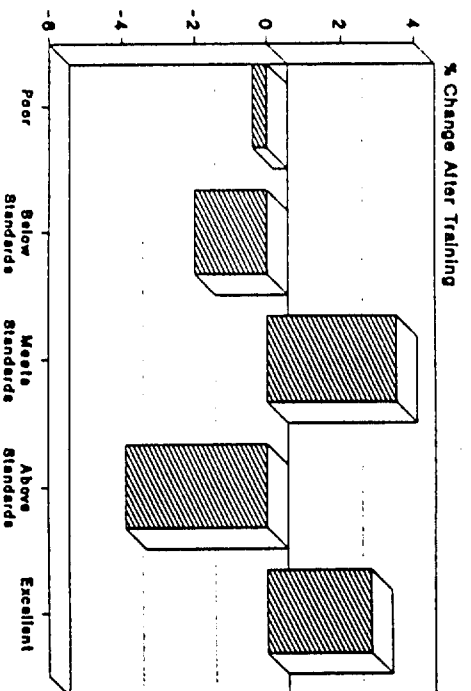
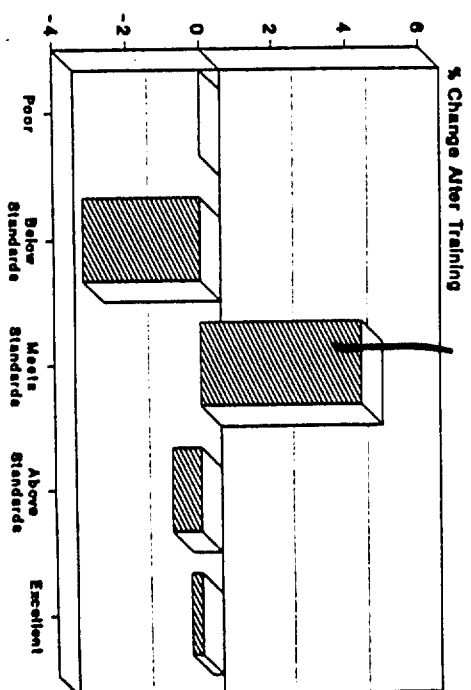


Figure 7: LOFT Differences After Training

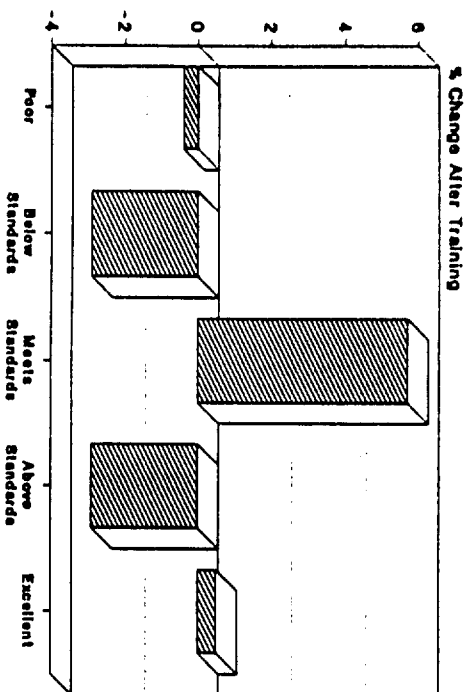
CONCERN FOR TASKS



INTERPERSONAL RELATIONSHIPS



OVERALL VIGILANCE



PREPARATION FOR ACTIVITIES

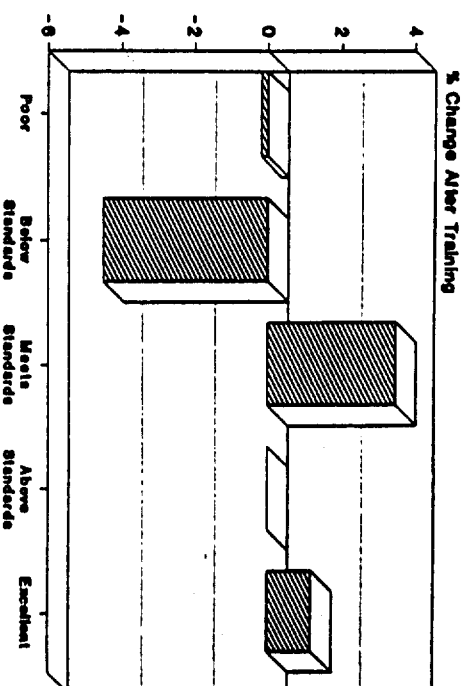
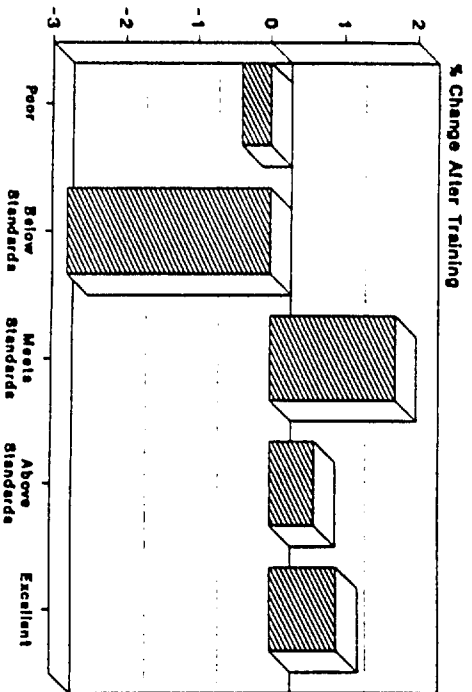
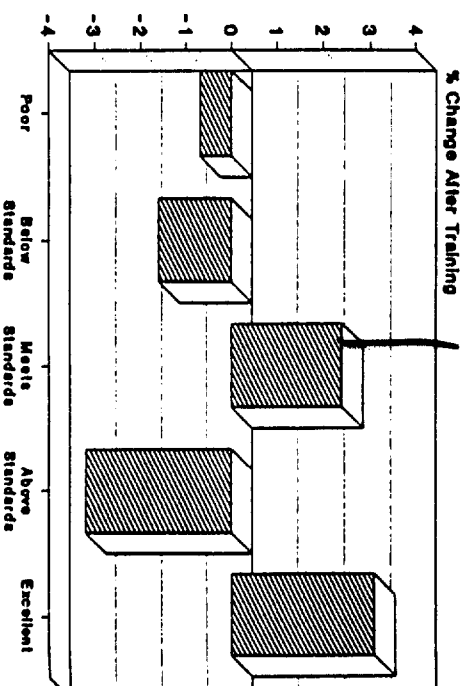


Figure 8: LOFT Differences After Training

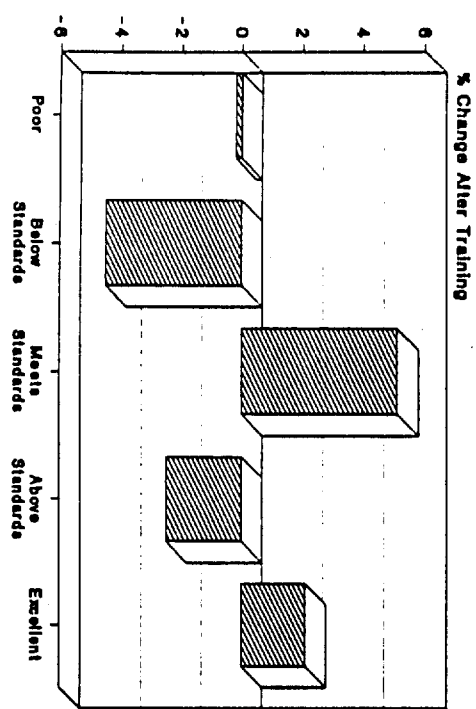
DISTRACTIONS PRIORITIZED



WORKLOAD DISTRIBUTED



OVERALL TECHNICAL PROFICIENCY



OVERALL CREW EFFECTIVENESS

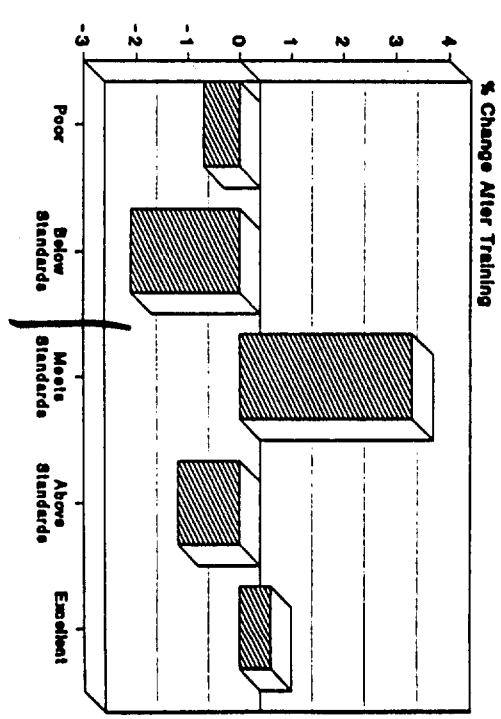
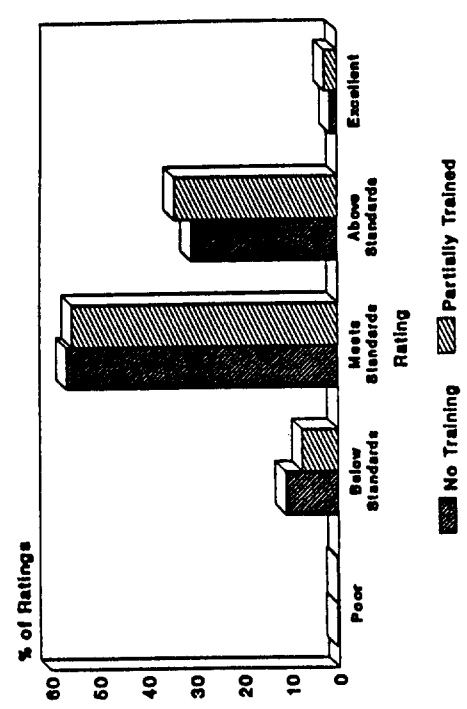


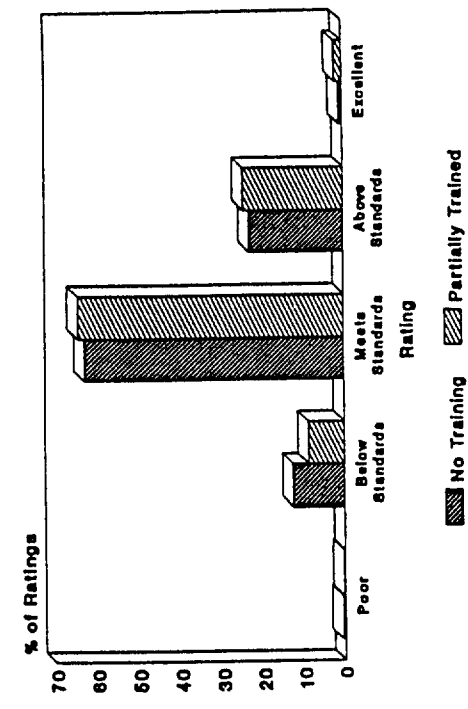
Figure 9: LOFT Differences After Training

A similar pattern existed in the line data from Airline A, as shown in Figures 10 through 13. In this case, over 2000 untrained crews were compared with approximately 1000 crews that had done some training. A partially trained category was used because this sample from the line did not contain crews in which every pilot had received both the seminar and LOFT training. In 12 areas, a statistically significant difference existed between untrained and partially trained crews. ($F(1,2932)=1.97$, $p < .018$). Two areas showed no significant changes. They were Concern for Accomplishment of Tasks at Hand ($F(1,2932)=1.4$, $p = .053$), and Interpersonal Relationships/Group Climate ($F(1, 2932)=.833$, $p = .181$). However, these two areas, especially Interpersonal Relationships/Group Climate, were strongly skewed toward the positive end of the scale even in the untrained category. Again in all areas, a substantial drop in the number of crews rated below standard was seen among crews exposed to CRM. On the opposite end of the scale, partially trained crews earned more '4' and '5' ratings. Therefore, on the line, crews seemed to have shifted their performance homogeneously to the right, whereas in LOFT, crews shifted upward into two areas--Meets Standards and Excellent. Figures 6 through 9 depict performance effects in LOFT, while Figures 14 through 17 show the shift in performance of line crews.

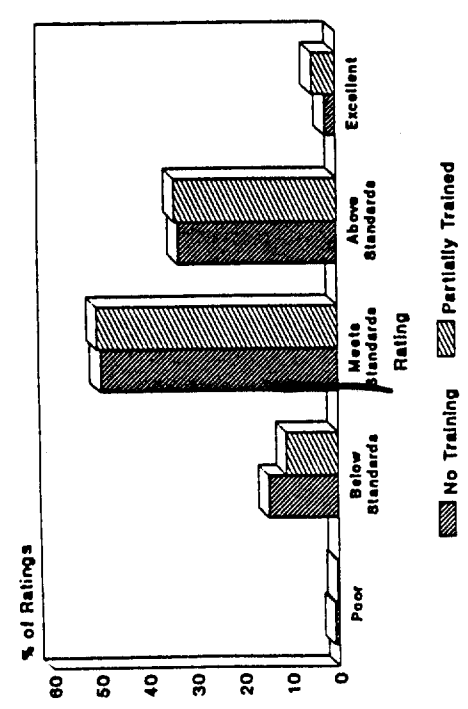
COMMUNICATION



ADVOCACY



BRIEFING



INQUIRY

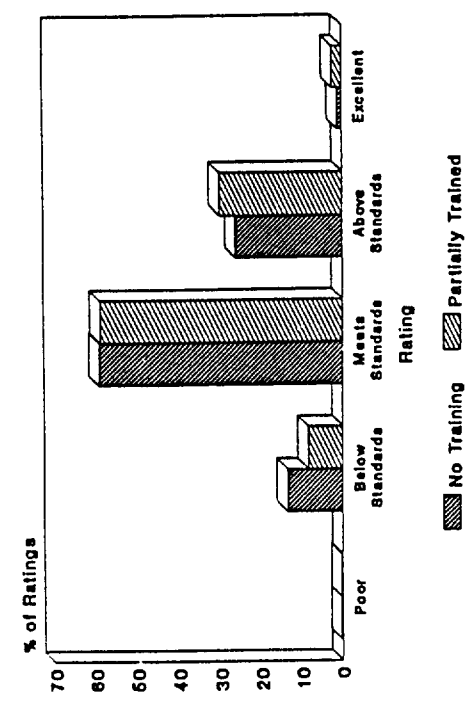
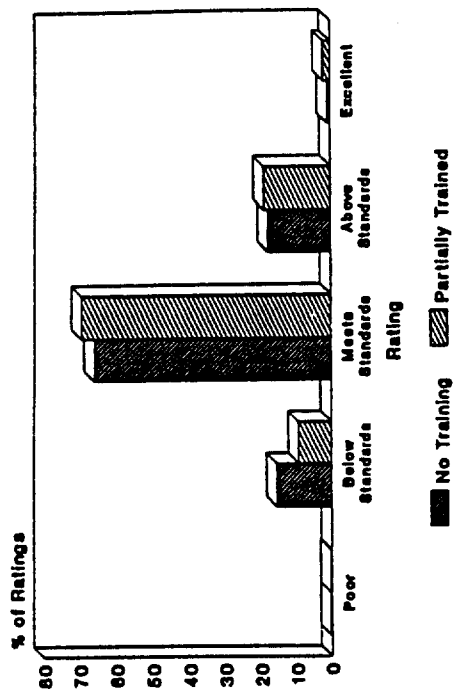


Figure 10: Line Ratings

CREW SELF-CRITIQUE



INTERPERSONAL RELATIONSHIPS

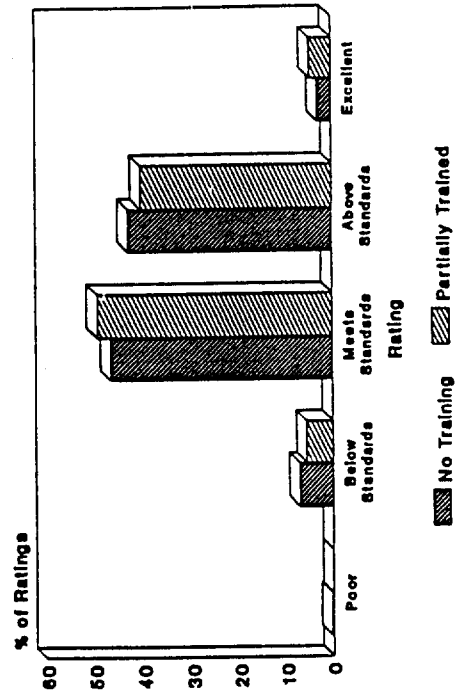
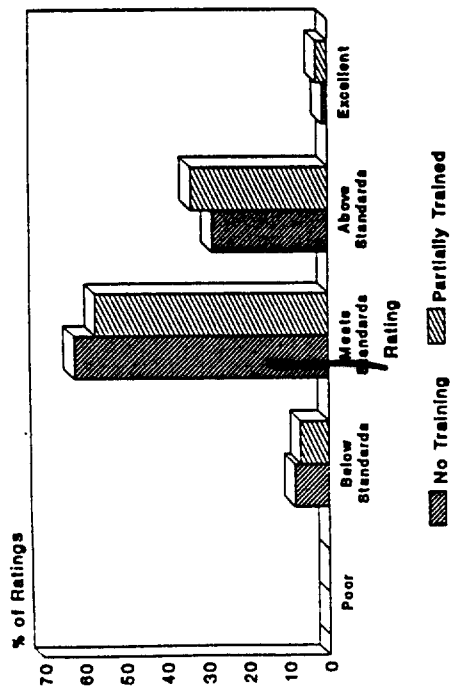
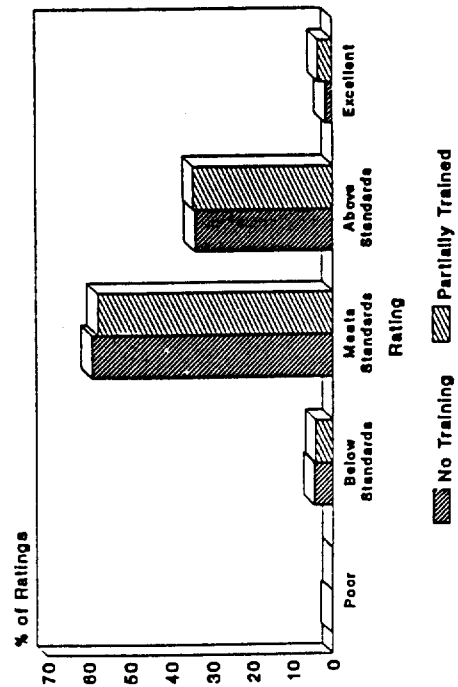


