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**HUMAN RESOURCES**

**COCKPIT RESOURCE MANAGEMENT:  
A SELECTED ANNOTATED BIBLIOGRAPHY**

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ANNOTATED BIBLIOGRAPHY**

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## SUMMARY

The concept of cockpit resource management (CRM) emerged during a 1979 study by the National Aeronautics and Space Administration (NASA) which was intended to study the interaction of pilot workload with errors. During this study, researchers began to realize that the stereotypical airline captain who "can do no wrong" was not feasible in today's complex jet aircraft. Several accidents and incidents may be traced directly to improper crew management or lack of coordination by the crew. NASA began to explore the feasibility of teaching generic management principles to flight crews. Several training programs have been developed, and some significant research has been conducted which further defines optimum CRM training and practice.

Line-Oriented Flight Training (LOFT) is a training method developed originally to relate simulator training more closely to actual "line" flying. Airlines found that they could enhance the sharing of experiences by simulating an entire flight, complete with incidents experienced in the real world, rather than repeated malfunctions taken out of context. It is important to note that LOFT is often utilized by airlines and other simulator users without employing the principles of CRM. However, LOFT is a valuable tool in CRM training.

Although by no means exhaustive, this selected annotated bibliography focuses on the major issues associated with CRM. This bibliography addresses current training practices, techniques which enhance crew coordination, and questions appropriate for systematic research.

## PREFACE

This annotated bibliography was developed in an effort to identify research issues relevant to military aircrew training system design. The effort was accomplished under the University of Dayton Research Institute (UDRI) Flying Training Research Support Contracts, Nos. F33615-84-C-0066 and F33615-87-C-0012, which were sponsored by the Air Force Human Resources Laboratory, Operations Training Division (AFHRL/OT). The author wishes to express his appreciation for the professional support of the following individuals:

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## COCKPIT RESOURCE MANAGEMENT: A SELECTED ANNOTATED BIBLIOGRAPHY

### I. INTRODUCTION

The Air Force has been concerned about enhancement of aircrew training to address higher-order skills usually gained through experience. In light of the present trend toward a younger, less experienced crew force, these skills need to be identified and addressed throughout all aircrew training programs. Crew coordination is one such skill, important in large aircraft. During the past decade, the concept of cockpit resource management (CRM) training has emerged within commercial airlines. Many accidents might have been prevented had the captain managed the cockpit in a different manner. Most airlines now provide CRM training to their crews. There is a great deal of anecdotal information on the success of these training programs showing where aircraft accidents may have been prevented as a result of CRM training. There is, however, very little sound empirical evidence to validate the effect of CRM training.

The Military Airlift Command (MAC) has instituted similar courses for all aircrews. The course title, Aircrew Coordination Training (ACT), was chosen to emphasize that the aircrew includes those individuals outside cockpit boundaries. The Strategic Air Command (SAC) is considering similar training for B-52 and KC-135 crews, where both the mission and cultural framework of the crew differ greatly from those of commercial airlines and, in many respects, from those of MAC.

This review of the literature has been conducted to establish a baseline of information which may be applicable to the development and refinement of these and other Air Force training programs.

Although the concept of crew coordination has been accepted for some time, several other concepts relating to human factors have also been recently included under the heading of CRM. It is important to differentiate between CRM and a simulation technique which has become invaluable in exercising CRM skills called Line-Oriented Flight Training (LOFT) (Lauber & Foushee, 1981b). A short discussion of both CRM and LOFT is in order.

The concept of cockpit resource management (CRM) emerged during a National Aeronautics and Space Administration (NASA) study of the relationship between pilot workload and errors (Ruffell Smith, 1979). During this study, researchers at NASA began to realize that the stereotype of the omniscient airline captain was not feasible in today's complex jet aircraft. Accident and incident reports also showed that improper or incomplete use of all resources available (other crew members, Air Traffic Control, home base) often leads to less-than-optimum handling of an innocuous situation which then deteriorates

catastrophically. CRM training usually consists of a seminar which elucidates the concepts of situational awareness, interpersonal communication, decision making and leadership, followed by some sort of practice session, either in a role-playing situation or in a simulated operational flight.

LOFT was originally designed to make simulator training more closely resemble operational "line" flying. By simulating an entire flight, including incidents experienced in the real world rather than repeated malfunctions taken out of context, airlines can enhance the sharing of experiences heretofore available only in verbal "hangar flying" sessions.

With the advent of CRM training, it was realized that LOFT could allow crews to practice and refine concepts learned in CRM training. Videotapes of LOFT flight segments are played back during debriefing to show crew members how they interact. The LOFT administrator, who does not interfere during the flight, identifies and presents significant events on the tape, enabling crew members to assess their own effectiveness. The administrator guides the discussion toward CRM issues, leaving technical performance for another section of the debrief. The tape is then ceremoniously erased to relieve crew members' fears regarding unauthorized use of the recording. Military organizations, such as MAC, prefer the term Mission-Oriented Simulator Training (MOST) to reflect the unique nature of their missions. It is important to note that LOFT and MOST are often utilized without emphasizing CRM principles. However, LOFT and MOST are valuable tools in CRM training.

Because the concept of CRM is a fairly recent one, most applicable publications are of recent origin. Concepts are becoming more refined as research efforts and operational concerns center on the important issues. Research is presently being conducted under NASA grants at Harvard University, the University of Texas, and the U.S. Air Force Academy, as well as at University of Dayton Research Institute through a contract with the Air Force Human Resources Laboratory, Operations Training Division (AFHRL/OT). The NASA Ames Research Center continues in-house research efforts in CRM as well. Future articles would most probably be published in proceedings of conferences succeeding those listed in this bibliography, or as technical reports by the research organizations themselves.

There are two main sections to this paper. The first is a discussion of observations from the various sources, arranged by topics of interest. These observations are not exhaustive, but represent important ideas not contained in the bibliographical annotations.

The second section is an annotated bibliography. Sources were selected which provide the most pertinent information

regarding CRM training, techniques, and questions appropriate for further systematic research.

The annotated bibliography is divided into two subsections. The first identifies proceedings of conferences which contain several articles of interest. The following section contains articles from these sources, as well as other separate articles.

## II. OBSERVATIONS

The notes which follow are intended to provide additional insights beyond those presented in the abstracts. Issues related to training are discussed first, followed by specific techniques which may enhance CRM in actual practice. Finally, suggestions for further research are discussed.

### Training Issues

The following compilation of notes from the various sources relates to training considerations. These observations fall into three categories: (a) guiding principles, (b) curriculum design issues, and (c) delivery systems.

#### Guiding Principles

Several concepts were discussed which apply to the theoretical or philosophical basis of CRM training. Whereas Ruffell Smith (1979) identified improper division of workload as a potential source of crew error, several other factors have subsequently been identified. Several concepts targeted for training are found in working group reports in Orlady and Foushee (1986) and are summarized in the following seven areas: communication, situation awareness, problem-solving, decision-making, judgment, leadership/followership, stress management, critique, and interpersonal skills.

Foushee (1985) stated that efforts at enhancement of crew coordination assume an effective crew member is in each crew position. Although NASA and the National Transportation Safety Board (NTSB) cite many problems attributable to lack of proficiency or skill on the part of a crew member, lack of proficiency may be addressed by more traditional training methods than LOFT or MOST. However, it may be apropos to provide techniques or procedures to identify and deal with an incompetent crew member as part of CRM training.

Attempts to change CRM practices among crew members require changing crew members' attitudes about how they should interact. Helmreich (1986b) noted that attitudes are resistant to change. He observed that aircrew members who go through some form of CRM training are often enthusiastic initially, but backslide unless

they are reinforced. "Recipients must believe that the program is meaningful and likely to produce personally useful results" (Helmreich, 1986b, p. 19). Flight crews must come to expect good cockpit resource management procedures to be the norm. This expectation must be reinforced by higher level management (Hackman, 1986; Helmreich, 1986b).