Figure 11: Line Ratings

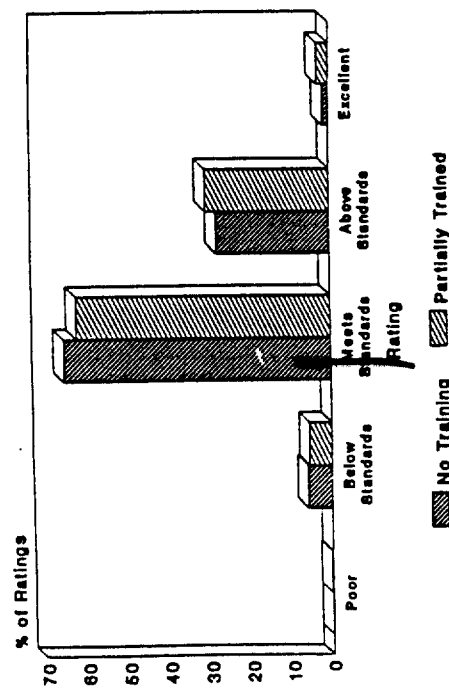
DECISIONS COMMUNICATED



CONCERN FOR TASKS



OVERALL VIGILANCE



PREPARATION FOR ACTIVITIES

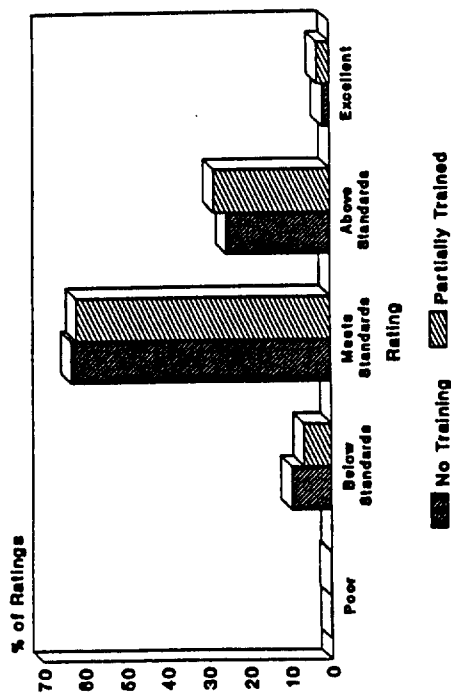
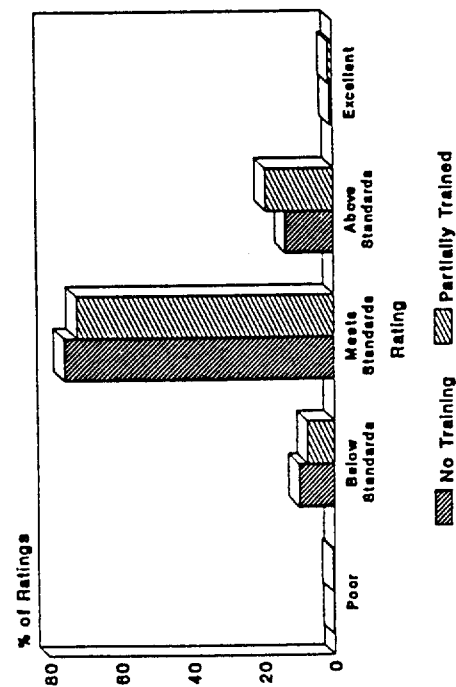
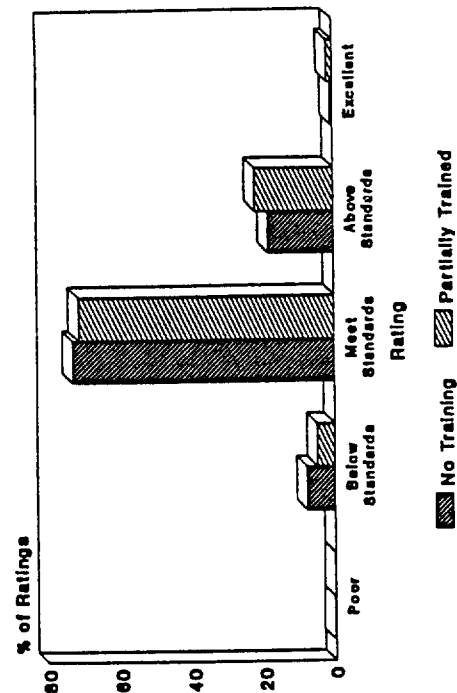


Figure 12: Line Ratings

DISTRACTIONS PRIORTIZED



WORKLOAD DISTRIBUTED



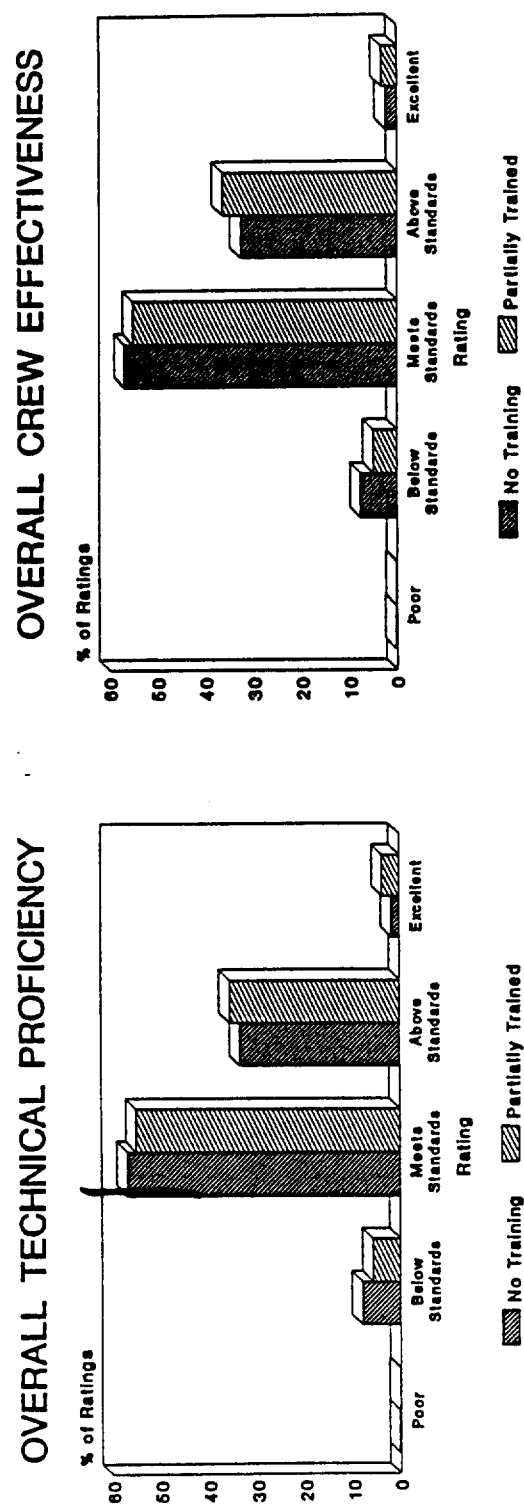
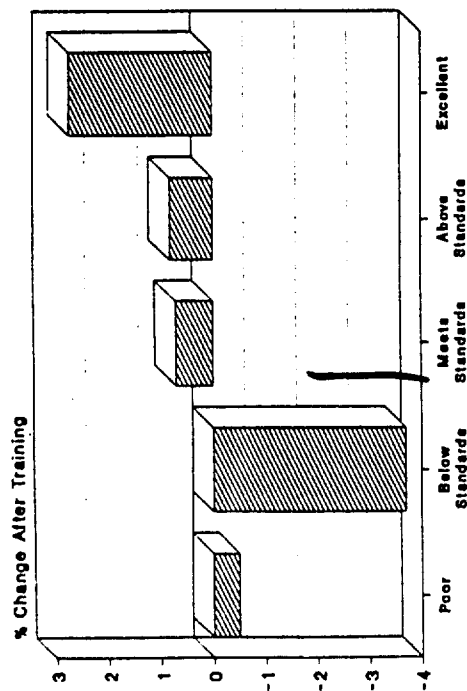
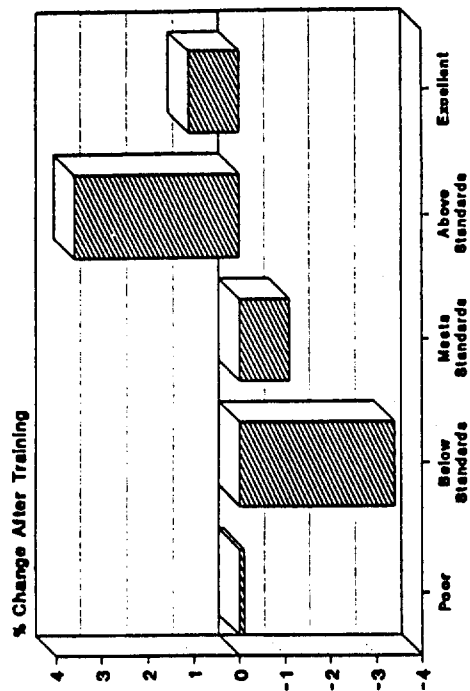


Figure 13: Line Ratings

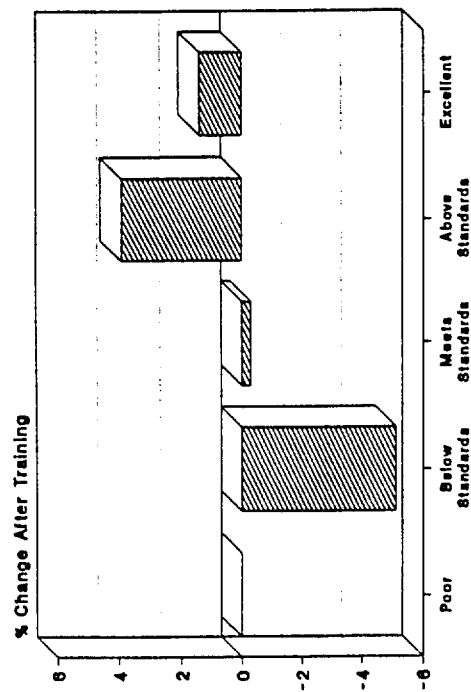
BRIEFING



COMMUNICATION



INQUIRY



ADVOCACY

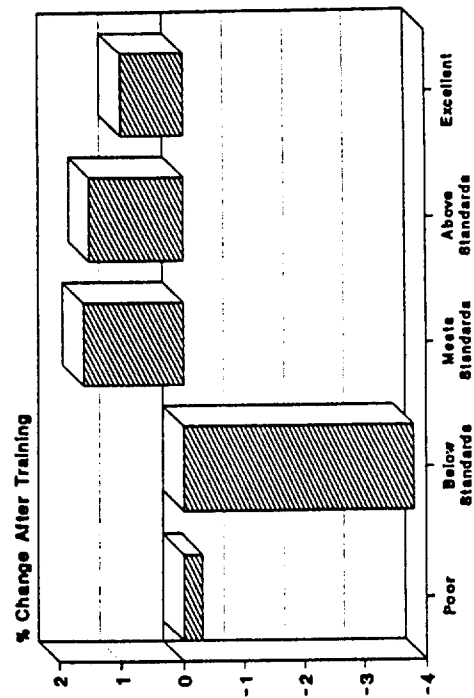
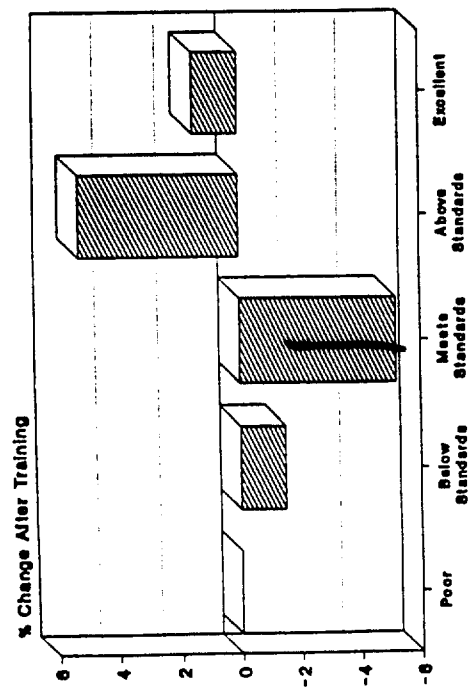


Figure 14: Line Differences After Training

DECISIONS COMMUNICATED



CREW SELF-CRITIQUE

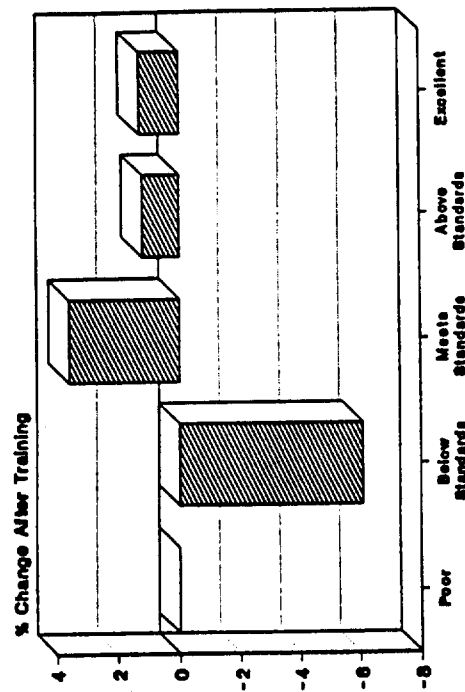
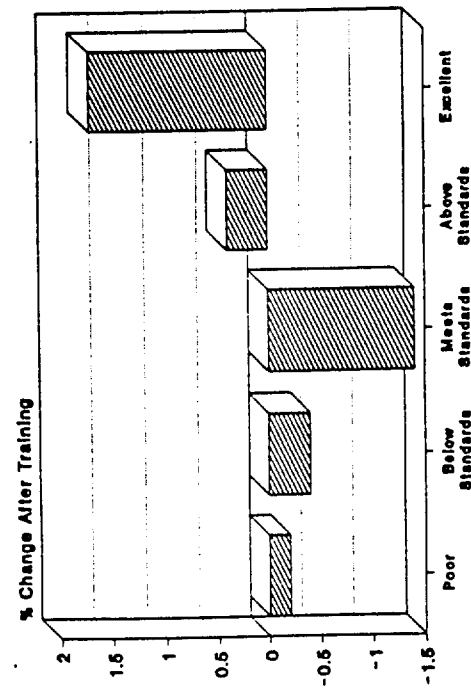
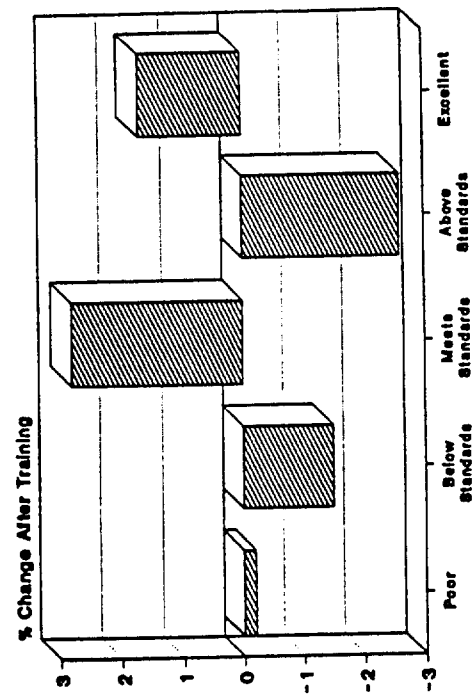


Figure 15: Line Differences After Training

CONCERN FOR TASKS



INTERPERSONAL RELATIONSHIPS



VIGILANCE

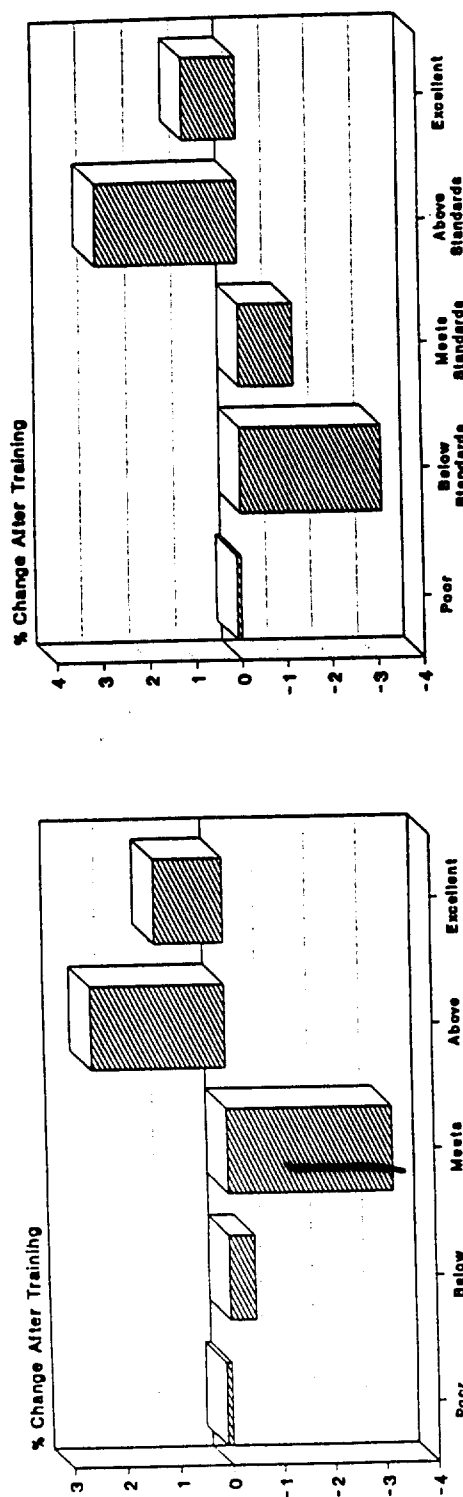
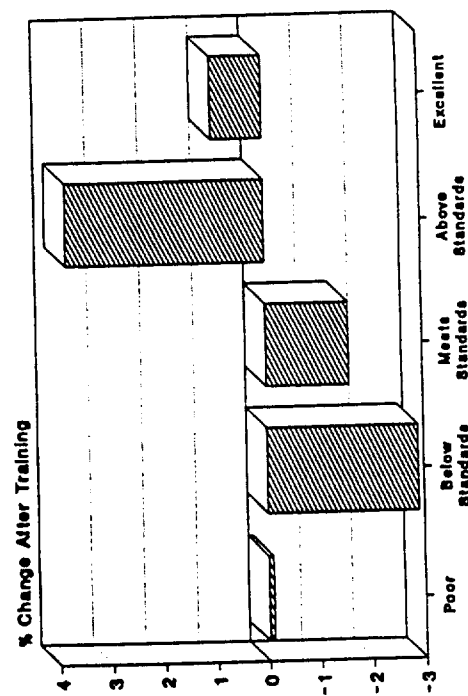
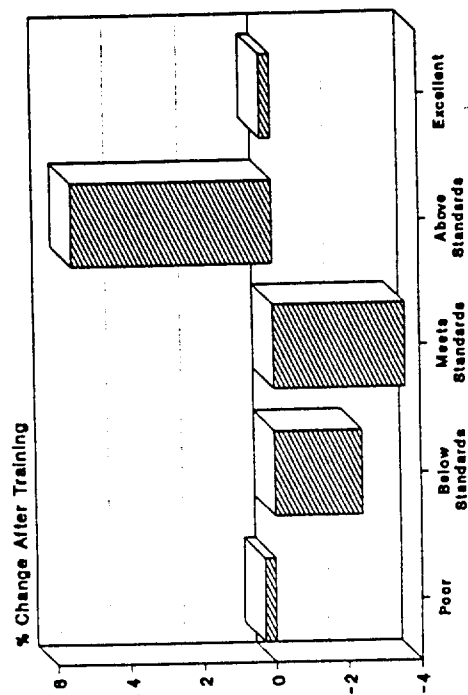