Personality factors constitute an additional barrier. Helmreich (1986b) observed that personality factors may pose a limitation on the potential impact of CRM training, that there are limits to what can be done with certain personality types. Research is needed to determine how training programs can be optimized for different personality types.

In an effort to determine the value of providing activities to enhance team cohesiveness, Helmreich (1980) performed research using motivated professional aquanauts working in a highly structured underwater environment in Project Tektite, and found that positive changes in crew performance led to increased group cohesiveness, but efforts which improved group cohesiveness had no effect on performance. Perhaps factors such as respect for each other's skills or satisfaction with group success may increase group cohesiveness. Additional research is needed to identify these factors.

Although CRM attitudes and expectations could be instilled much earlier in training than they are today, the emphasis in early training must be on individual skills. Until individual skills are mastered, the learning of group skills may impede the learning of individual skills. For example, Johnston (1966) trained five groups to perform a simulated radar-controlled aerial intercept. He found that training which aims at improving team skills inhibits development of individual skills. This has been borne out by the experience of airlines using LOFT-type training. The consensus of a NASA/Industry Workshop (Lauber & Foushee, 1981a) was that individual skill training should be carried out separately from CRM training. It would seem important to introduce CRM concepts early in a student's career with an organization, yet techniques for using these concepts might not be practicable until sufficient technical skill is achieved.

Lauber (1980) stated that the real problem facing the pilot is that decisions are made under conditions of "bounded rationality." In other words, the decision maker always works with imperfect information. There must be a motivation for change. Decisions are made only when the current alternative becomes unsatisfactory, rather than when a better course of action presents itself.

## Cockpit Resource Management Curriculum Elements

Performance-based CRM training objectives cannot be as easily established as those in specific skill training. Many of the expected changes are in the realm of attitudes and commitments. As a result, a variety of curriculum elements are found in the various training programs in existence. As a framework for discussion, the outline composed by the Curriculum Working Group described in Orlady and Foushee (1986, pp. 193-202) will be used in a slightly modified form. Most curriculum elements suggested can be included under one of the following headings: (a) situational awareness, (b) communications and interpersonal skills, (c) leadership and decision making, (d) problem solving, (e) critique.

Situational Awareness. Many accidents and incidents have been related to loss of situational awareness by the crew. Bolman (1979) discussed a concept he labeled "theory of the situation;" i.e., beliefs and cognitive patterns relative to the immediate environment. This concept is related to the broader topic of situational awareness. Bolman noted that in most accidents where CRM was a factor, the pilot's theory of the situation was in error and there were data available which so indicated. Bolman further stated that a person has a "theory of practice," which is made up of (a) core values (basic criteria for making choices); (b) beliefs and hypotheses about the experienced world; (c) skills (learned behavior patterns); and (d) outcomes which are used as feedback to modify these core values, beliefs and skills. A crew member's theory of practice should lead to questioning an erroneous theory of the situation.

Bolman discussed four factors which increase the probability that a faulty theory of the situation will be detected and revised: (a) a theory of practice which builds in inquiry and testing in anomalous situations, (b) abilities of crew members to combine skills in advocacy and inquiry, (c) an open management style of the captain, and (d) role system and procedures for role modification shared mutually by the crew.

Bolman identified two training goals which would enhance a crew member's theory of practice: (a) Train crew members to react assertively when they sense the possibility that any crew member's theory of the situation is in error. Crew members must feel an obligation to insist that the theory be tested in such an event. (b) Train crew members to accept such challenges from other crew members. Whenever the theory of the situation is challenged, the crew member has an obligation to seek information with which to test the validity of his theory. Each crew member must develop a theory of practice which calls for testing or inquiry whenever there is ambiguity or anomaly in the theory of the situation.

Bolman listed seven areas in which training is needed to enhance the crew members' recognition of an erroneous theory of the situation: (a) understanding interaction between the situation and their theory of practice; (b) distinguishing between espoused theory and theory in use; (c) exploring the possibility of discrepancies in their own theory of the situation or theory of practice; (d) developing skill in inquiry, advocacy, and "on line learning"; (e) developing a theory of practice that emphasizes those skills; (f) developing a conceptual understanding of interpersonal processes and role issues; and (g) practicing the skill of implementing these concepts.

Several other authors have recommended curriculum elements to enhance situational awareness. Many of the elements contained in the People Express program described by Bruce and Jensen (1986) are aimed at such enhancement. These elements include home study sessions on identifying the problem, developing a short-term strategy, and monitoring changes that would affect the flight situation. Schwartz (1986) suggested five elements that contribute to good situational awareness: (a) training and experience to build a basis for judgment about the situation, (b) technical skill to allow more residual attention to devote to awareness of the situation, (c) spatial orientation--knowing where you are and where you want to go, (d) CRM skills which assist in maintaining and regaining situational awareness, and (e) sound physical health and attitude.

Schwartz (1986) also listed 10 clues which are indicative of a loss of situational awareness: (a) a feeling of ambiguity, (b) a fixation or preoccupation, (c) an empty feeling or confusion--when a pilot or crew member is unsure of the state or condition of the aircraft, (d) violating minimums or consideration of doing so, (e) consideration or use of undocumented procedures, (f) realizing that nobody is flying the aircraft, (g) realizing that nobody is looking out the window, (h) failure to meet targets--when parameters or expectations are not met, (i) allowing discrepancies to go unresolved, and (j) departure from standard operating procedures.

Communications and Interpersonal Skills. Interpersonal skills including communication skills comprise the interactional arena of CRM activity. Many of the communication and interpersonal behavior patterns which have become institutionalized in aircraft cockpits are not conducive to effective crew coordination. Bolman (1979), Christian and Morgan (1986), and Fiedler (1986) have all recommended that crew members practice inquiry and advocacy in their flight crew activities. Bruce and Jensen (1986) have discussed working toward the optimum balance of authority and assertiveness.

Leadership and Followership. Leadership encompasses all the skills, attitudes, and procedures involved in focusing the team

effort on the task. Although there is generally one designated leader at each level of control, any member of the team may be required to provide leadership in a subtask for which he has either superior expertise or specific responsibility. Most courses provide curriculum elements to enhance both leadership and followership skills. Management style and management techniques are used as a focus for leadership discussion (Bruce & Jensen, 1986; Carrol & Taggart, 1986; Fiedler, 1986; Schwartz, 1986).

A major concern is that crew members at each position should understand their role in relation to optimized crew interaction. Bolman (1979) pointed out the need to examine traditional assumptions about management and superior-subordinate relationships. Several authors have suggested changes in the traditional role of both captains and subordinate crew members (Bruce & Jensen, 1986; Christian & Morgan, 1986; Fiedler, 1986; Lauber, 1980; Margerison, McCann, & Davies, 1986).

Problem Solving and Decision Making. Improved problem solving and decision making are at the heart of the effort to reduce crew error accidents and incidents. The very fact that a crew is composed of more than one informed person allows the pooling of resources to solve problems. When a team is forced to reach a single group decision, one of several possibilities may occur: (a) the decision suggested by the strongest, most vocal, or most respected member may be accepted without examination; (b) the team may reach a compromise decision that is better than the average of all members' individual decisions; or (c) the decision reached may be better than the best decision made by any member of the team. The latter alternative is, of course, the ideal synergistic result. The concept of synergy in problem solving is central to the optimum utilization of all crew resources. Halliday, Biegalski, and Inzana (1986) provided a model for achieving a synergistic decision.

Critique. Carroll and Taggart (1986) included skill at critiquing as part of a crew's responsibility. Through constructive critique, the crew can improve their performance over time. Pre-mission analysis and planning should anticipate problems based on what went well or poorly in the past. An ongoing review during the flight, as suggested by Halliday, Biegalski, and Inzana (1986), assists in keeping crew members involved in problem solving, and situationally aware. Debriefing, or post-flight critique, may cover what went well, what went poorly, and any unresolved conflicts. The Curriculum Development Working Group report (Orlady & Foushee, 1986) suggested that two elements of critique are of basic concern: (a) remembering to perform a critique, and (b) structuring the critique itself.