Figure 16: Line Differences After Training

WORKLOAD DISTRIBUTED



DISTRACTIONS PRIORITIZED



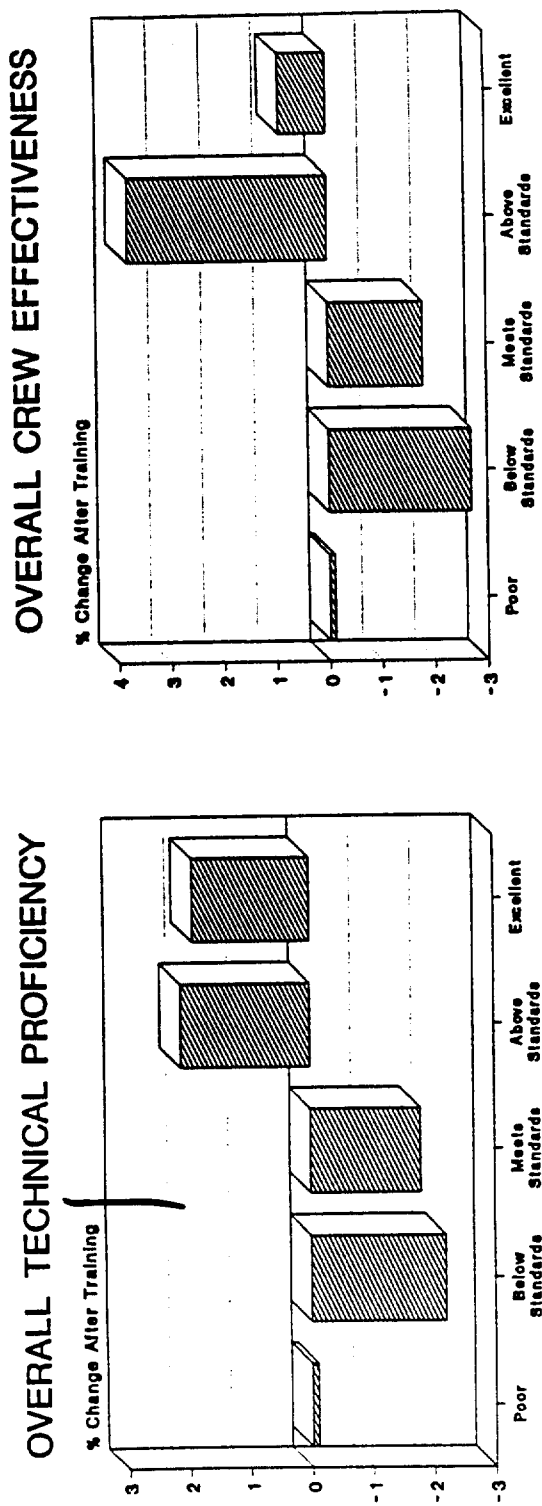


Figure 17: Line Differences After Training

During 1990, Airline A observers continued to record behavioral interactions of crews. At this point, every pilot had received the seminar and LOFT training in 1989. Those not with the company in 1989, participated in a CRM seminar during their initial training. They also accomplished LOFT scenarios during the year. A valuable comparison of behaviors in Airline A across time is shown in Figure 18. Crews improved the most in the Briefing and Crew Self-Critique categories, gaining approximately one-half a standard deviation. Least improvement was seen in the categories of Task Concern and Technical Proficiency.

Having seen how crews behaved in the cockpit before and after indoctrination into the concepts of CRM, the next question was, "What behaviors most often trigger excellent ratings and correspondingly, what behaviors most often trigger poor ratings?" Armed with 6804 valid observations from 1989, I found that Airline A evaluators gave excellent scores most often in the areas of Interpersonal Relationships/Group Climate, Briefing, and Task Concern. On the other hand, evaluators gave poor scores most often in the areas of Assertion/Advocacy, Distractions Avoided or Prioritized, and Briefing. Figures 19 and 20 depict the behaviors that most often trigger excellent or poor ratings.

Figure 18: Airline A Behavioral Interactions Across Time

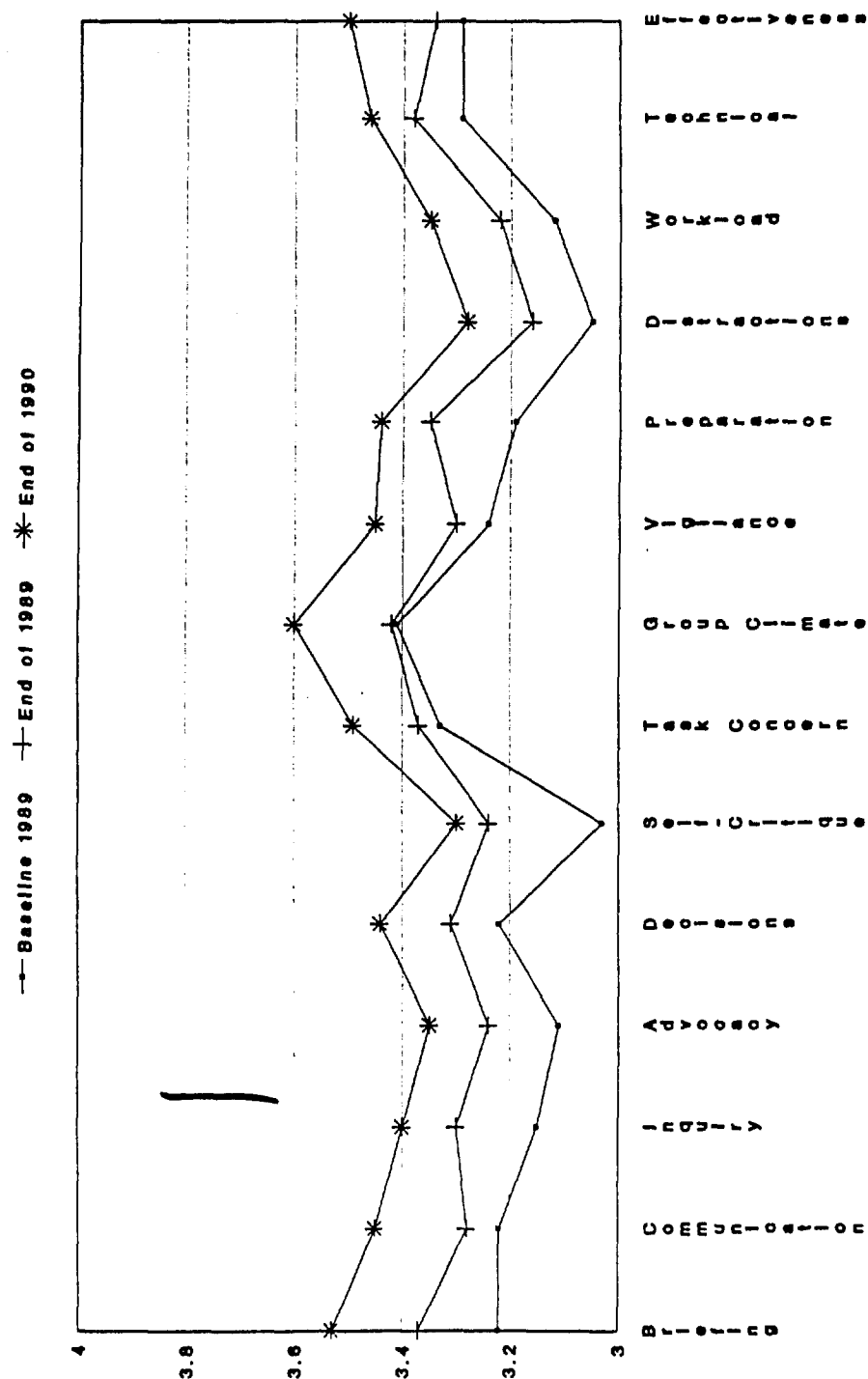


Figure 19: What Triggers
Excellent Ratings?

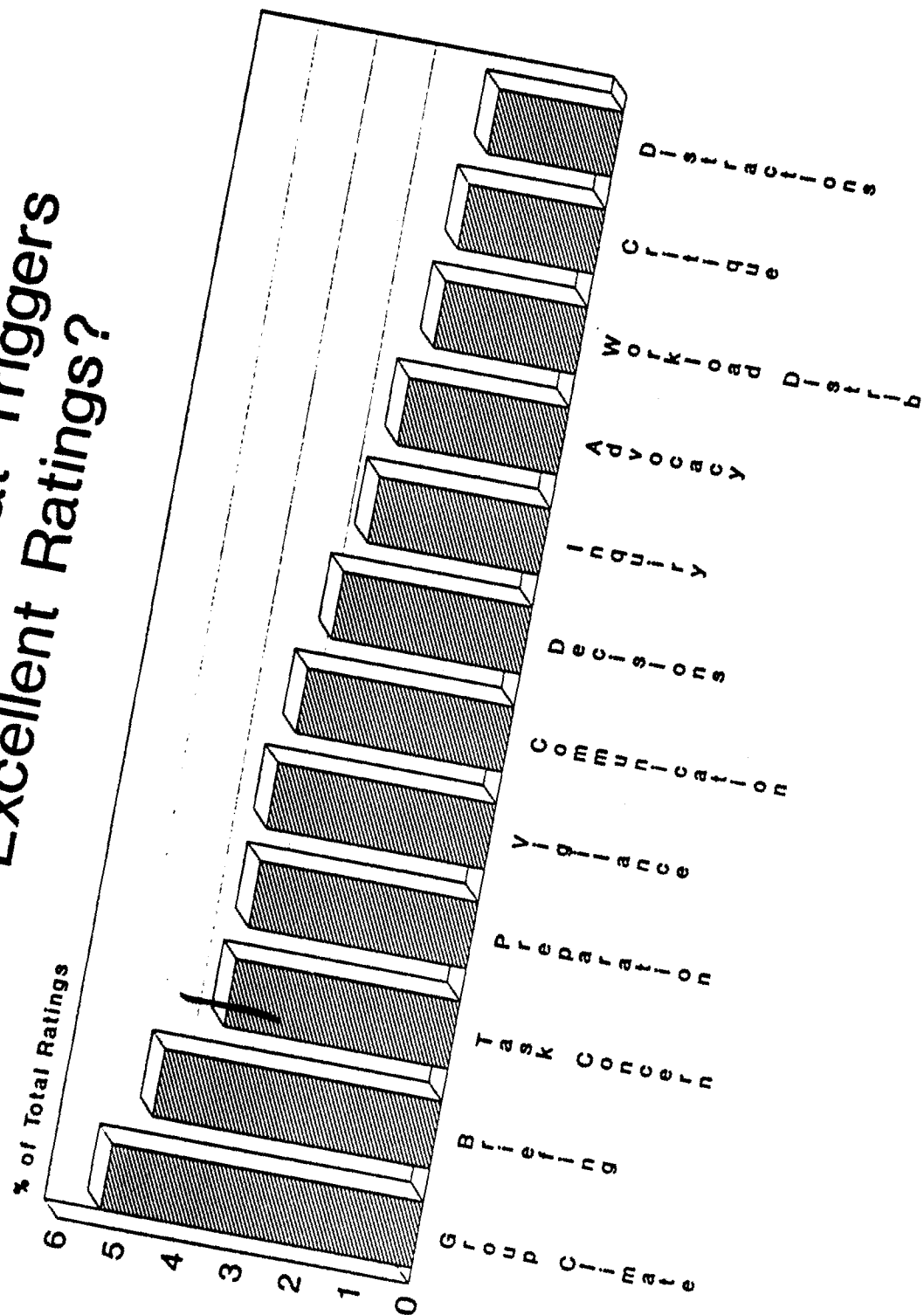
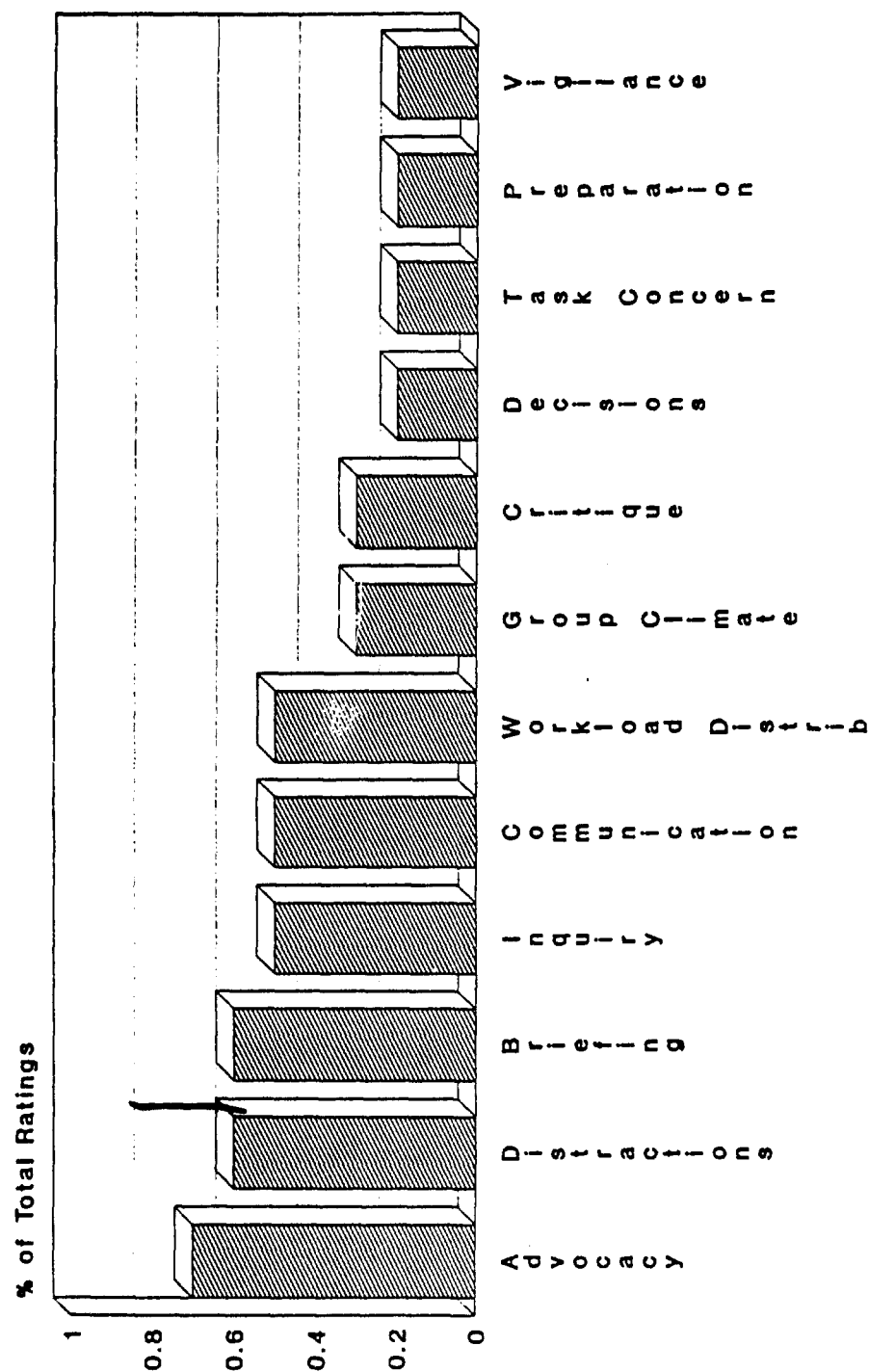


Figure 20: What Triggers
Poor Ratings?



In 1990, Airline A observers said that the triggers of excellent behavior were Interpersonal Relationships/Group Climate, Briefing, and Vigilance. On the opposite side of the spectrum, the most often cited poor behaviors were Assertion/Advocacy, Distractions Avoided or Prioritized, and Communication. This airline showed much overlap in its key excellent and poor behaviors. A point worth noting is that Briefings were no longer drawing a substantial number of poor ratings.

The Airline A data were unique in that all crewmembers were exposed to and practiced CRM concepts in the simulator during a one year period. On the other hand, Airline B trained its crews as they became due for their annual training; however, Airline B was unique in that it had a history of emphasizing crew concept flying.

Again I asked the same question, "Do crews exhibit changed behavior due to CRM training?" The answer to this question was very muddled for Airline B. At first glance the raters were reporting that crews with no training in 1987 were performing at the same level as completely trained crews in 1989. However, an initial analysis of the data in mid-1988 had found improvements in crew behavior. Based on this lead, I examined only the 1987 data. Indeed, crews that had been exposed to the formal CRM program were outperforming their untrained counterparts in the areas of Inquiry, Decisions Communicated, Task Concern, Interpersonal Relationships/Group Climate, Preparation, and Overall Crew Effectiveness,

($F(1,174)=2.43, p < .042$). Upon scrutiny of the 1988 data, I found that the airline observers saw no difference between trained and untrained crews. That effect held for the 1989 data as well.