Cultural Considerations. Cavanagh and Williams (1986) discussed six differences between airline crews and MAC crews which must be addressed in designing cockpit resource management training for MAC: (a) military rank structure and the possibility of rank reversal in the crew, (b) the variety of missions and unfamiliar destinations, (c) crew qualifications and relatively low experience levels, (d) the lifestyle of the crew, (e) labor relations, and (f) miscellaneous concerns associated with military aviation and training.

### Delivery Systems

Simulator training as provided by LOFT or MOST is of great value in allowing practical application of CRM concepts. However, initial training of these concepts is required before crew members can receive the maximum benefit from the simulation.

Academic Training. Many different courses have been developed over the past few years to provide the conceptual background for CRM. Results of a survey conducted by the International Air Transport Association (White, 1986) showed that eight airlines employed the lecture method, five used the seminar workshop, four included simulator training and LOFT, two airlines provided home study courses, and one used an audio/visual presentation. There was no consensus among the airlines surveyed as to whether the CRM training should stand alone or be integrated as part of a total training package. Four airlines offered the course to captains only, whereas seven provided it to all crew members. Clearly, there has been little effort in systematic training requirements analysis and scientific course development.

The question arises: Is there an optimum training method? A comprehensive review of managerial training studies (Burke & Day, 1986) indicated that training which centers on specific problems tends not to generalize to other types of management problems. The most generalizable results were found using the lecture method (Burke & Day, 1986). The study also found that training programs which focused on increasing motivation or improving values as measured by objective learning criteria were more effective than those aimed at problem solving or decision making. Two methods which provided generalizable gains were Leader Match, where individuals learned to adapt either their work situation or their leadership style to fit their personality, and behavior modeling. Although the results for sensitivity training were statistically inconclusive due to high variance among training situations, a positive effect was found there as well.

Bolman (1979) has developed successful training programs for lawyers, managers, education administrators, and ministers. He has included the following three factors in each program:

(a) presentation of relevant theories; (b) discussion of case examples and examples from the learners' experiences; and (c) simulation of practice problems with a chance for discussion, feedback, and repeated practice. Although not the only possible format for CRM training, several independently developed programs include these factors.

He posed three challenges for designers of CRM courses: (a) creating effective training experiences, (b) integrating new experiences with existing training, and (c) questioning traditional assumptions about management and superior-subordinate communication.

Foushee (1985) listed three major elements found in most CRM training programs. First, there is usually a classroom presentation to increase student awareness of the problems and proposed solutions. Next, there is an opportunity for practice and feedback. This is usually presented as encounter drills, role-playing, personality and attitude measures, or LOFT. The final element is a plan for reinforcement. Cockpit resource management principles are embedded in the total training program.

The length of training varies. White (1986) reported that among those airlines responding to the survey, course length varied from 3 to 16 days. Twelve home study units are used in the course developed at People Express (Bruce & Jensen, 1986). Initial CRM training at the 1550th Combat Crew Training Wing (CCTW) at Kirtland AFB (Fiedler, 1986) uses 1 day for academics and 1 day for a MOST mission. This training was added to the normal annual refresher training, which had previously been purely a system review and instrument refresher training. A 1-day format including a MOST mission is planned for those who have had the initial 2-day session.

Cockpit resource management training will be effective only if it is administered in the entire crew context. It is not for the captain only. However, as stated earlier, it seems there may be a limitation on combining CRM training with the individual skill training required for each crew member.

Line-Oriented Flight Training (LOFT). Although not specifically designed for CRM training, LOFT provides a valuable platform for practice and personal evaluation of CRM skills. The flight crew is videotaped during the mission, allowing each crew member to see how he interacts with others. By seeing themselves interact during a videotape replay of critical events, crew members can more effectively internalize lessons learned.

A NASA-sponsored conference was held in early 1981 to refine and clarify what is meant by "LOFT" as used in airline training (Lauber & Foushee, 1981a, 1981b). Representatives from various airlines described their LOFT training programs. Many airlines

discussed varied uses of operational context simulation in training. As a result of this conference, specific guidelines were provided for LOFT as used in CRM training (as opposed to other uses of operational context simulation).

In the introduction to the conference proceedings, Lauber listed seven essential features of LOFT which enhance CRM training: (a) High fidelity simulation allows realistic simulation of line operations. The more realistic the simulation, the more likely it is that crews will "play the game." (b) Training is provided for the complete crew rather than for the captain only. The emphasis is on how the crew works together rather than whether mistakes were made. (c) Training is conducted in a real-world context in real time, with no use of freeze or replay and with no interaction with the instructor other than as a provider of simulated outside communications. (d) Problems are included which have no single acceptable solution. (e) Training emphasizes the use of all available resources including hardware, software and "liveware." (f) LOFT should provide experience from which learning can occur, as opposed to testing. (g) CRM is, in part, the management of human error. Training must be conducted so as to maximize the probability that error, when it does occur, will be detected. Therefore, training requires the presence of errors or error-inducing situations (Lauber & Foushee, 1981a).

Nunn (1981) reported that one Federal Aviation Administration (FAA) inspector initially had a negative attitude toward the concept of LOFT because of his experience with "Full Mission Scenarios" in SAC. The inspector indicated that a SAC Full-Mission Scenario consisted of one emergency after another until the crew broke." His negative attitude was dramatically reversed after he flew a LOFT scenario and took part in the debriefing. It is important to test-fly each LOFT scenario several times to verify workload and manageability. One crew member is purposely placed in an overload at some point in the flight. A good flight deck manager should recognize this condition (Whitehead, 1981).

One airline feels it is beneficial for crews to spread the word on what happened in their scenario (Sommerville, 1981) in that informal conversations about lessons learned enhance the corporate knowledge base. However, several scenarios should be based on the same planning information so that crews are unable to predict the scenario when they come to the simulator. Nothing should tip off the crew as to what problems to expect. If the crew can tell what and where the problems will be before they begin the mission, they will not get the most out of the training.

Several comments related to the training and conduct of instructors used in LOFT training. The Instructor Training and

Qualifications Working Group listed six training requirements for LOFT instructors: (a) conduct of crew briefing in the LOFT context; (b) observation and understanding of CRM areas such as "crew concept," "crew coordination," etc.; (c) pacing and conduct of the LOFT scenario; (d) observation and understanding interpersonal skills; (e) development of skill in interacting with crews during briefing, LOFT, and debriefing; and (f) assessment of skills in all areas of CRM and all facets of operational flying (Lauber & Foushee, 1981b).

In the mind of the students, there will always be a gap between simulators and the real world. The instructor should encourage students to "play the game" to reduce this gap (Lauber & Foushee, 1981a).

More than one instructor may be needed for LOFT. One instructor could run the simulation and provide realism, and the other observe and write comments. Alternatively, one instructor could evaluate the flight engineer and the other, the pilots (Lauber & Foushee, 1981a).

No deviations from the script should be allowed on the part of the instructor. Where the crew has several legitimate options, instructions are usually provided in the script for such contingencies (Whitehead, 1981, p. 86). If the crew decides on a course of action that is not covered in the script, the instructor should not take away the real-world choices of the crew without providing a realistic reason. Ideally, the instructor should be trained to allow deviations and still provide realism.

Instructors take on a new role in debriefing after a LOFT mission. In the LOFT debrief, the instructor cannot lead the crew to think that he has the only correct solution (Jensen, 1981). The instructor must permit participants to exhaust their evaluation before proceeding to items noted by the instructor (Nunn, 1981). The instructor may increase the involvement of hesitant crews in the debrief by asking questions. The crew may be given an overview of the flight in a descriptive fashion, then asked how they thought the session went (Jensen, 1981).

The atmosphere of training to proficiency must prevail. If a student needs further training, that student should be called aside privately and assured that this is not to be considered a failure and that there is no job jeopardy involved (Nunn, 1981). The purpose of remedial training should be viewed as an opportunity to run through a scenario more efficiently, rather than to embarrass the crew (Lauber & Foushee, 1981a). A key question for instructors is not whether errors were made, but whether the pilots recognized and understood why the errors were made (Nunn, 1981).

Many airlines have found that other uses of operational context simulation could be valuable in transitioning to new aircraft and other initial training because it familiarizes the trainee with the normal flight operations from takeoff to landing. The number of aircraft flights required in becoming operationally qualified can be reduced.

A number of people have expressed the conviction that LOFT cannot replace all training. Crew members still need "batting practice" on such things as difficult approaches or slippery runway conditions (Lauber & Foushee, 1981b).

Individual skill training should not be conducted during LOFT. If the flight engineer is troubleshooting a system malfunction while the pilots are flying a difficult approach in weather, there is no chance to practice synergistic crew coordination (Cavanagh & Traub, 1981). One airline is concerned that flight engineers do not get an in-depth systems review in a LOFT session. This review is usually conducted during their regualification check (Whitehead, 1981). Systems review is important training, but it should occur elsewhere (Cavanagh & Traub, 1981).

#### Cockpit Resource Management Techniques

Several specific techniques have been mentioned which might assist crews in arriving at the best decision possible and in discovering errors which could lead to serious consequences. Lauber (1980) provided a list of suggested operational guidelines: (a) delegate both flying and monitoring responsibilities overtly; (b) emphasize that monitoring is as important as flying; (c) emphasize that the pilot responsible for flying must not attempt secondary tasks; (d) use external sources to resolve conflicting interpretations of fact; (e) cross-check with an independent source if information from two sources is in conflict; and (f) emphasize that each crew member has an obligation to make known any doubt about procedures, clearances, or the flight situation. Other comments were related to: (a) situational awareness; (b) workload management; and (c) communications.

#### Situational Awareness

Several things can be done during the relaxed, low workload times in the cockpit: Crew members can be directed to re-focus on the flying task if their attention has been straying; crew members can be encouraged to do some contingency planning and project how the flight might progress; or a debrief and critique of the last segment of the flight can be conducted (Hackman, 1986).

Halliday, Biegalski, and Inzana (1986) presented a visual representation of the "synergy formula" which is designed to maintain situational awareness and question any challenge to it. Each student takes a copy of the visual to the aircraft, along with directions for initiating an in-flight review.

Komich (1985b) suggested polling each crew member during the crew brief as to what is unusual about the next flight segment. Crew members should state either what is unusual, or that they see nothing unusual.

### Workload Management

"Many discrete errors and wrong decisions were related to overloading one particular crew member, particularly when he was engaged in reciting and complying with checklists for the procedures connected with abnormal operation. It was also seen in some cases how compliance with these procedures could interfere with the monitoring cover built into standard operating procedures" (Ruffell Smith, 1979, p. 21). Checklists should be designed and performed so as not to remove a crew member from specific monitoring responsibilities. "From a psychological viewpoint, the leader, decisionmaker is the least appropriate person to be overburdened" (Helmreich, 1980, p. 24).

### Communications

Johnston (1966) proposed that team communications should be minimized during coordinated activity unless required information can be passed by verbal communication only. Williges, Johnston, and Briggs (1966, p. 473) noted, "Verbal communication when not required by the task plays an insignificant role in teamwork." Federal Aviation Regulations (FARs) restrict flight crews from engaging in nonessential conversations during critical phases of flight such as taxiing, takeoff and landing, and generally all phases of flight below 10,000 feet (Title 14 U.S.C. Sect. 121.542b & c).

### Research Questions

Several questions have been raised by the authors cited. In addition, related questions have surfaced in discussions with others during this review. Most issues were mentioned by several authors and will be discussed together.

### Crew Formation

As crew members gain experience with one another over time, do they become increasingly expert in working as a team? If so, how long does this team formation process take? Do some CRM strengths decrease over time with the same crew? Foushee (1985) suggested looking at the possible negative aspects of long-term

interaction such as complacency, group-think, resignation, and boredom. The permanently assigned crews of the SAC B-52 and KC-135 aircraft would seem to be an ideal research arena for these questions. These crews stay together for a year or more.

Kidd, Kinkade, and Weiner (1958) found that subjects in a simple simulation of a team approach to ground-controlled intercepts attained stable levels of cooperation and interaction in a very short time. Although the data were too sparse to generalize, in tasks with increased stress there was no interference with group formation. It would seem that continued growth might be seen in some subtle indications of CRM behavior over longer periods of association.

Ruffell Smith (1979) concluded that, on large aircraft, flight crews that had not flown with each other needed one leg (takeoff through landing) to become accustomed to each other. No research has investigated whether permanent hard crews would continue to improve crew coordination (Foushee, 1985).

There may be a more optimal method of integrating individual skill training with crew training so as to reduce the effect noted by Johnston (1966) that crew training inhibits learning of individual skills.

#### Evaluation Criteria

Hackman (1986) proposed that the primary criterion of crew effectiveness is: Does the performance of the crew fully meet (or better, exceed) the standards and expectations of others who have a legitimate stake in how the crew performs? This seems to define the arena of evaluation. However, many decisions and tradeoffs are required. Various stakeholders' objectives may be prioritized differently depending on who makes the evaluation. A diverted flight meets some of the stakeholders' expectations, but the passengers are going to complain bitterly.

Several aspects of CRM defy evaluation because criteria have not been identified or are not available. Bolman (1979) suggested that because pilots never have complete information, they continually operate with a theory of the situation which may or may not be correct. How can education and training reduce the probability of an erroneous theory of the situation? What factors might assist pilots in recognizing an erroneous theory of the situation? What methods or techniques could assist flight crews in testing and monitoring the theory of the situation?

Personal satisfaction and learning also contribute positively to crew effectiveness. How can we measure satisfaction (Hackman, 1986)?

Due to the nature of what we are trying to measure, many of our evaluations are subjective. There is a need to find methods which enhance objectivity.

"Researchers need to improve their reports evaluating organizational interventions such as providing information on the degree of range restriction, criterion, and predictor reliabilities, sample characteristics, and a thorough description of their methodology" (Burke & Day, 1986, p. 243).

### Effect of Personality

Helmreich (1986b) found that although personality factors did not predict performance in training, they became increasingly good predictors of actual performance as time went by. The "honeymoon effect" during training masked true interaction. Personality factors would, therefore, be more important to a long-duration crew than to one which disbands after a few flights. Are there indications of personality factors which would aid in selecting long-duration crews? Are there personality types for which training would be ineffective? Can training programs be optimized for various personality types?

It may be possible that an authoritarian captain may be disliked in normal operations but take charge effectively in emergencies. The socially oriented captain may be effective in the reverse order (Helmreich, 1980).

Ruffell Smith (1979) noted a tendency for crew members to take over some of the responsibilities in a crisis from captains in whom they had less confidence. What factors should influence a crew member's decision to take over some or all of the captain's responsibilities?

### Attitudes

Helmreich (1986b) found that attitudes of captains differed from other crew members on a number of issues regarding appropriate management of the flight deck. Does this disagreement indicate less-than-optimal crew coordination, or should there be different attitudes among first officers and flight engineers based on role and responsibility differences?

Pilots who were rated as either superior or below average in management of their flight deck by check airmen were asked to fill out a questionnaire. Certain factors on Helmreich's Cockpit Management Attitude Questionnaire (CMAQ) predicted check airman ratings of superior or below average in over 95% of the cases. The CMAQ could be a useful tool in studying the effectiveness of CRM training (Helmreich, Foushee, Benson, & Russini, 1985).