Since an anchoring effect could have caused this improvement and then perceived degradation of performance, the demographics of the raters themselves was examined. Airline B had a core of 126 evaluators accomplishing the Line/LOFT Worksheet. Of those, 35% began sending data in 1988 and 34% began recording data in 1989. The instruction concerning Worksheet completion, however, took place in 1987. After conferring with the airline managers responsible for their program, a very plausible explanation for the results emerged. New observers were simply scoring behavioral interactions based on their own intuition. However valid that intuition may have been, it was skewed by the organizational influences that had already occurred in Airline B. Since documented performance improvements were shown in 1987, crews in Airline B were interacting more efficiently. When new raters came on line in 1988 and 1989, they were observing fully CRM-trained crews. These raters, unstandardized in using the five-point rating scale, possibly used the midpoint, 3, to imply "average". However, the average Airline B crew was actually performing at a higher level than in 1987. This finding highlighted the importance of standardized observers. Airline B, and also Airline A, heeded this warning and conducted additional training sessions for their raters.

Though an anchoring problem existed, it did not affect the triggers of excellent and poor behavior of Airline B crews. Observers gave highest scores most often in the areas of Task Concern, Interpersonal Relationships/Group Climate, and Vigilance. Poor scores were most often given for Crew Self-Critique, Inquiry, and Assertion. See Figures 21 and 22.

Figure 21: What Triggers
Excellent Ratings in Airline B?

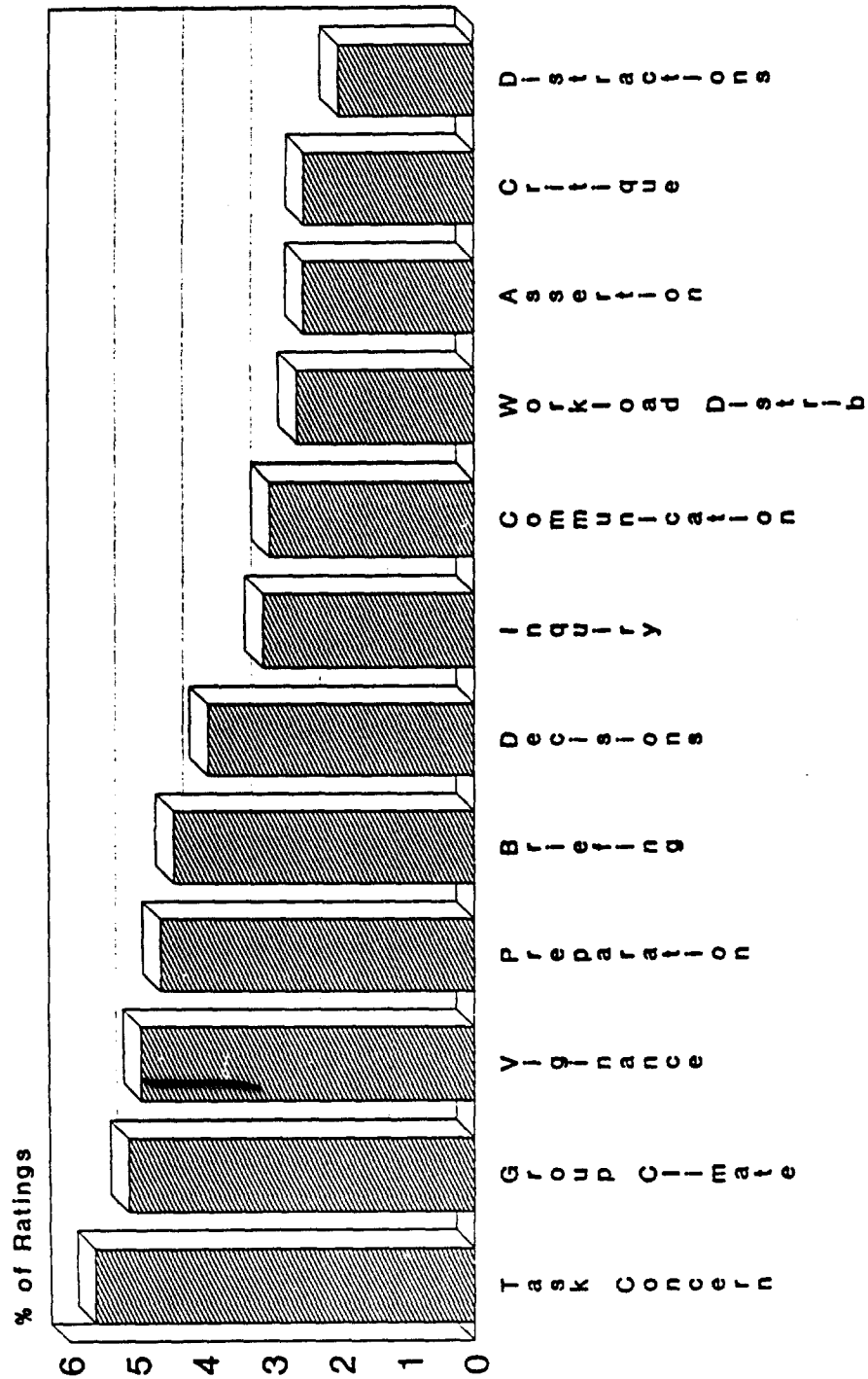
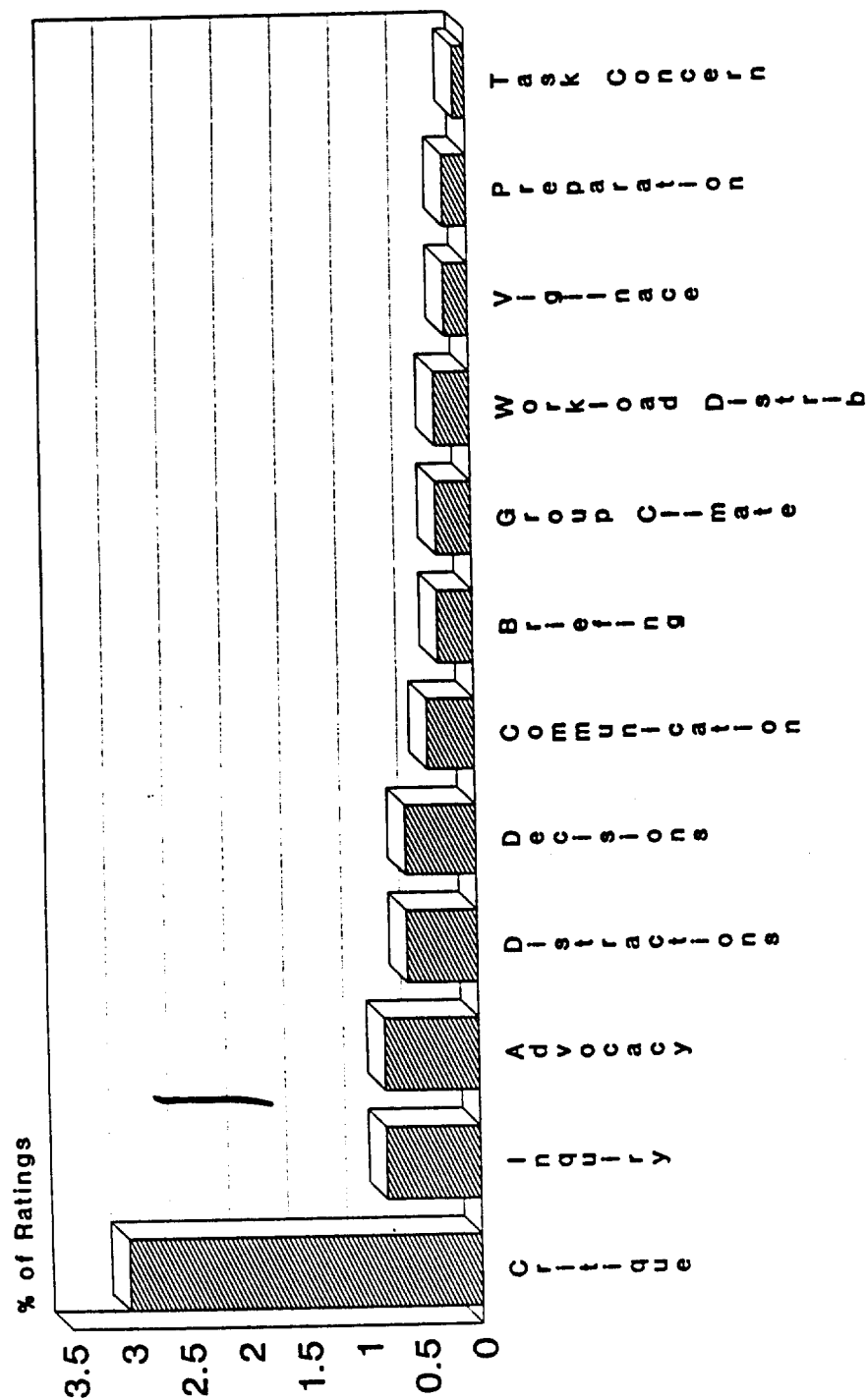


Figure 22: What Triggers
Poor Ratings in Airline B?



Having shown that CRM training did indeed improve the performance of crews in two different airlines, the rich data set was ripe for a deeper look. The most obvious area to explore was the fleet differences. Did crews behave differently in the different aircraft types? The Airline A data provided an answer. (Airline B data was not examined because of its anchoring problem.)

A MANOVA done on 6129 cases from 1989 yielded a significant difference between eight fleets, $F=2.49$, $p = .000$. Specific behavioral ratings driving the difference, using $\alpha = .05/14 = .0038$, were all categories except Decisions Communicated, Vigilance, and Distractions Avoided. Figure 23 depicts the means by fleet for Technical Proficiency and Overall Crew Effectiveness.

For the data gathered in 1990, a MANOVA on 3756 cases replicated the significant difference found in the previous year, $F=2.034$, $p = .000$. Significant behavioral ratings causing the difference, again using $\alpha = .0038$, were all categories except Advocacy, Decisions Communicated, Interpersonal Skills/Group Climate, and Technical Proficiency. Figure 24 shows the means by fleet for Technical Proficiency and Overall Crew Effectiveness.

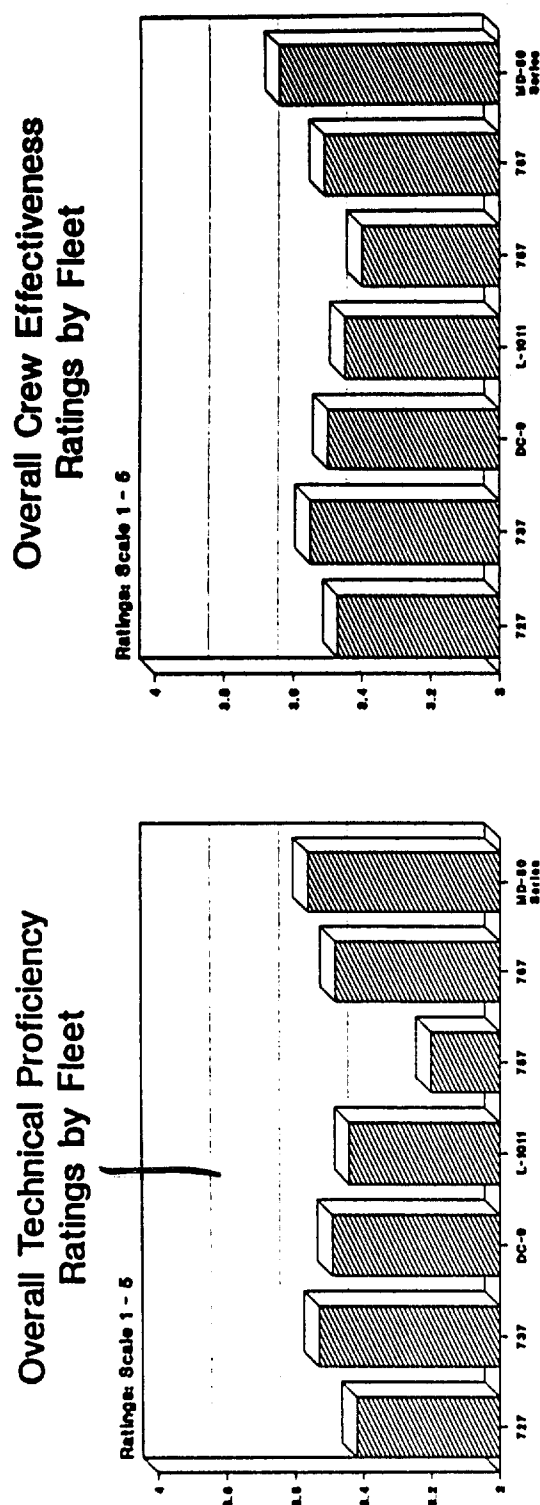
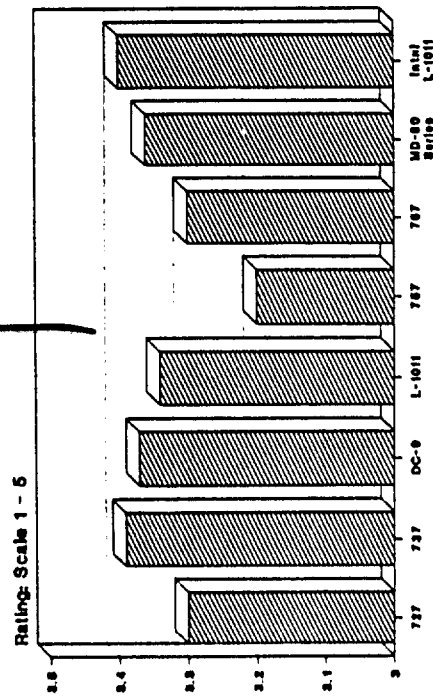


Figure 24: 1990 Fleet Differences

Overall Technical Proficiency
Ratings by Fleet



Overall Crew Effectiveness
Ratings by Fleet

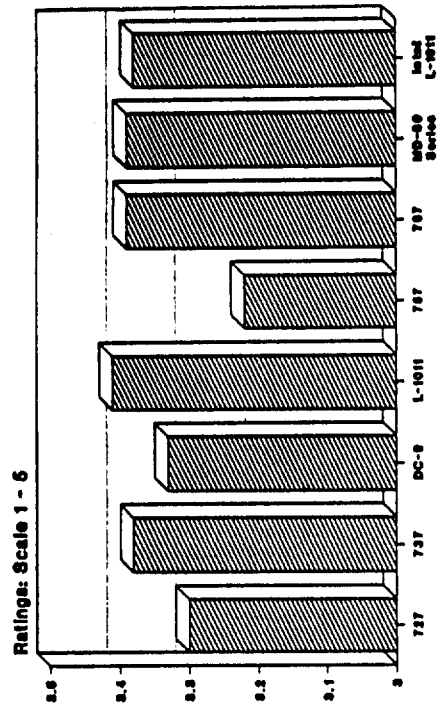


Figure 23: 1989 Fleet Differences

Knowing that crews were interacting differently depending on which aircraft type they were flying, the next step was to find reasons for that difference. Two possibilities were advanced versus standard technology and 2-person versus 3-person crews. Data from 1989 observations in Airline A were subjected to a MANOVA to compare the two technology levels. This analysis was separated into Line and LOFT observations, since these contrasting types of observations were significantly different.

The hypothesis that behavioral characteristics of crews in advanced technology cockpits differ from the behavioral characteristics of crews in standard instrument cockpits was supported by the data. A significant difference (MANOVA $F=3.27$, $p = .000$) existed between 2761 advanced cockpit crews and standard cockpit crews on the line. Areas driving that difference were Briefings and Task Concern with standard technology crews outperforming advanced technology crews. See Table 1 for performance means.

Table 1
Mean Ratings of Line Crews in 1989

	<u>ADVANCED TECHNOLOGY</u>	<u>STANDARD</u>
BRIEFING	3.19	3.28
COMMUNICATION	3.20	3.27
INQUIRY	3.16	3.19
ASSERTION/ADVOCACY	3.12	3.14
DECISIONS COMMUNICATED	3.21	3.27
SELF-CRITIQUE	3.09	3.06
TASK CONCERN	3.27	3.37
GROUP CLIMATE	3.39	3.43
VIGILANCE	3.23	3.27
PREPARATION/PLANNING	3.22	3.22
DISTRACTIONS AVOIDED	3.06	3.07
WORKLOAD DISTRIBUTED	3.12	3.15
TECHNICAL PROFICIENCY	3.25	3.33
CREW EFFECTIVENESS	3.29	3.33

Likewise in LOFT, 3325 advanced and standard instrument cockpit crews differed significantly, (MANOVA $F=2.73$, $p = .000$). No areas stood out as causing the difference, however the 14 categories of behavioral characteristics show a trend in the same direction. In the LOFT observations, advanced technology crews outperformed the standard technology crews. Table 2 shows these results.

Table 2
Mean Ratings of LOFT Crews in 1989

	<u>ADVANCED TECHNOLOGY</u>	<u>STANDARD</u>
BRIEFING	3.41	3.37
COMMUNICATION	3.32	3.27
INQUIRY	3.32	3.25
ASSERTION/ADVOCACY	3.27	3.20
DECISIONS COMMUNICATED	3.37	3.29
SELF-CRITIQUE	3.24	3.24
TASK CONCERN	3.37	3.37
GROUP CLIMATE	3.48	3.43
VIGILANCE	3.35	3.31
PREPARATION/PLANNING	3.34	3.32
DISTRACTIONS AVOIDED	3.09	3.15
WORKLOAD DISTRIBUTED	3.21	3.21
TECHNICAL PROFICIENCY	3.35	3.36
CREW EFFECTIVENESS	3.41	3.34

In 1990, a different pattern resulted. The MANOVA done on the line data was not significant. No statistical difference was seen by observers of 958 advanced and standard technology crews, $F = .86$, $p = .603$. However, a significant difference was evident in LOFT, $F = 2.60$, $p = .001$, for a sample size of 2661. All behavioral interaction categories, except Workload Distributed, were driving the difference. Table 3 shows the mean ratings of LOFT crews in 1990.

Table 3
Mean Ratings of LOFT Crews in 1990

	<u>ADVANCED TECHNOLOGY</u>	<u>STANDARD</u>
BRIEFING	3.70	3.56
COMMUNICATION	3.59	3.46
INQUIRY	3.59	3.41
ASSERTION/ADVOCACY	3.47	3.36
DECISIONS COMMUNICATED	3.54	3.44
SELF-CRITIQUE	3.44	3.33
TASK CONCERN	3.61	3.50
GROUP CLIMATE	3.71	3.60
VIGILANCE	3.58	3.45
PREPARATION/PLANNING	3.57	3.47
DISTRACTIONS AVOIDED	3.37	3.29
WORKLOAD DISTRIBUTED	3.46	3.37
TECHNICAL PROFICIENCY	3.60	3.49
CREW EFFECTIVENESS	3.64	3.52

Figures 25 and 26 depict the critical behaviors for crews flying LOFT scenarios in 1990. Figure 25 contrasts the behaviors for which crews earn highest scores in advanced and standard technology aircraft. Figure 26 contrasts the lowest scored behaviors in the two types of aircraft.