The technical ability of crew members may also affect attitudes. For example, a less competent stick-and-rudder pilot may project confidence and knowledge to cover up (Helmreich, 1986b). An interesting finding by Ruffell Smith (1979) was that the percent rise in heart rate of the flight engineer prior to the onset of a mechanical problem correlated with more errors. Could this be related to a self-perceived lack of competence or proficiency?

### III. ANNOTATED BIBLIOGRAPHY

A few notes regarding this section are in order. In each case, the abstract provided by the referenced author was given first priority. In cases where the entire abstract was used intact, the abstract will be followed by the symbol "(A)" to indicate that the wording was entirely that of the referenced author. In other cases, the abstract has been edited, paraphrased, or rewritten. Though some of the words or phrases are those of the referenced authors, the use of quotation marks has been avoided in order to maintain continuity for the reader.

#### Proceedings of Conferences Containing Articles of Interest

Collie, R. L., & Lauber, J. K. (Eds.). (1984). Flight Training Technology for Regional/Commuter Airline Operations: Regional Airline Association/NASA Workshop Proceedings (NASA CP 2348). Moffett Field, CA: NASA Ames Research Center.

The focus of this workshop is on training requirements, state-of-the-art training technology, advanced training concepts and cockpit resource management (CRM). Ten papers were presented on the subject of CRM. Although aimed primarily at regional airlines, many concepts contained in these proceedings are also applicable to a more general population. A transcript of the discussion by participants follows each presentation. Reports of working groups are included.

Cooper, G. E., White, M. D., & Lauber, J. K. (Eds.). (1979). Resource Management on the Flight Deck: Proceedings, NASA/Industry Workshop (NASA CP 2120). Moffett Field, CA: NASA Ames Research Center.

Airlines are showing greater concern for fostering better use of available resources under high workload situations. New research and training programs are being developed independently by various organizations to enhance aircrew capabilities. Workshop participants included senior officers of major airlines who are responsible for aircrew training, representatives of cognizant government agencies, and specialists in human factors work as it applies to aircrew operations.

Session 1. Formal presentations by nonindustry representatives on the background and human factors aspects of the problem, each followed by a verbatim transcript of discussion.

Session 2. Formal presentations by airline representatives describing current industry approaches to training resource management (followed by discussion).

Session 3. Small group discussions and analyses by participants, aimed at developing conclusions and recommendations.

Jensen, R. S. (Ed.). (1987). Proceedings of the Fourth International Symposium on Aviation Psychology. Columbus, OH: The Ohio State University, Aviation Psychology Laboratory, and Association of Aviation Psychologists.

Paper sessions address cockpit resource management and related topics such as communication and judgment.

Jensen, R. S. (Ed.). (1983). Proceedings of the Second Symposium on Aviation Psychology. Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

Two sessions on cockpit resource management include seven articles. There are also two sessions on the related subject of pilot judgment.

Jensen, R. S., & Adrion, J. (Eds.). (1985). Proceedings of the Third Symposium on Aviation Psychology. Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

Paper sessions address cockpit resource management, cockpit communication, and pilot judgment.

Lauber, J. K., & Foushee, H. C. (Eds.). (1981a). Guidelines for Line-Oriented Flight Training Volume I: Proceedings of a NASA/Industry Workshop (NASA CP 2184). Moffett Field, CA: NASA Ames Research Center.

Volume I provides a synopsis of guidelines derived from papers and discussions presented in Volume II. Specific guidelines are presented for: (a) design and development of LOFT scenarios, (b) real-time LOFT operations, (c) LOFT debriefing, (d) training and qualification of LOFT instructors, and (e) other uses of LOFT and line-oriented flight simulation.

Lauber, J. K., & Foushee, H. C. (Eds.). (1981b). Guidelines for Line-Oriented Flight Training Volume II: Proceedings of a NASA/Industry Workshop (NASA CP 2184). Moffett Field, CA: NASA Ames Research Center.

Although Line-Oriented Flight Training (LOFT) is an invaluable tool in CRM training, some operators describe other uses of LOFT independent of CRM. Paper sessions describe current approaches to LOFT. The volume also includes a transcript of the discussions following each session, and reports of working groups on scenario design, real-time LOFT operations, performance evaluation and assessment, and instructor training and qualifications.

Lee, G. E. (Ed.). (1986). Proceedings, Psychology in the Department of Defense, Tenth Annual Symposium. Colorado Springs, CO: U.S. Air Force Academy.

Paper sessions deal with group effectiveness, team training, leadership, and flight crew performance.

Orlady, H. W., & Foushee, H. C. (Eds.). (1986). Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455). Moffett Field, CA: NASA Ames Research Center.

The most comprehensive source to date, this document includes papers on cockpit resource management training in airline, general aviation, and military flight operations. Working groups provided reports on curriculum development, techniques for CRM training, integration into the total training curriculum, effectiveness of CRM training, CRM training in corporate/regional operations, and military applications of CRM.

#### Individual Sources

Beach, B. E. (1981). Eastern Air Lines LOFT program. In J. K. Lauber & H. C. Foushee (Eds.), Guidelines for Line-Oriented Flight Training Volume II: Proceedings of a NASA/Industry Workshop (NASA CP 2184, pp. 56-70). Moffett Field, CA: NASA Ames Research Center.

This paper describes LOFT training at Eastern Airlines, including scenario design strategies, a description of instructor training and standardization, and performance assessment.

Time is not compressed in their simulator. Everything is done in real time. If the entire crew is not available, some other training will be conducted, rather than continuing LOFT with an instructor filling the vacant seat. LOFT should be training, not checking. If extra training is needed, it is provided after the scenario. In 1980, five people were given additional training of the 224 scenarios that were conducted.

The instructor acts as an evaluator rather than a participant in the scenario. Instructor standardization is a problem. Precise scripts or automated lessons in the simulator assist in conducting standard scenarios.

Debriefing is commenced by the crew members themselves as they exit from the simulator. The role of the instructor is one of summation: what went wrong, and why. Discussion by workshop participants follows.

Biegalski, C. S. (1987). The synergy diamond as a model for human behavior. In R. S. Jensen (Ed.), Proceedings of the Fourth International Symposium on Aviation Psychology (pp. 419-425). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory, and Association of Aviation Psychologists.

The goal of this paper is to provide a common language for use in discussing the elements which affect synergy within an aircrew. The "Synergy Diamond" is a non-mathematical model in which the horizontal axis represents individual behavior, ranging from completely self-sufficient to completely democratic. The vertical axis represents the level of the synergy achievable with different types of individuals. Three types of crew members are described who reduce the level of synergy achievable. The first either refuses to participate, or is too preoccupied to become involved. The second is described as a misfit, or "bumbling idiot." The third is one who actively tries to place the blame, or make another crew member look bad. Synergy is increased if crew members strive to find what is right for the situation as well as for the team.

Bolman, L. (1979). Aviation accidents and the 'theory of the situation.' In G. E. Cooper, M. D. White, & J. K. Lauber (Eds.), Resource Management on the Flight Deck: Proceedings, NASA/Industry Workshop (NASA CP 2120 pp. 31-58). Moffett Field, CA: NASA Ames Research Center.

Flight crews can never be entirely certain that they know for sure the situation of their flight. Inevitably, they develop 'theories of the situation'--a set of goals, beliefs, and behaviors that provides a coherent picture of what is happening and what action is appropriate. In many routine situations, those theories accord so closely with reality that there is little stimulus to be concerned about the validity and appropriateness of the theory. In more complex and difficult situations, the chances of error in the theory become much higher. The skills and willingness of a flight crew to be alert to possible errors in the theory become critical to their effectiveness and their ability to ensure a safe flight. (A)

This paper identifies four major factors that determine the likelihood that a faulty theory will be detected and revised: (a) the 'theories of practice' that pilots have developed through training and experience--and particularly the degree to which those theories build in inquiry and testing in situations of confusion, anomaly, and crisis; (b) the abilities of crew members to combine skills in advocacy and inquiry; (c) the management skills and style of the captain; and (d) the degree to which the role system in the cockpit is well understood, and procedures for role modification are mutually shared. Discussion by workshop participants follows.