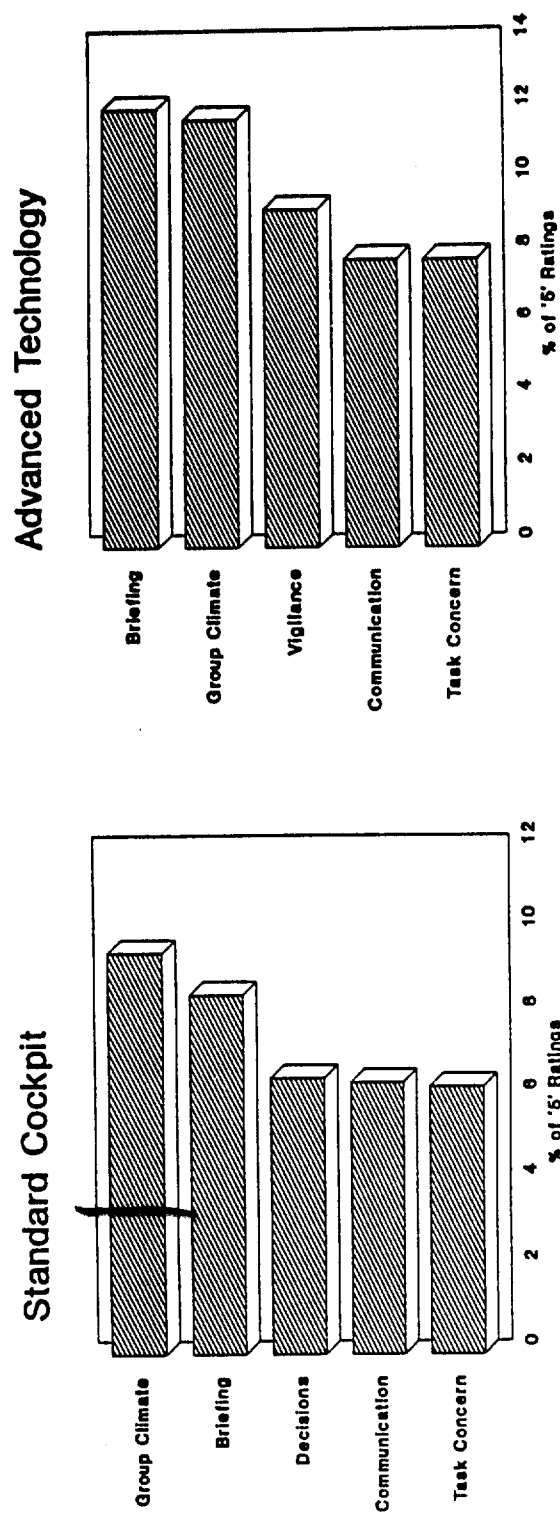


Figure 25: Highest Scored Behaviors

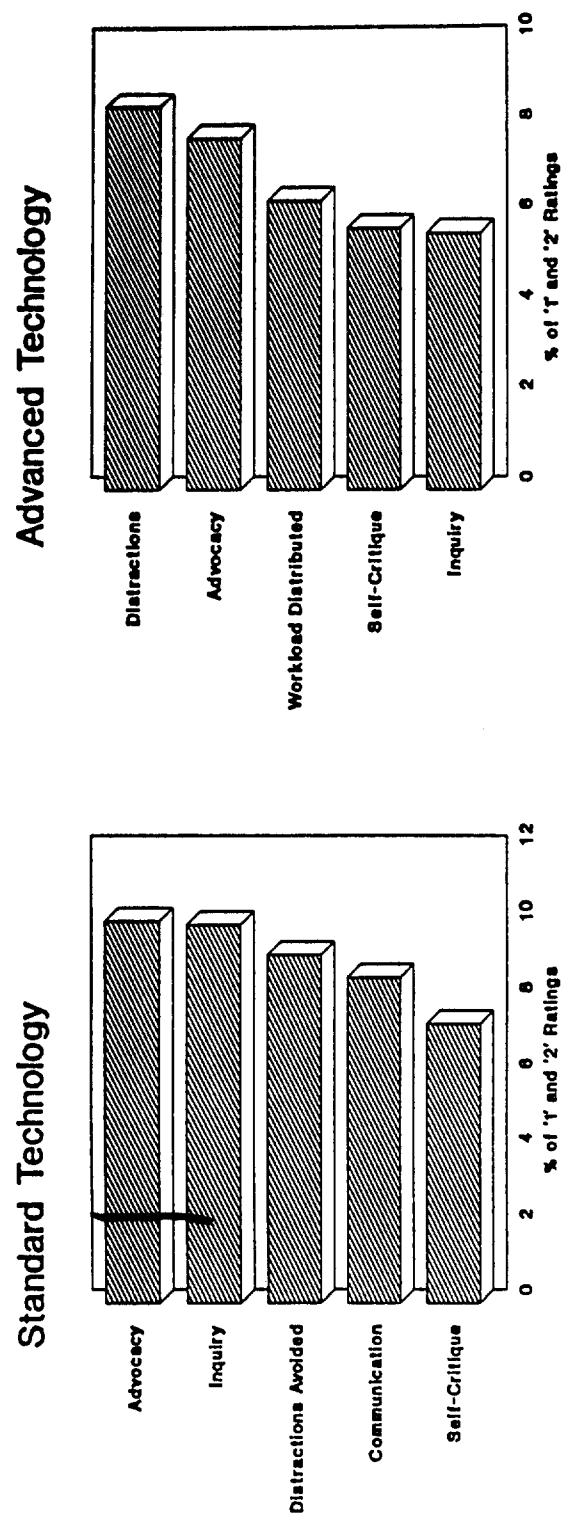


Figure 26: Lowest Scored Behaviors

Besides the advanced versus standard technology explanation, fleet differences could exist due to the 2-person versus 3-person interactions. Again, this question was analyzed separately for line and LOFT observations. In 1989 line observations, a significant difference existed between 2775 2-person and 3-person crews, (MANOVA $F = 4.47$, $p = .000$). Areas driving that difference were Crew Self-Critique and Distractions Avoided. See Table 4.

Table 4
Mean Ratings of Line Crews in 1989

	<u>2-PERSON</u>	<u>3-PERSON</u>
BRIEFING	3.23	3.30
COMMUNICATION	3.26	3.26
INQUIRY	3.20	3.15
ASSERTION/ADVOCACY	3.13	3.15
DECISIONS COMMUNICATED	3.25	3.26
SELF-CRITIQUE	3.09	3.02
TASK CONCERN	3.35	3.32
GROUP CLIMATE	3.44	3.38
VIGILANCE	3.27	3.23
PREPARATION/PLANNING	3.22	3.20
DISTRACTIONS AVOIDED	3.10	3.01
WORKLOAD DISTRIBUTED	3.16	3.10
TECHNICAL PROFICIENCY	3.33	3.27
CREW EFFECTIVENESS	3.34	3.28

Significant differences also were evident in 3335 LOFT observations, (MANOVA $F = 1.96$, $p = .017$). In this case, Briefings and Crew Self-Critique accented the 2-person versus 3-person distinction. Table 5 shows LOFT means.

Table 5
Means Ratings for LOFT Crews in 1989

	<u>2-PERSON</u>	<u>3-PERSON</u>
BRIEFING	3.41	3.34
COMMUNICATION	3.30	3.26
INQUIRY	3.29	3.24
ASSERTION/ADVOCACY	3.22	3.19
DECISIONS COMMUNICATED	3.32	3.28
SELF-CRITIQUE	3.28	3.21
TASK CONCERN	3.40	3.34
GROUP CLIMATE	3.46	3.42
VIGILANCE	3.32	3.31
PREPARATION/PLANNING	3.34	3.30
DISTRACTIONS AVOIDED	3.14	3.14
WORKLOAD DISTRIBUTED	3.22	3.21
TECHNICAL PROFICIENCY	3.38	3.34
CREW EFFECTIVENESS	3.38	3.33

In 1990, Airline A crews replicated their 1989 behavior. Again on the Line, a MANOVA showed that each type of crew behaved significantly different from the other, $F = 2.94$, $p = .000$. Sample size was 958. Crew Self-Critique and Workload Distributed were the critical behaviors. Mean Ratings on the line in 1990 are shown in Table 6.

Table 6
Mean Ratings of Line Crews in 1990

	<u>2-PERSON</u>	<u>3-PERSON</u>
BRIEFING	3.41	3.36
COMMUNICATION	3.38	3.32
INQUIRY	3.33	3.23
ASSERTION/ADVOCACY	3.28	3.24
DECISIONS COMMUNICATED	3.41	3.35
SELF-CRITIQUE	3.21	3.05
TASK CONCERN	3.42	3.37
GROUP CLIMATE	3.52	3.54
VIGILANCE	3.39	3.32
PREPARATION/PLANNING	3.32	3.29
DISTRACTIONS AVOIDED	3.22	3.13
WORKLOAD DISTRIBUTED	3.32	3.18
TECHNICAL PROFICIENCY	3.37	3.28
CREW EFFECTIVENESS	3.42	3.36

Also in LOFT, a MANOVA revealed a significant crew size difference, $F = 5.63$, $p = .000$, $N = 2661$. All scored behaviors except Advocacy and Distractions Avoided were significant, $p = .000$. Table 7 depicts LOFT behavior means.

Table 7

Mean Ratings for LOFT Crews in 1990

	<u>2-PERSON</u>	<u>3-PERSON</u>
BRIEFING	3.68	3.52
COMMUNICATION	3.58	3.43
INQUIRY	3.53	3.39
ASSERTION/ADVOCACY	3.41	3.37
DECISIONS COMMUNICATED	3.53	3.42
SELF-CRITIQUE	3.45	3.29
TASK CONCERN	3.61	3.46
GROUP CLIMATE	3.71	3.57
VIGILANCE	3.56	3.43
PREPARATION/PLANNING	3.55	3.45
DISTRACTIONS AVOIDED	3.35	3.29
WORKLOAD DISTRIBUTED	3.47	3.33
TECHNICAL PROFICIENCY	3.60	3.46
CREW EFFECTIVENESS	3.63	3.49

Since significant differences within cockpits of different technology levels and cockpits of different crew sizes were found, I investigated the possibility of a confound between the two types. A confound could have existed since the advanced technology cockpits were flown by 2-person crews. However, MANOVA analyses showed that this was not the case. By analyzing only 2-person crews, I found a significant difference in behavioral performance between advanced and standard cockpit crews, replicating in the same directions as the 1989 and 1990 data reported earlier. See Table 8.

Table 8
Technology Level Differences Within 2-Person Crews

<u>1989</u>			
Line	F=3.04	p = .000	N = 1870
LOFT	F=2.79	p = .000	N = 1691
<u>1990</u>			
Line	F=0.79	p = .676	N = 613
LOFT	F=1.88	p = .025	N = 1034

Also, by analyzing only standard technology crews, a significant difference due to crew size was again replicated. In both 1989 and 1990 data sets, 2-person crews tended to outperform their 3-person counterparts. See Table 9.

Table 9

*Crew Size Differences Within Standard Technology Crews*1989

Line	F=4.41	p = .000	N = 2080
LOFT	F=2.12	p = .009	N = 2608

1990

Line	F=2.86	p = .000	N = 648
LOFT	F=5.07	p = .000	N = 2101

Within Airline and Across Fleet

The first data gathering method, within airline and within fleet, yielded important information. It showed that crews in two different airlines improved their effectiveness in the cockpit as a result of CRM training. It also highlighted significant differences between crews flying different aircraft types. To determine if these differences were subculture artifacts or actual disparities, Airline A accomplished a one-month audit of its crews. Eight observers received additional training on the completion of the Line/LOFT Worksheet to insure that all of them were thoroughly anchored in the five-point scale. During October 1990, these eight raters did 172 line observations within their own airline, but across different aircraft types.

Verifying the earlier find that crews were interacting more effectively, these eight instructors recorded higher ratings in all categories than had been seen during the pre-CRM audit done in 1989. Figure 27 compares the scores obtained during each audit. Behavioral dimensions which improved the most were Task Concern, Inquiry, and Briefing. Least improvement was seen in Workload Distributed, as depicted in Figure 28.

Airline A observers most often rated Interpersonal Skills/Group Climate, Briefing, and Task Concern as being above standards. They saw Communication, Crew Self-Critique, and Decisions Communicated as most often below standards. Figure 29 shows their findings.

Figure 27: Characteristics of Behavioral Ratings

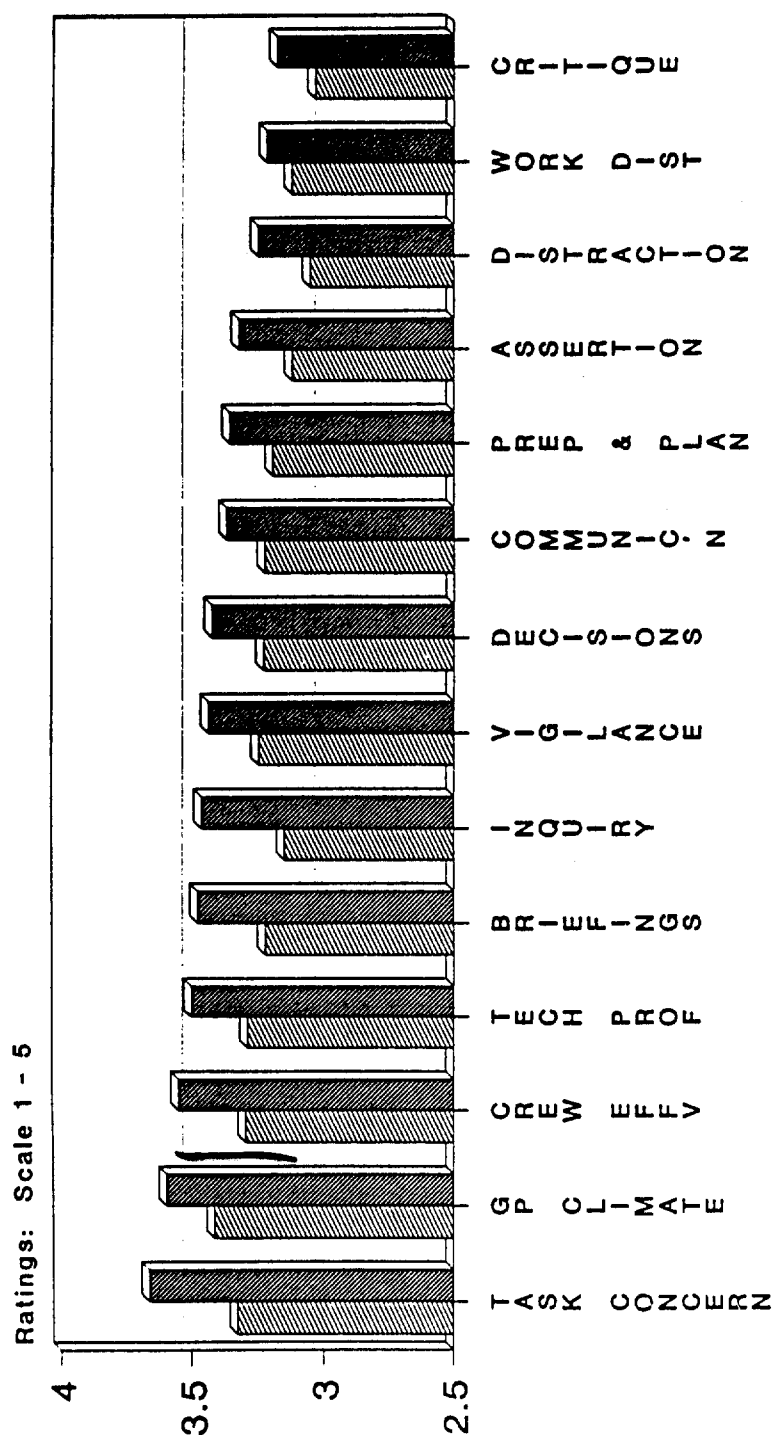
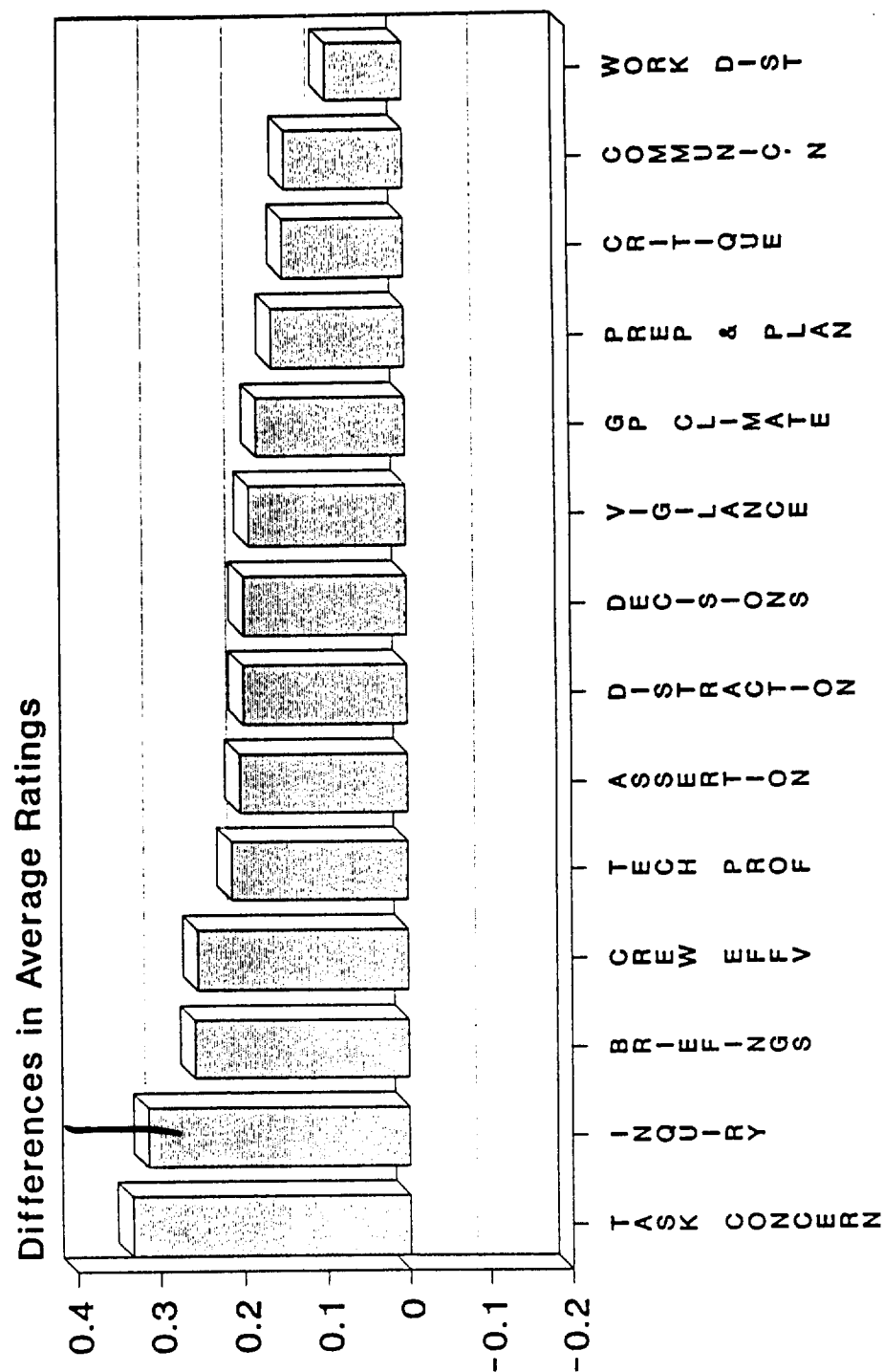