Bruce, K. D., & Jensen, D. (1986). Cockpit resource management training at People Express. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 50-56). Moffett Field, CA: NASA Ames Research Center.

This paper describes the CRM training at People Express developed by Cockpit Management Resources, Inc. Topics discussed include the essential elements of resource management training, the strengths and weaknesses of current approaches, implementation of CRM training at People Express, and the effectiveness of their CRM training.

The course consists of 12 study units. The first two examine the professional flying environment. The others deal with specific CRM elements such as communications, short-term strategy, challenge and response, authority/assertiveness balance, cockpit management style, workload, state of the cockpit, pilot error, judgment and decision making, and emergencies. These topics are presented in three modes. Textual and videotape materials are provided as self-study materials to be completed prior to semiannual seminars. Full-mission simulation is the focus of the entire program.

Five problem areas are suggested for future development: (a) precisely identify the essential elements of CRM; (b) translate those elements into practical behaviors or procedures; (c) establish clear and realistic performance standards; (d) design effective training programs; and (e) observe, measure, and document positive results.

Burke, M. J., & Day, R. R. (1986). A cumulative study of the effectiveness of managerial training. Journal of Applied Psychology, 71, 232-245.

The published and unpublished literature on the effectiveness of managerial training has produced conflicting results and left more unanswered questions than definitive statements concerning the effectiveness of managerial training. In the present study, meta-analysis procedures were applied to

the results of 70 managerial training studies to empirically integrate the findings of the studies. The meta-analysis results for 34 distributions of managerial training effects representing six training content areas, seven training methods, and four types of criteria (subjective learning, objective learning, subjective behavior, and objective results) indicated that managerial training is, on the average, moderately effective. For 12 of the 17 managerial training method distributions, the 90% lower bound credibility values were positive, and thus the effectiveness of these training methods, at least at a minimal level, can be generalized to new situations. It is stressed that although this meta-analysis assisted in clarifying what we have learned about managerial training, a great deal of empirical research on managerial training is needed before more conclusive statements can be made. (A)

Carroll, J. E., & Taggart, W. R. (1986). Cockpit resource management: A tool for improving flight safety (United Airlines CRM training). In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 40-46). Moffett Field, CA: NASA Ames Research Center.

This paper describes the CRM training provided by the CRM Company, a joint venture of Scientific Methods, Inc. and United Airlines, Inc. Attitudes prior to training indicate that 84% of the trainees believe that their operating style is about as effective as possible, compared to 30% at the end of training.

Cavanagh, D., & Traub, W. (1981). United Airlines LOFT training. In J. K. Lauber & H. C. Foushee (Eds.), Guidelines for Line-Oriented Flight Training Volume II: Proceedings of a NASA/Industry Workshop (NASA CP 2184, pp. 43-55). Moffett Field, CA: NASA Ames Research Center.

This paper describes the use of Line-Oriented Flight Training (LOFT) in United Airlines recurrent and transition training. United uses LOFT in recurrent training as a specific FAA-approved program. Line-oriented training in a broader sense is used in recurrent training. Additionally, a complete B-727 transition syllabus is under consideration in which every flight starts as a LOFT scenario. In the latter stages, the entire period is a LOFT scenario. Line-Oriented Checks (LOCs) are used for Type-Rating checks which use a more realistic profile to accomplish the majority of rating requirements. Additional required maneuvers are then accomplished at the end of the LOC. Discussion by workshop participants follows.

Cavanagh, D. E., & Williams, K. R. (1986). The application of CRM to military operations. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455 pp. 135-144). Moffett Field, CA: NASA Ames Research Center.

There are distinct similarities between the crew roles in the cockpits of civilian airliners and military air transports. Many of the attitudes and behaviors exhibited by civilian and military crew members are comparable; hence, much of the training in the field of cockpit resource management is equally appropriate to both. At the same time, there are significant differences which require assessment to determine their implications for training. Differences relative to military rank, purpose, crew qualifications, crew lifestyle, labor relations, etc. are discussed.

Christian, D., & Morgan, A. (1986). Crew coordination concepts: Continental Airlines CRM training. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 68-74). Moffett Field, CA: NASA Ames Research Center.

This paper describes several different management theories, their relevance to CRM training, and how each applies to the Crew Coordination Concepts Workshop at Continental Airlines. Most theories place emphasis and responsibility for success on the manager or leader. Although many different labels are used, they all present behavioral options in terms of two basic dimensions: task and relationship. It is suggested that assertive behavior--as represented by the high task, high relationship quadrant--is always the desirable behavior in the cockpit.

A review of accidents and NASA studies indicates the following contributing factors as those most frequently observed: preoccupation with minor mechanical problems, inadequate leadership, failure to delegate tasks and assign responsibilities, failure to set priorities, inadequate monitoring, failure to utilize available data, and failure to communicate intent and plans.

Cole, D. L. (1987). Aircrew coordination training for C-141 loadmasters (Report No. 87-0510). Maxwell AFB, AL: Air University, Air Command and Staff College.

All Military Airlift Command (MAC) C-141 Flight Simulator Branches have recently started Aircrew Coordination Training (ACT). This training is currently required only for pilots and flight engineers. The loadmaster performs as an integral part of the C-141 crew. Should this training be mandatory for loadmasters? The opinions of military and civilian experts in the field of crew coordination, and C-141 crew members are

examined. The study concludes that the Military Airlift Command should make Aircrew Coordination Training mandatory for all C-141 loadmasters. (A)

Dormant, D. (1979). A trainer's guide to change agency. National Society for Performance and Instruction Journal, 18(3), 7-10.

Training effectiveness can be increased by analysis of the stages which people go through as they change, as they adopt new ways of doing or thinking. Six stages are described, leading from where one first learns about an innovation to where one finally accepts it as an integral part of his or her life. Following awareness, these are: interest, mental tryout, real-world tryout, adoption, and integration.

Federal Aviation Administration. (1981). Line-Oriented Flight Training Programs (FAA AC 120-35A). Washington, DC: U.S. Government Printing Office.

This advisory circular sets out the conditions for FAA approval of LOFT programs, and the conditions for approval of reduced requirements for recurrent training.

Fiedler, M.T. (1986). USAF CRM training in the 1550th Combat Crew Training Wing. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 145-147). Moffett Field, CA: NASA Ames Research Center.

This paper contains a description of the Aircrew Coordination Training (ACT) program designed and implemented by the 1550th CCTW at Kirtland AFB, NM, for C-130 and heavy-lift helicopters. The use of Mission-Oriented Simulator Training (MOST) and future plans for ACT are discussed.

Responsibilities of aircrew members are described with regard to the areas of inquiry, advocacy, conflict resolution, decision making, and critique. Barriers are identified which may limit the effectiveness of military aircrews in these areas. Concepts of leadership and followership are introduced through the use of a grid representation. Discussion follows on ways of interacting with various leadership styles.

Foushee, H. C. (1982). The role of communications, socio-psychological, and personality factors in the maintenance of crew coordination. Aviation, Space, and Environmental Medicine, 53, 1062-1066.

There is increasing evidence that many air transport incidents and accidents are the result of the improper or inadequate utilization of the resources accessible to flight deck

crew members. These resources obviously include the hardware and technical information necessary for the safe and efficient conduct of the flight, but they also include the human resources which must be coordinated effectively. The focus of this paper is upon the human resources, and how communication styles, socio-psychological factors, and personality characteristics can affect crew coordination. (A)

Foushee, H. C. (1985). Realistic training for effective crew performance. In Proceedings, 4th Aerospace Behavioral Engineering Technology Conference (pp. 177-181). Warrendale, PA: SAE, Inc.