Figure 28: Audit ratings Relative to
Pre-CRM Ratings



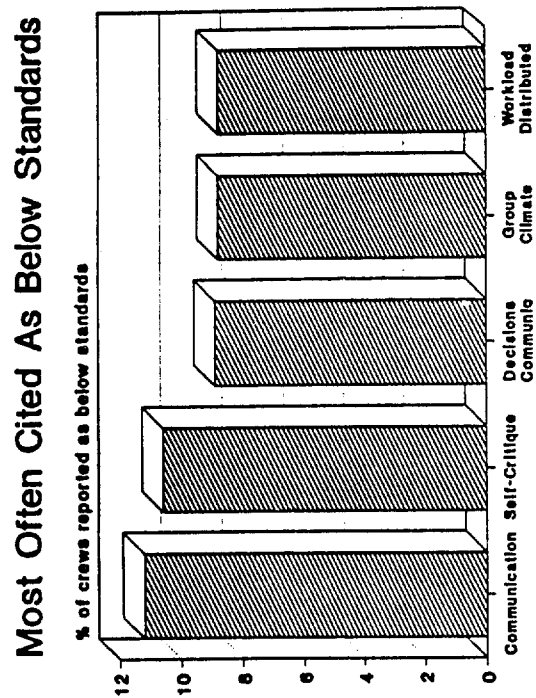
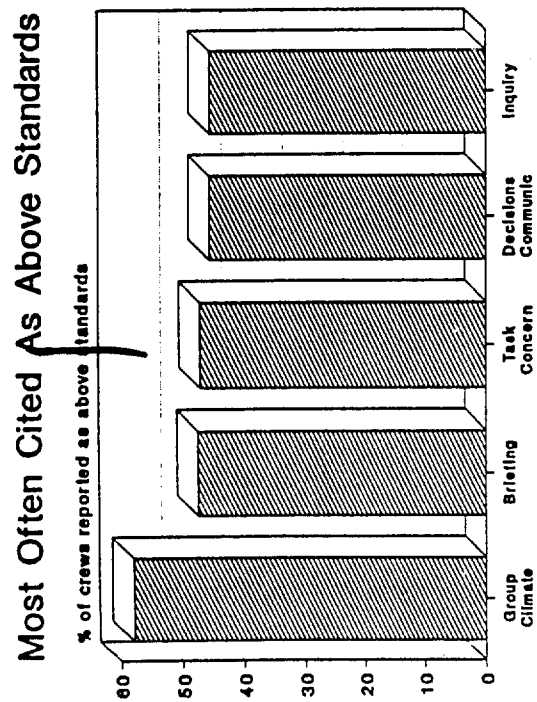


Figure 29

A major interest in this audit was the fleet differences found in the within airline and within fleet study. Though the sample size was inadequate for a MANOVA analysis, by an ANOVA it revealed two differences. One was in the category of Task Concern ($F(6, 151) = 3.21, p = .005$). The other was in Overall Crew Effectiveness ($F(6, 154) = 9.27, p = .002$). An interesting finding was that crews flying different aircraft were not significantly different on the Technical Proficiency dimension.

An ANOVA comparing advanced technology to standard cockpit crews was significant only in the area of Task Concern ($F(1, 156) = 7.49, p = .007$). In a reversal of the within airline and within fleet 1989 data, the advanced technology crews had higher means for Task Concern, Technical Proficiency and Overall Crew Effectiveness. Table 10 depicts these means.

Table 10
Mean Ratings of Line Crews During the Audit

	<u>ADVANCED TECHNOLOGY</u>	<u>STANDARD</u>
TASK CONCERN	3.79	3.52
TECHNICAL PROFICIENCY	3.56	3.40
CREW EFFECTIVENESS	3.60	3.44

The 2-person versus 3-person comparison was significant in three areas. Decisions Communicated, ($F(1, 146) = 4.32, p = .039$), and Task

Concern, ($F(1,156) = 7.41, p = .007$) were significantly different. Also, significant was the Overall Crew Effectiveness category ($F(1,159) = 4.04, p = .046$). Again, Technical Proficiency differences were not significant. Two-person crews continued to outperform their 3-person counterparts. See Table 11.

Table 11
Mean Ratings of Line Crews During the Audit

	<u>2-PERSON</u>	<u>3PERSON</u>
DECISIONS COMMUNICATED	3.49	3.23
TASK CONCERN	3.75	3.45
TECHNICAL PROFICIENCY	3.52	3.42
CREW EFFECTIVENESS	3.60	3.35

Though the audit sample size was small, it yielded rich descriptive statistics. The following four figures show how a particular rater saw fleet variations in two global categories, Technical Proficiency and Overall Crew Effectiveness. The first three bars (two for Rater #7730) depict that rater's means for particular aircraft types. The last set of bars in each category depict the overall mean derived from all 172 observations for particular aircraft types. These four raters were chosen simply because they had done five or more observations in the aircraft depicted in their graph. Figures 30 through 33 follow.

Figure 30: Rater #1288

Fleet Differences

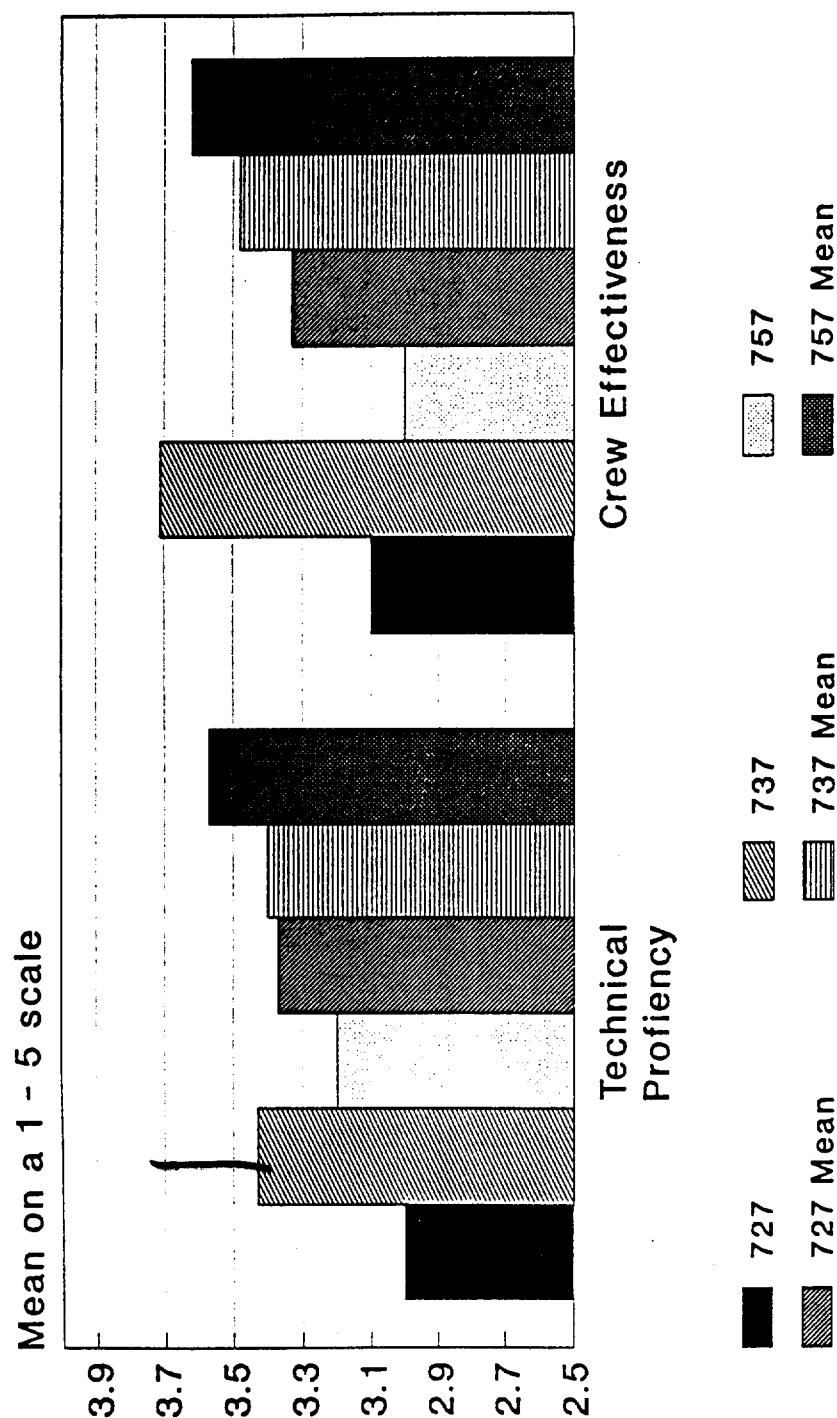


Figure 31: Rater #3145

Fleet Differences

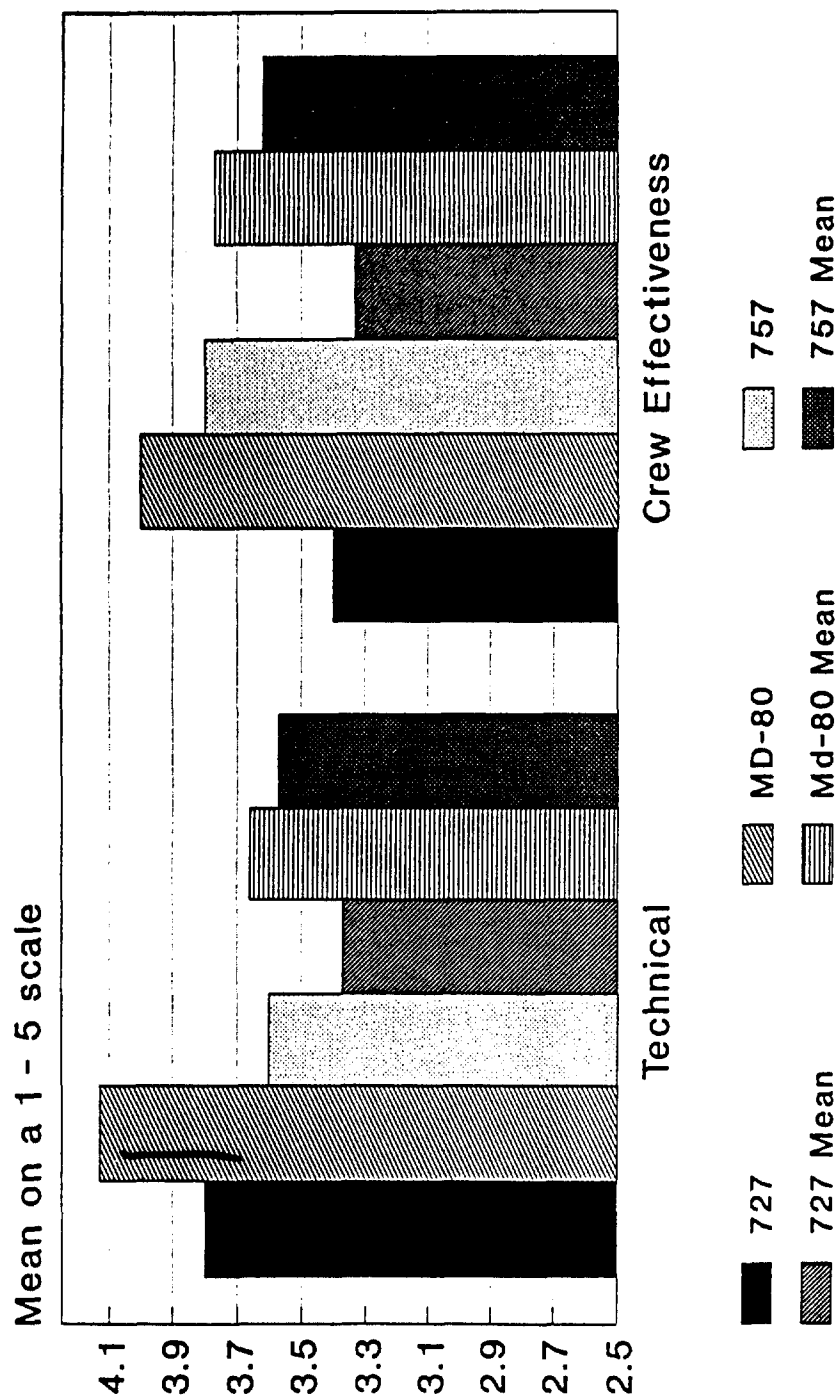


Figure 32: Rater #6670 Fleet Differences

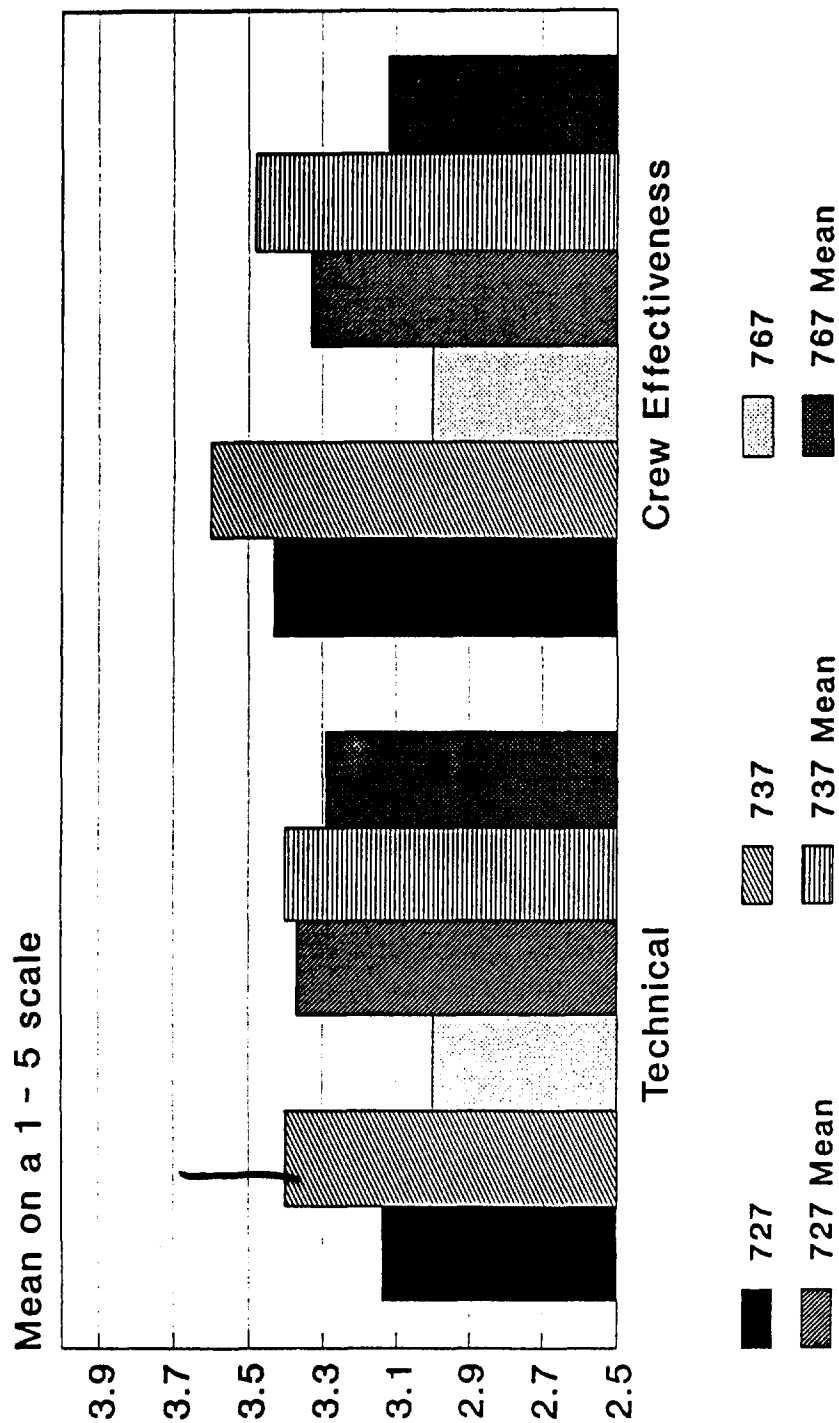
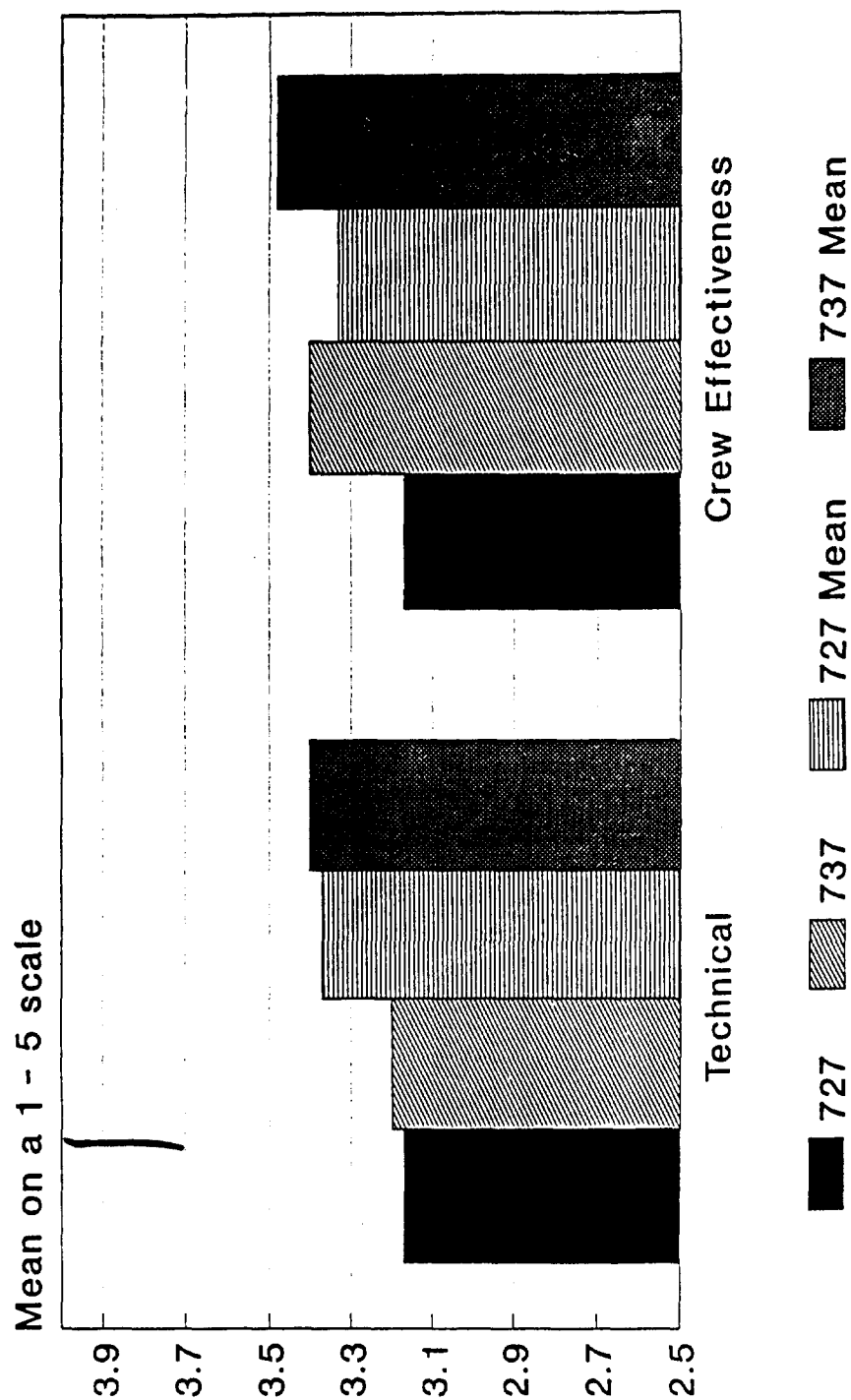