Evaluation of incident and accident statistics reveals that most problems occur not because of lack of proficiency in pilot training, but because of the inability to coordinate skills into effective courses of action. Line-Oriented Flight Training (LOFT) and Cockpit Resource Management (CRM) programs provide training which will develop both individual crew member skills, as well as those associated with effective group function. A study conducted by NASA at the request of the U.S. Congress supports the argument for training that enhances crew performance in addition to providing individual technical skills, and is described in detail. (A)

Foushee, H. C., Lauber, J. K., Baetge, M. M., & Acomb, D. B. (1986). Crew factors in flight operations: III The operational significance of exposure to short-haul transport operations (NASA Technical Memorandum 88322). Moffett Field, CA: NASA Ames Research Center.

Excessive flight crew fatigue as a result of trip exposure has long been cited as a factor with potentially serious safety consequences. Laboratory studies have implicated fatigue as a causal factor associated with varying levels of performance deterioration depending on the amount of fatigue and the type of measure utilized in assessing performance. From an operational standpoint, these studies have been of limited utility because of the difficulty of generalizing laboratory task performance to the demands associated with the operation of a complex aircraft.

This study examined the performance of 20 volunteer twin-jet transport crews in a full-mission simulator scenario that included most aspects of an actual line operation. The scenario included both routine flight operations and an unexpected mechanical abnormality which resulted in a high level of crew workload. Half of the crews flew the simulation within two to three hours after completing a three-day, high-density, short-haul duty cycle (Post-Duty condition). The other half of the crews flew the scenario after a minimum of three days off duty (Pre-Duty condition).

The results of this study revealed that, not surprisingly, Post-Duty crews were significantly more fatigued than Pre-Duty crews. However, a somewhat counter-intuitive pattern of results emerged on the crew performance measures. In general, the performance of the Post-Duty crews was significantly better than the performance of the Pre-Duty crews. Post-Duty crews were rated as performing better by an expert observer on a number of dimensions relevant to flight safety. Analysis of the flight crew communication patterns revealed that Post-Duty crews communicated significantly more overall, suggesting, as has previous research, that communication is a good predictor of overall crew performance.

Further analysis suggested that the primary cause of this pattern of results is the fact that crew members usually have more operating experience together at the end of a trip, and that this recent operating experience serves to facilitate crew coordination, which can be an effective countermeasure to the fatigue present at or near the end of a duty cycle. These results have important aircrew training and aviation safety implications. (A)

Frankel, D., & Elliott, B. (1979). The more things stay the same. National Society for Performance and Instruction Journal, 18(3), 11-13.

A logical framework is described which can be used to identify individuals who can serve as effective change agents and to monitor, assess, and provide feedback regarding processes of change that are occurring or will be occurring in an organization. Seven skills required of a change agent include: (a) should be comfortable with persons at all levels of the organization, (b) should have both interactive skills and technical knowledge, (c) should be familiar with a broad range of research and evaluation procedures for the impending change, (d) should be able to make effective presentations, (e) should be free of prohibitive mores of the bureaucratic structure, (f) should have no other managerial responsibilities, and (g) should be able to distinguish between problems and symptoms.

A four-stage process for evaluating the effectiveness of the change agent is suggested: (a) Obtain carefully chosen baseline data. (b) After the change agent has worked on several projects, locate changes and perceived changes by polling the staff at all levels. (c) Reference the baseline data to determine if the change has actually occurred. (d) Trace backward from the changes, looking for the influence of the change agent.

The ideal change agent is described as a proactive ombudsman or "ombuddy" who would study the organization, actively seeking situations which may call for change.

Frankel, R. M. (1985). "Captain, I was trying to bring up the fact that you made a mistake earlier:" deference and demeanor at 30,000 feet. In R. S. Jensen & J. Adrion (Eds.), Proceedings of the Third Symposium on Aviation Psychology (pp. 403-410). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

Examination of 28,000 reports made to the Aviation Safety Reporting System from 1976-1981 revealed that 70% contained evidence of failures and breakdowns in communicating or relaying information. This paper reports results obtained using videototechnology and microinteractional analyses to study communication dynamics in the cockpit.

Preliminary evidence from the analysis of a single error suggests that there may be some practical utility to viewing cockpit communication as a microinteractional process. Qualitative and quantitative studies of interactional complexity, deference, and demeanor will increase our understanding of the dynamic group processes involved in communication breakdowns in the cockpit. In addition, the use of a video-based research paradigm may enhance the development and impact of training programs in communication skills.

Geis, C. E. (1987). Changing attitudes through training: A formal evaluation of training effectiveness. In R. S. Jensen (Ed.), Proceedings of the Fourth International Symposium on Aviation Psychology (pp. 392-398). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory, and Association of Aviation Psychologists.

Measured attitudes regarding the management of the cockpit were evaluated following a specially designed human factors training program. A highly significant difference in attitude was measured as a result of that training. With over 75% of the mishaps attributable to human factor problems, flight managers now have a training technique at their disposal to change attitudes through training. Implications of the results for human factors training programs are discussed. (A)

Giffin, W. C., Rockwell, T. H., & Smith, P. E. (1985). A review of critical in-flight events research methodology. In R. S. Jensen & J. Adrion (Eds.), Proceedings of the Third Symposium on Aviation Psychology (pp. 321-328). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

Four studies are summarized:

1. Twelve instrument-rated pilots were given a knowledge survey before participating in full-mission scenarios in the GAT-1 flight trainer. Realistic Critical In-Flight Events (CIFEs)

were presented. The findings were as follows: (a) Cockpit management style varies widely among pilots. (b) Good stick-and-rudder pilots have excess capacity and maintain good performance before, during, and after the CIFE. More-marginal pilots show increased frequency and amplitude of heading and altitude excursions and experience communication difficulties in the face of a CIFE. (c) Pilots who score well on the knowledge tests tend to perform well in diagnosis and decision-making.

2. Forty instrument-rated subjects participated in paper-and-pencil CIFE tests where information was available from an experimenter if asked. This design was intended to reduce costs and provide better data regarding cognitive responses. The results were: (a) There was no correlation between knowledge of aircraft systems and total flight hours. (b) Diagnostic performance was highly correlated with knowledge scores. (c) Knowledge was inversely related to total diagnostic inquiries. (d) Total diagnostic inquiries were inversely related to correctness. (e) Pilots with good diagnostic performance were characterized as being knowledgeable about aircraft systems, employing few tracks and few inquiries per track, and emphasizing time in their decision to divert. They were not differentiated by flight hours, ratings, training, or type of flying.

3. Forty-two instrument-rated subjects participated in an experimenter-free computer-aided testing of CIFE scenarios. The findings were: (a) Subjects had the most difficulty identifying vacuum pump failure. (b) Less-experienced pilots use more diagnostic tracks. (c) High correctness scores are positively related to high mean time between inquiries. (d) Individual pilots use similar strategies across scenarios. (e) The only discernible learning effect across scenarios is that time between inquiries decreases. (f) Pilots show a strong preoccupation with symptoms at the expense of positional awareness.

4. Twenty instrument-rated pilots were given several activities to elicit models of pilot decision making in CIFE. The study showed: (a) Attention is attracted to unexpected events. (b) Pilots tend to believe data from failed instruments. (c) Pilots tend to rely on instrument readings without cross-checking other instruments.

Ginnett, R. C (1987). First encounters of the close kind: The formation process of airline flight crews. Unpublished doctoral dissertation, Yale University, New Haven, CT.

Members of airline cockpit crews often have never worked together or even met prior to their scheduled flight. While virtually all such crews accomplish their primary task, some crews operate better as teams than do others. One important influence on team functioning is the behavior of the crew's leader--the captain. Crew members report that they can determine

how effective a given captain will be as a crew leader in the first few minutes of the crew's life. This research examined six captains who were effective crew leaders and four who were less effective. Data were collected both during the time of crew formation and during line operations.