Figure 33: Rater #6670 Fleet Differences



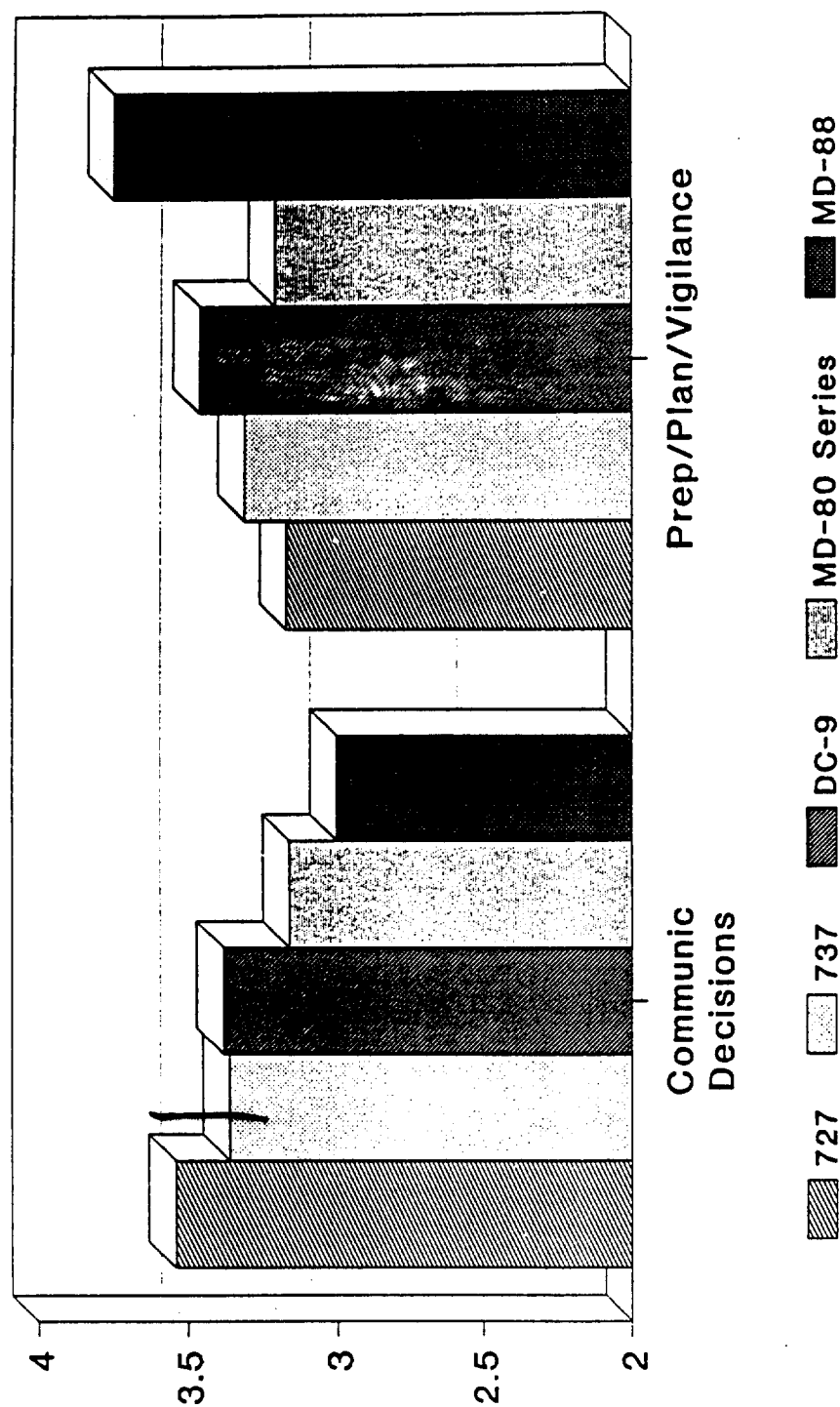
Another rich source of information was the comments these evaluators recorded on their worksheets. The comments highlight both effective and ineffective interaction styles taking place in the different types of aircraft. See Appendix B for these descriptions.

Across Airlines and Across Fleets

The final method of viewing behavioral interactions is much broader in scope. Having confirmed behavioral improvements and fleet differences in effectiveness by the previous two methods, it was time to obtain an unbiased view across several airlines. The small group of NASA/UT researchers mentioned earlier was trained in the use of the Line/LOFT Worksheet and then began doing observations across five different airlines in December 1990. As of 1 April, 1991, the group had observed 115 crews on the line and in LOFT. Since only six observations were done on LOFT crews, these have been excluded from the analysis.

One of my first interests was to explore the fleet differences found by the previous two methods. Even with this small sample size, fleet differences were found in the areas of Communication/Decisions ($F(13,80) = 2.89, p = .002$) and Preparation/Planning/Vigilance ($F(12,83) = 2.00, p = .035$). Figure 34 depicts means in these categories from aircraft in which more than three observations were accomplished.

Figure 34: Means for Categories
In Which Fleet Differences Exist



Since fleet differences existed in this set of data gathered across airlines and across fleets, the next logical question was to explore the possibility that technology level differences were driving the disparities. Unfortunately, only 6 of the ratings were done on crews flying advanced technology aircraft. This analysis must wait until the data set matures; however, on a purely descriptive level, the advanced technology crews outperformed their counterparts in nine of ten categories. (Standard technology crews earned higher ratings only in the Decisions Communicated category.) Whether these are significant differences is something a larger sample will reveal.

The other reason behind these fleet differences could be the crew size. An ANOVA was significant only in the category of Communication/Decisions ($F(1,92) = 1.54, p = .049$). Within this category, 2-person crews earned a mean of 3.29 and 3-person crews earned a mean of 3.52. Note though that out of ten categories, 2-person crews had higher means than did 3-person crews in six categories.

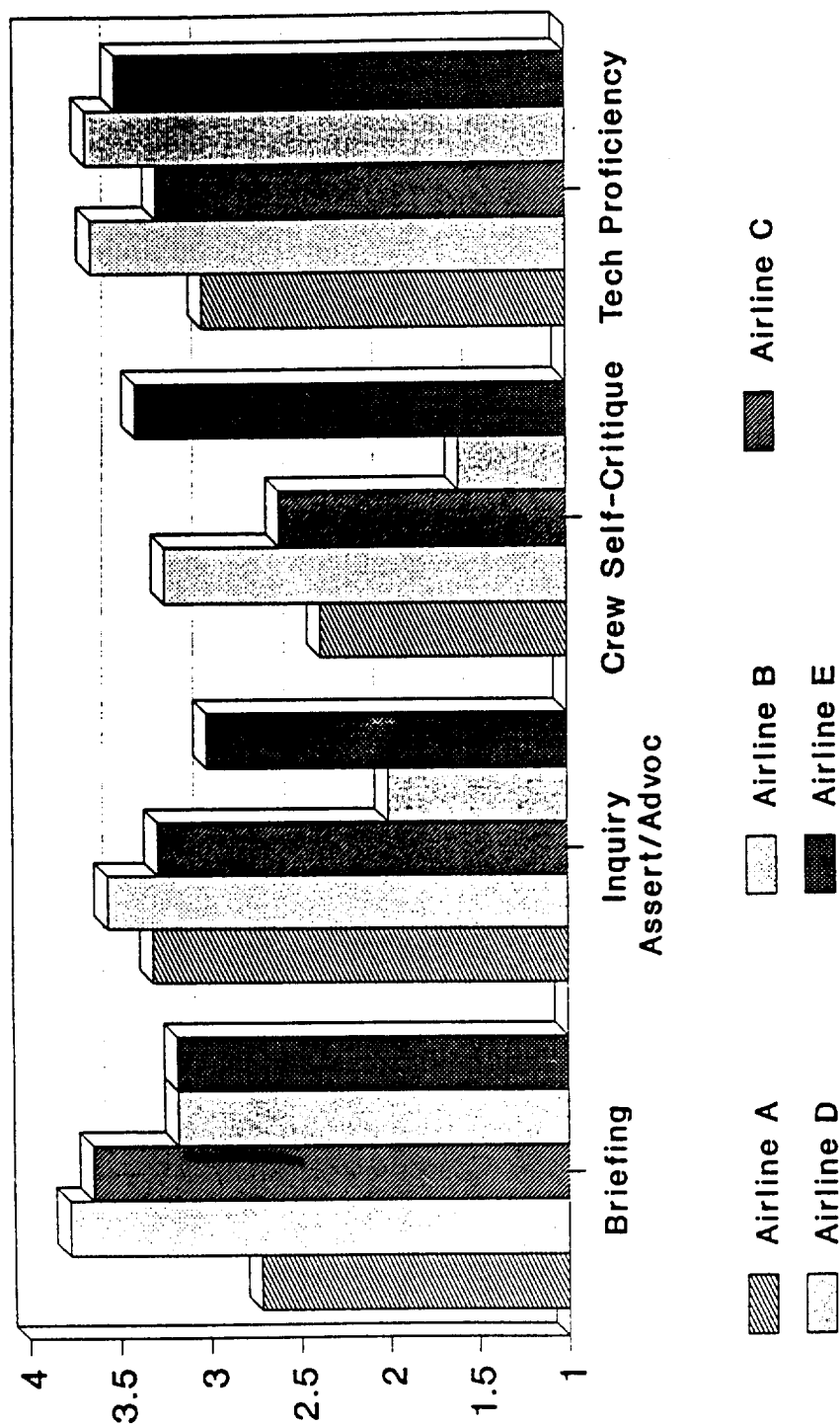
An opportunity in this portion of the study existed to objectively compare crew performance across airlines. Though the airline industry prides itself on its standardization, significant differences do exist. Table 12 shows where these differences are significant. Figure 35 then shows the mean ratings of these airlines in these particular categories.

Table 12
Categories Showing Significant Differences Between Airlines

Category	df	F	p
Briefing	4, 90	6.86	.000
Inquiry/Advoc/Assertion	4, 90	3.80	.007
Crew Self-Critique	4, 90	5.94	.000
Technical Proficiency	4, 92	1.56	.010

Even in its early stages, this small sample already confirms fleet differences, hints at technology and crew size differences, and for the first time illustrates that airlines do indeed differ in how their crews perform. As it matures, this method of data gathering will enhance our view of crew interactions.

Figure 35: Means for Categories In Which Airline Differences Exist



CHAPTER FIVE

Based on data from these two airlines, Cockpit Resource Management training has improved the behavioral interaction effectiveness of crews on the line and in LOFT. Airline A experienced the clearest improvement. This airline carefully trained its data takers and implemented an aggressive program for all of its pilots in a 2-month period. Airline B, while also showing improvement, fell prey to the hazards of untrained, unanchored observers. Airline B crews exhibited significant improvement in their interactions during 1987. However, by 1989, approximately 69% of the observers recording data had never been anchored in the five-point scale. By that point, they were watching only fully trained crews and their ratings muddled the clear data obtained earlier. Therefore, the importance of anchored observers was highlighted in that study.

An interesting finding concerning fleet differences occurred. Though the airline industry prides itself on being highly standardized, crews from different fleets obviously interact in different ways. The data from the within airline and within fleet method strongly supported the hypothesis that significant differences in behaviors exist between fleets. One of the reasons for that difference can be attributed to the advanced technology cockpit versus standard cockpit configuration. Airline A crews in 1989, exhibited significant differences based on their configuration with advanced cockpit crews performing at a higher level in LOFT, but with standard cockpit

crews outperforming their counterparts on the line. The following year, when all pilots had completed CRM training, no significant difference was noted between the two technologies on the line, but advanced technology crews continued to significantly dominant in LOFT.

The within airline and across fleet line audit done by Airline A replicated the findings from the within airline and within fleet method. Fleet differences did exist on the line, however the technology level was not a significant cause, though advanced technology crews still tended to earn higher ratings. Perhaps the LOFT environment, which emphasizes abnormal situations, allows advanced technology cockpit crews to put that technology to use in flying the aircraft. Then crews are allowed more time to gather information about the problem, discuss options, and decide on a course of action, thereby fully using each other's knowledge. Standard technology crews do not have the option of telling the aircraft to fly to a specific point in space. They must be more actively involved in flying, which decreases the amount of time and resources they can contribute to solving a problem.

Another reason for the fleet differences seems to be crew size. Again using Airline A data, significant differences were found between 2-person and 3-person crews. Two-person crews consistently outperformed 3-person crews in both line and LOFT operations during 1989 and 1990. Two-person crews also earned higher ratings during the within airline and across fleet study. While the third person is an extra set of eyes, that extra

communication node seems to detract more than aid behavioral operations. Keeping in mind the early studies of groups, it is interesting to note that Simmel (1950) was impressed with the cohesiveness of the dyad. He proposed that a triad would be plagued by the formation of coalitions and imprecise communication, while the dyad would be more effective in reaching its goals.

Other reasons for fleet differences certainly exist. The positive ratings of crews flying the B-737 and the MD-88 could be due to the younger crews typically flying those aircraft. These pilots could be more accepting of CRM concepts because they consider the training just one among many steps needed to make them safe pilots. Also, younger pilots may have 'grown up' in a less authoritarian flying environment than did the older captains who settle comfortably into flying the B-727. Having a background of cooperation would encourage younger pilots to be more involved crewmembers. Unfortunately, the three data sets used in this study cannot address these speculations, but future investigations should examine these and may discover other reasons for fleet differences.

This study also discovered significant differences between crews flying for different airlines. Though the airline industry is supposedly highly standardized, evidence shows that different airline crews clearly fall on a continuum of effective performance.

In answer to the FAA's question, "Does CRM training effect the performance of airline crews?", the answer is a definite "Yes". Since the

inception of CRM training programs in two airlines, crew performance has improved. This study has also highlighted significant differences between fleets that can be attributed in part to technology level and crew size. Two-person crews using advanced technology are the most effective in dealing with the abnormal situations presented in LOFT. On the line, crew size is a factor in the fleet differences with 2-person crews once again performing at a higher level. While technology level was not a significant factor in fleet differences in day-to-day line operations, advanced technology cockpit crews tend to earn higher scores for their crew effectiveness.

Appendix A

NASA/UT

LINE/LOFT WORKSHEET

FLIGHT AND EQUIPMENT INFORMATION		LINE <input checked="" type="checkbox"/>	LOFT <input type="checkbox"/>						
FROM/TO <u>INTELEX</u>	EQUIP. <u>707</u>	RATER <u>1019</u>							
HOURS ON DUTY <u>4.30</u>	TAKEOFF/LDGS <u>1/1</u>	BASE <u>M/1019</u>	CA <u>FO</u> <u>FE</u>						
I. EVALUATION (LINE ONLY - S OR U) <table> <tr> <td><u>S</u></td> <td><u>S</u></td> <td><u>S</u></td> </tr> <tr> <td>CA</td> <td>FO</td> <td>FE</td> </tr> </table>				<u>S</u>	<u>S</u>	<u>S</u>	CA	FO	FE
<u>S</u>	<u>S</u>	<u>S</u>							
CA	FO	FE							
II. COMMUNICATIONS AND DECISION MAKING									
A. Pre-flight briefing									
1. Thorough, addresses coordination; planning, and problems anticipated.	CA <u>S</u>	FO <u>S</u>	FE <u>S</u>						
2. Open communication established among crewmembers	CA <u>S</u>	FO <u>S</u>	FE <u>S</u>						
B. In flight									
1. Timing of communications proper.	CA <u>S</u>	FO <u>S</u>	FE <u>S</u>						
2. Communications relevant, complete, and verified.	CA <u>U</u>	FO <u>U</u>	FE <u>U</u>						
3. Active participation in decision making process encouraged and practiced.	CA <u>S</u>	FO <u>S</u>	FE <u>S</u>						
4. Alternatives weighed before decisions are final.	CA <u>S</u>	FO <u>S</u>	FE <u>S</u>						
5. Inquiry practiced	CA <u>S</u>	FO <u>S</u>	FE <u>U</u>						
6. Advocacy practiced	CA <u>S</u>	FO <u>S</u>	FE <u>S</u>						
7. Critique practiced	CA <u>U</u>	FO <u>U</u>	FE <u>U</u>						
8. Appropriate IMMEDIATE action taken if time not available for <u>crew</u> decision making.	CA <u>-</u>	FO <u>-</u>	FE <u>-</u>						
III. INTERPERSONAL (MANAGEMENT) STYLES AND ACTIONS									
1. Shows concern with accomplishment of tasks at hand.	CA <u>S</u>	FO <u>S</u>	FE <u>S</u>						
2. Shows concern with interpersonal relationships among crewmembers.	CA <u>S</u>	FO <u>-</u>	FE <u>S</u>						
IV. WORKLOAD AND PLANNING									
1. Work overloads reported, work prioritized or re-distributed.	CA <u>S</u>	FO <u>S</u>	FE <u>U</u>						
2. Plans ahead for high workload situations.	CA <u>U</u>	FO <u>S</u>	FE <u>U</u>						
3. Appropriate resources used in planning.	CA <u>S</u>	FO <u>S</u>	FE <u>U</u>						

NASA/UT

LINE/LOFT WORKSHEET

V. CREW ATMOSPHERE AND COORDINATION

1. Overall workload	Low	1	2	3	4	5	High
2. Overall vigilance	Inattentive	1	2	3	4	5	Alert
3. Interpersonal climate	Hostile	1	2	3	4	5	Friendly
4. Preparation and planning	Late	1	2	3	4	5	Well in advance
5. Distractions avoided or prioritized	Poor	1	2	3	4	5	Excellent
6. Workload distributed and communicated ..	Poor	1	2	3	4	5	Excellent
7. Conflict resolution (If observed, otherwise blank)	Poor	1	2	3	4	5	Excellent
✓ 8. Overall TECHNICAL proficiency	Poor	1	2	3	4	5	Excellent
✓ 9. Overall Resource Management	Poor	1	2	3	4	5	Excellent
✓ 10. Overall CREW effectiveness	Poor	1	2	3	4	5	Excellent

VII. SUPPLEMENTARY INFORMATION: Conditions which significantly influenced the flight (Include weather, ATC, pre-existing mechanicals, in-flight abnormal events, etc.) Describe below:

Completed FORM Seminar: CA _____ FO _____ FE _____ ("X" if completed)
 Completed LOFT: CA X FO X FE X ("X" if completed)

VIII. COMMENTS:

Item # _____ Comments:

AIR LINES CRM EVALUATION SHEET

SECTION I. PERSONNEL DATA

	Type Training					Evaluation							
PROFICIENCY CHECK	CAPT	<input type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>	S or U	CAPT	<input type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>
LINE CHECK	CAPT	<input checked="" type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>		CAPT	<input checked="" type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>
OTHER _____	CAPT	<input type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>		CAPT	<input type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>
LOFT # _____	CAPT	<input type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>	Complete Y or N	CAPT	<input type="checkbox"/>	F/O	<input type="checkbox"/>	S/O	<input type="checkbox"/>

BASE

CAPT	F/O	S/O
------	-----	-----

CREW COMPLETED
CRM SEMINAR PHASE(S)? (X)

A	B	A	B	A	B
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CAPT	F/O	S/O	CAPT	F/O	S/O

EQUIPMENT D2-9
NO. T.O. & UNOS 2

TIME OBSERVED 2430
RATER # 6024

SECTION II. EVALUATION

(Circle)

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

In some cases the actions of a particular crew member may be particularly significant to the outcome of the flight. In cases where this happens, enter the relevant item number from above next to the position of the crew member and circle the rating.

CAPT Item # _____ 1 2 3 4 5 _____

F/O Item # _____ 1 2 3 4 5 _____

S/O Item # _____ 1 2 3 4 5 _____

AIR LINES CRM EVALUATION SHEET

SECTION III. REPEATED MANEUVERS

NUMBER OF REPEATS TO ATTAIN SATISFACTORY PERFORMANCE

1. Emergencies and Abnormals
2. Rejected Takeoff
3. Takeoff Engine Failure
4. Departures and Arrivals
5. Holding
6. Steep Turns (PIC Only)
7. Approaches to Stalls
8. Non-Precision Approaches
9. Manually Controlled ILS Engine-Out
10. Rejected Landing Through Missed Approach
11. Missed Approach
12. Approach and Landing - 50% Power Loss
13. Normal ILS
14. Lower Than Standard Minimums Certification

CAPT	FO	SO

SECTION IV. COMMENTS

Describe Abnormal or Emergency Conditions, Conflicts, or Individual Behaviors Rated in Section II. Also comment on Extreme Ratings from Section II.

SECTION V. SUPPLEMENTARY INFORMATION

Describe Conditions Which Significantly Influenced the Flight, ATC, Weather, Mechanical, Abnormal Events, Etc.

NASA/UT LINE/LOS CHECKLIST

I. FLIGHT AND EQUIPMENT INFORMATION

Airline _____ Date (Mo,Yr) _____ RATER ID. _____

LOFT ☐ LOE ☐ SPOT ☐ LINE CHECK (S or U) ☐ Line Observation ☐

Scenario ID _____ Pilot flying: CA ☐ FO ☐

ROUTING _____ A/C Type & Series _____ HOURS OBSERVED _____ # LEGS OBSERVED _____

Demographics	Captain	First Officer	Flight Engineer
Completed Initial CRM (Y, N, or ?)	<input type="text"/>	<input type="text"/>	<input type="text"/>
Number of CRM Recurrent Sessions	<input type="text"/>	<input type="text"/>	<input type="text"/>
Number of LOS/LOFT Sessions	<input type="text"/>	<input type="text"/>	<input type="text"/>
Crewmember Domicile	<input type="text"/>	<input type="text"/>	<input type="text"/>
Flight Hours in this Aircraft	<input type="text"/>	<input type="text"/>	<input type="text"/>
Flight Hours in this Position	<input type="text"/>	<input type="text"/>	<input type="text"/>
Approximate Age	<input type="text"/>	<input type="text"/>	<input type="text"/>

II. CREW EFFECTIVENESS MARKERS

1. Briefings (conduct and quality)	None/Poor	1	2	3	4	5	Excellent
2. Inquiry/Assertion/Advocacy	None/Poor	1	2	3	4	5	Excellent
3. Crew self-critique (decisions and actions)	None/Poor	1	2	3	4	5	Excellent
4. Communications/Decisions	Poor	1	2	3	4	5	Excellent
5. Leadership-Followership/Concern for tasks	Poor	1	2	3	4	5	Excellent
6. Interpersonal relationships/Group climate	Poor	1	2	3	4	5	Excellent
7. Preparation/Planning/Vigilance	Poor	1	2	3	4	5	Excellent
8. Workload distributed/Distractions avoided	Poor	1	2	3	4	5	Excellent
9. Overall TECHNICAL proficiency	Poor	1	2	3	4	5	Excellent
10. Overall CREW effectiveness	Poor	1	2	3	4	5	Excellent

III. SUPPLEMENTARY INFORMATION:

11. Environmental workload Low 1 2 3 4 5 High

Other conditions which significantly influenced the flight (include weather, ATC, pre-existing mechanicals, in-flight abnormal events, IOE, extra crewmembers, etc.): Describe below.

IV. SPECIAL CIRCUMSTANCES: This section provides data on non-standard situations or behaviors that may influence crew performance. If conflicts occur, rate how effectively they were resolved.

12. Severity of abnormal or emergency situation Low 1 2 3 4 5 High

13. Conflict resolution Poor 1 2 3 4 5 Excellent

In some cases the actions of a particular crewmember may be particularly significant to the outcome of the flight. In cases where this happens, enter the relevant item number from above, check the position of the crewmember involved, and circle the rating assigned.

☐ ☐ ☐ ☐ Poor 1 2 3 4 5 Excellent
Item No. Captain First Officer Engineer

☐ ☐ ☐ ☐ Poor 1 2 3 4 5 Excellent
Item No. Captain First Officer Engineer

☐ ☐ ☐ ☐ Poor 1 2 3 4 5 Excellent
Item No. Captain First Officer Engineer

☐ ☐ ☐ ☐ Poor 1 2 3 4 5 Excellent
Item No. Captain First Officer Engineer

V. COMMENTS: Describe abnormal or emergency conditions, conflicts, or individual behaviors rated in Section II. Also comment on extreme (1 or 5) ratings from Section II.

Item #

Comments

Appendix B

SELECTED COMMENTS FROM THE ADVANCED CRM INSTRUCTORS

727

1. Felt Captain did not establish open, fluid communications with "A" line Flight Attendant. It was very brief with no opportunity for feedback and accomplished after arrival of final paperwork. Captain was extremely proficient, just so quiet it seemed to hamper good, open communications within crew. First Officer exhibited "nonchalant" attitude toward flight engineer. It seemed a little disrespectful on occasion. Second officer was working hard to be a part of "loop" and challenged incorrect altitude in altitude selector window with proper level of assertive statement. Captain did set high standards and expectations for safe, efficient flight.
2. Captain never communicated his plans. Left First Officer out of loop. First Officer never made attempt to draw out plans. Captain was very low on approach, RED/RED probably on purpose, but nothing was said nor any questions asked.
3. Captain set tone by introducing First Officer and Second Officer as "best you'll ever see!" That invited crew to enter in. First Officer asked about peculiarities which might exist at destination he had not previously flown to. He took initiative to use engine anti-ice when no one else did; Captain had established atmosphere which invited inquiry and critique; Climate was exceptionally amicable, relaxed and at the same time, professional.

4. Captain appeared new to the aircraft and while he didn't self disclose this to me the way he was using the talents of a seasoned First Officer and Second Officer led me to believe this. He gave one of the most thorough relevant briefings I have yet seen, and the crew responded to this as a team and they would work for and with this Captain to accomplish the task at hand. Weather was a factor and the crew did well. First Officer and Second Officer used crewmember diplomacy to help guide some of the tasks like should we seat the Flight Attendants, etc., during high work loads. The abnormal was the amber LED indicator in flight. This was caused by airfoil anti-ice, but I was the only one who had seen that before. The crew Second Officer went through the book and saw the note about A/I and the Second Officer and suggested that we turn it off to see if that was all, Captain said okay and the light went out. They discussed if A/I was necessary, and decided no and left the wing A/I off. Good job!

5. Captain very knowledgeable, dominated crew and hampered input. Second Officer appeared removed and alienated.

737

6. Quiet cockpit very little communication or coordination. Captain would change switch positions without communicating to First Officer. First Officer would later be surprised to find switch in the new position. Captain relied completely on autopilot. Captain would set up altitude capture, for example, and go on to something new and never monitor if altitude capture was taking place. Solo operation.

757

7. This was a very uneventful segment flown between two high density airports. Crew interacted very effectively. Though, interestingly the one time the Captain failed to communicate his plan (a descent clearance) he entered the data in the Flight Management System incorrectly and it was several minutes before the First Officer discovered the error. First Officer asked that I relay his dissatisfaction with procedural change not allowing pilot flying to maneuver his/her own flaps. Captain noted that new young First Officers are extremely well-trained and eager to participate. He went further in saying that if there is any one group which is difficult to work with it is the "academy guys".

757/767

8. Departure was delayed due to late aircraft arrival. Captain was on top of situation and kept passengers and Flight Attendants informed of progress and expected departure time. Crew worked well together although the relation was not overly friendly. (large age spread): Senior Captain--Junior First Officer). During last minute runway change they helped each other get the magic setup without heads down time. Captain supported Flight Attendant in Charge with a problem with one of the Flight Attendants--good mutual respect, even though his briefings were "short".

767

9. Captain very overpowering and strong willed. Within first 2 minutes told me he was a fighter pilot and if Delta would hire all fighter pilots, they

would not need CRM because they wouldn't have any problems. Played tricks on First Officer (like changing radio frequency to nonworking frequency). Overconfident, never opened flight kit, flew departure and approach without Jepp's. First Officer humbled himself for survival purposes, could not have been assertive, adapted well to Captain for effective teamwork.

10. Captain irritated because of a problem with his chief pilot--could not keep his mind on the task.

11. Captain did not ask or communicate anything to First Officer during the leg. The first time the First Officer or I knew something was going to happen is when the Captain picked up the microphone and asked ATC for deviations, direct routes, climb for turn or early descent--and it was the First Officers leg!

12. A one-man show, no resource management. All the requests were reasonable and appropriate for the situation and the First Officer seemed to have adapted to this style but the flow of info was zero. Both front to back (Captain to cabin) and left to right (Captain to First Officer).

MD-88

13. During ground (taxi) congestion, Captain became annoyed and "stepped" on both his co-pilot and several other aircraft to obtain taxi instructions. In my own opinion, co-pilot had called as much as possible. Captain then told co-pilot he was not aggressive enough (since he had finally obtained clearance). Neither crewmember was comfortable in critiquing actions and reviewing results because atmosphere was not comfortable.

Captain seemed to dominate both actions and words. Both crewmembers were dedicated to getting job done, just done in very "authoritative" atmosphere.

14. Both Captain and First Officer were excellent about sharing information concerning plans for action. Descent, somewhat abnormal due to very structured profile, was well briefed and altitudes double cross-checked to insure compliance. Captain was quiet by nature, but could have imparted more information about flight to Flight Attendants and set better cockpit atmosphere. When I introduced myself, neither pilot responded with their own names, but turned back and looked forward during very low workload time. After 15-20 minutes atmosphere relaxed some, and good discussion ensued.

15. Captain set excellent tone/atmosphere. Allowed First Officer to challenge and questions were encouraged. An example was a log book write-up made by Captain. Captain read the write-up to the First Officer and asked for comments and any other observations. First Officer was comfortable asking questions and quick to want to keep in the loop of info flow.

16. Crew did exceptional job relating delayed departure info to agents and flight attendants. Also kept passengers informed of status. During high work load periods, task were well divided and prioritized. One communications area seemed weak. Assumed Flight Attendants were knowledgeable of current abnormal situation without any communications taking place. One

crew member was reluctant to turn around and address Flight Attendants directly with complete, appropriate feedback to ensure communications loop.

17. Captain was speaking with such quiet, incomplete way, it was difficult to understand him. He directed First Officer to work on minor problem to the point normal inflight duties suffered. The "plan" or actions occurring were not communicated well by Captain or First Officer, probably because of preoccupation with minor maintenance problem. First Officer did on occasion question Captain on plan for approach and try and keep other crew members in loop.

18. In my ten years of service, this review is of one of the best, most effective, flight crews I have seen. The Captain led the way with a dynamic personality and positive can do attitude. His humor and hard work ethic set an extremely good tone. The other crew members flourished in this atmosphere working hard (as hard as possible) to accomplish the task and give the best service possible to "our" customers. Even as I do this rating a day later, and not being a part of the original crew, I can't help feel I was an integral part of this crew on this particular flight segment. The First Officer added immensely by his technical proficiency and "team member" attitude.

19. I was with this crew for 3 legs plus the layover. The first leg was short with weather and about as high a workload you can get in a 2-man operation. The Captain was too busy to "play the game of CRM" so all the positive things he did I think are the norms. Very good job by both of the

crew both from the operations point of view and the CRM standpoint. This is the way I wish all the operation was. Good climate for open communication all ways, super job.

L-1011

20. From the outset, it seemed that the Captain was not pleased to have me in the cockpit. He made several negative references to CRM however this did not interfere with effective crew interaction. Captain briefings were very thorough, referencing manuals and procedural plates. He did not hesitate to acknowledge confusion and obtain clarification over a procedure or clearance that might have been misunderstood. The climate for effective communication was exceptionally good. Subordinates did not hesitate to express opinions counter to Captain's, and all such interactions was done with good humor. Second Officer was particularly adroit at accommodating both Captain and First Officer while making a PA concerning flight progress.

UNIDENTIFIED

21. Captain used Flight Management System at 1500' AGL on climbout instead of monitoring instruments/traffic. Pilot Flying (First Officer) copied ATIS. Did not ask Pilot Not Flying to act as teammate. Captain took aircraft from Pilot Flying (First Officer) just after touchdown at high speed.

22. This crew had minimum communication for entire flight. Captain was not in aircraft until 3 minutes prior to scheduled a pushback. Before start checklist read after papers were received and doors closed. No talking in

cruise and Captain tuned his own navigation radios for approach even though he was flying.

23. An excellent crew that relaxed and worked well as a team. Second Officer felt comfortable enough to point out switches in wrong position. First Officer flew leg and made approach to near minimums. Planned ahead and did very well, Captain was excellent Pilot Not Flying and everyone knew their role.

24. On a short flight leg this aircraft was held up extremely high because of lower traffic. First Officer first started expressing concern by making several references to altitude in relationship to distance from the airport. Finally made an excellent series of inquiries; "Do you want to S-turn?", "Do you want a 360 degree turn?" Through the passage of timely and accurate information, successful inquiries, and coordinate total crew effort the landing was safe and uneventful. Great to watch!!

25. Good crew. Captain was very active in decision making, planning and communicating. Also very active in actions, sometimes unfortunately so. On First Officer's leg Captain was still on controls at 80 KIAS on takeoff roll, confusing First Officer as to who was flying. No positive change of control then or on landing roll. Captain also made autopilot inputs in flight while First Officer was Pilot Flying and didn't tell him about it. Overall though, a very good crew.

26. Co-pilot was Pilot Flying. He did not ask the Captain to do any Pilot Not Flying duties and Captain didn't volunteer to do them. Pilot Flying did most everything by himself.

27. This crew was dominated by two young "fighter types". They were not disrespectful, but neither were they strong team players. Captain maintained decorum but the atmosphere was icy and therefore lacked the sort of interaction that would include thorough briefings and discussion of possible irregularities.

28. Captain gave most effective Flight Attendant briefing I have ever heard. Both First Officer and Second Officer practiced effective assertion. First Officer was female and very disturbed at treatment she had just received by chief pilot over a problem with a Captain. She was angry and bitter and rightfully so. She did not allow this to affect her professionalism. Second Officer was an older man and had been with five airlines. He seemed to be competing with Captain and somewhat argumentative. However, Captain was still able to build an effective team.

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VITA

Cathy Colebrook Clothier was born in Orange, Texas, on February 19, 1960, the daughter of Norman Edward Colebrook and Judith Ann Colebrook. After completing her work at Little Cypress-Mauriceville High School, Orange, Texas, in 1978, she entered the United States Air Force Academy in Colorado Springs, Colorado. She received a Bachelor of Science in Engineering and a commission as a Second Lieutenant in the Air Force in June, 1982. She then attended Undergraduate Pilot Training at Vance Air Force Base, Enid, Oklahoma. After earning her wings, she trained in the KC-135 Stratotanker at Castle Air Force Base, Merced, California. In November, 1983, she reported for duty at McConnell Air Force Base, Wichita, Kansas. During her tour, she upgraded from pilot to aircraft commander to instructor/evaluator pilot. Through evening classes, she earned a Master of Arts in Human Resources Development from Webster University in May, 1989. In September, 1989, she entered The Graduate School of The University of Texas, sponsored by the Air Force.

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