The effective captains created multiple conditions for team effectiveness from the moment their crews first met. In initial briefings, for example, they affirmed the boundary of the group, discussed aspects of the work that required coordination (both within the crew, and with others), and fostered norms that encouraged teamwork. They also lessened crew members' traditional dependence on the captain by actively engaging members in their briefings. Although each used different tactics, the team effectiveness strategies used in the briefings remained consistent throughout the life of their crews. The less-effective captains did not exhibit consistent team leadership strategies. Instead, each exercised control in ways that interfered with team effectiveness. Two of these captains inappropriately controlled their crews while the other two exhibited inappropriate control of their own behaviors.

The findings show that crew members import both information and expectations into the crew formation process. In a short time, a captain breathes life into this imported "shell," thereby creating a working crew. Effective captains affirm and enhance the shell, while less-effective captains abdicate or undermine it. Implications of the findings for the design and leadership of teams in organizations are explored. (A)

Goguen, J., Linde, C., & Murphy, M. (1984). Crew communication as a factor in aviation accidents. In Twentieth Annual Conference on Manual Control (NASA CP 2341, pp. 217-248). Moffett Field, CA: NASA Ames Research Center.

A major objective of this research was to determine those communication patterns which are most effective in specific situations. Two main contributions of this study are a set of validated hypotheses about crew communication patterns and the development of a novel methodology for formulating and testing such hypotheses. Transcripts from eight commercial aviation accidents were used as data.

The following eight hypotheses were formulated and tested:  
(a) Speech acts to superiors are more mitigated. (b) Speech acts are less mitigated in crew-recognized emergencies (CREs). (c) Speech acts are less mitigated during crew-recognized problems (CRPs). (d) Captains and subordinates differ in frequency of planning and explaining. (e) Planning and explanation are less common in CREs. (f) Planning and explanation are more common during CRPs. (g) Topic-failed speech acts (expressions of a new topic not followed by the same topic

from another speaker) are more mitigated. (h) Unratified draft orders (proposed suggestions not accepted by the captain) are more mitigated.

Hackman, J. R. (1986). Group-level issues in the design and training of cockpit crews. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 23-39). Moffett Field, CA: NASA Ames Research Center.

Admittedly, some value may be gained by building the knowledge and skill of individual crew members; cockpit crews always operate in an organizational context. This paper focuses on the team and organizational factors that can be modified to enhance the ability of well-trained crews to work together effectively.

Three questions help to determine the effectiveness of crews: (a) Does the performance of the crew fully meet (or better, exceed) the standards and expectations of others who have a legitimate stake in how the crew performs? (b) As crew members gain experience with one another over time, do they become increasingly expert in working as a team? (c) Does the experience of being in the crew contribute positively to the personal learning and satisfaction of each individual member? Four critical times in the crew life cycle are described: (a) pre-arrival, (b) team creation, (c) task execution, and (d) team termination.

Halliday, J. T. (1987). The ISD process in CRM. In R. S. Jensen (Ed.), Proceedings of the Fourth International Symposium on Aviation Psychology (pp. 447-450). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory, and Association of Aviation Psychologists.

This paper describes an application of Instructional Systems Design (ISD) to CRM courseware. CRM tasks were first stated as an active observable behavior, then analyzed for their criticality, frequency, difficulty, and level of interactive teamwork. The ISD process offers a systematic, analytical approach to CRM training. Each design team member has to justify his or her rationale to other members throughout the process. Without a framework similar to the ISD process, any CRM course can deteriorate into nothing but a series of individual preferences.

Halliday, J. T., Biegalski, C. S., & Inzana, A. (1986). CRM training in the 349th Military Airlift Wing. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 148-157). Moffett Field, CA: NASA Ames Research Center.

This paper contains a description of the Aircrew Resource Management (ARM) course developed by the 349th MAW at Travis AFB, CA, for C-5 crews in the Air Force Reserve. All crew members including loadmasters participate. The heart of the program is the synergy formula, and a flow chart for synergistic decision making.

Helmreich, R. L. (1980). Social psychology on the flight deck. In G. E. Cooper, M. D. White, & J. K. Lauber (Eds.), Resource Management on the Flight Deck: Proceedings, NASA/Industry Workshop (NASA CP 2120, pp. 17-30). Moffett Field, CA: NASA Ames Research Center.

Social psychological and personality factors that can influence resource management on the flight deck are discussed. It is argued that personality and situational factors intersect to determine crew responses and that assessment of performance under full crew and mission conditions can provide the most valuable information about relevant factors. The possibility of training procedures to improve performance on these dimensions is discussed. (A) Discussion by workshop participants follows.

Helmreich, R. L. (1984). Cockpit management attitudes. Human Factors, 26(5), 583-589.

Distinctions are drawn between personality traits and attitudes. The stability of the personality and the malleability of attitudes are stressed. These concepts are related to pilot performance, especially in the areas of crew coordination and cockpit resource management. Airline pilots were administered a Cockpit Management Attitudes Questionnaire; empirical data from that survey are reported and implications of the data for training in crew coordination are discussed. (A)

Helmreich, R. L. (1986a). Pilot selection and performance evaluation: A new look at an old problem. In G. E. Lee (Ed.), Proceedings, Psychology in the Department of Defense, Tenth Annual Symposium (pp. 274-278). Colorado Springs, CO: U.S. Air Force Academy.

Limitations on the validity of pilot selection strategies are discussed. Major problems are caused by clinging to an obsolete stereotype of the pilot as a single figure facing the elements in isolation and by limiting the performance criterion to behavior during training. It is argued that this leads to an incorrect underemphasis on the role of personality factors in

long-term performance. Performance criteria should be obtained in an operational environment with stress on crew as well as individual behavior. The implications of changing approaches to evaluation on selection are discussed. (A)

Helmreich, R. L. (1986b). Theory underlying CRM training: Psychological issues in flight crew performance and crew coordination. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 15-22). Moffett Field, CA: NASA Ames Research Center.

Psychological theory and research relating to cockpit resource management are summarized. Several studies are cited which examine the relationships between performance and attitudes, abilities, and personality. Implications for the design of CRM/LOFT training are suggested. Further research is needed in the evaluation of the effectiveness of CRM/LOFT and establishing baseline data on the resource management as it is practiced now.

Helmreich, R. L., Foushee, H. C., Benson, R., & Russini, W. (1985). Cockpit resource management: Exploring the attitude-performance linkage. In R. S. Jensen & J. Adrion (Eds.), Proceedings of the Third Symposium on Aviation Psychology, (pp. 445-450). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

Measured attitudes regarding cockpit management were contrasted for pilots whose line-flying performance was independently evaluated by Check Airmen as above or below average. A highly significant discriminant function was obtained indicating that these attitudes are significant predictors of behavior. The performance of 95.7% of the pilots was correctly classified by the analysis. Implications of the results for cockpit resource management training and pilot selection are discussed. (A)

All pilots rated "average" were eliminated, as were those where discrepancies existed between ratings by at least two Check Airmen.

Helmreich, R. L., & Seim, F. M. (1985). Cockpit management attitudes: II. Position, organizational, and personality factors (NASA-University of Texas Report 85-3). Austin, TX: University of Texas.

Cockpit Management Attitudes Questionnaires were administered to 244 captains, 170 first officers, and 73 second officers of one airline, and 154 second officers from another airline. Relationships between attitudes and crew position, experience in flight operations and personality are explored.

Although the range of experience was limited, some tentative results are presented. In comparing experience and attitudes, the more-experienced pilots attached less importance to the debriefing and critique, saw training as a less important responsibility of captains, felt strongly that a relaxed attitude is essential, and sought to avoid negative comments about procedures of other crew members. They also felt that captains should encourage their first officers to question procedures. Although tentative, these differences, supported by anecdotal evidence regarding cohort differences in attitude, may suggest that attitude differences may become a source of conflict among different experience levels.

The correlations between personality factors and attitudes showed a number of significant relationships but did not suggest that the personality-attitude linkage was strong enough to vitiate the effects of training in cockpit resource management.

Jensen, D. (1981). American Airlines LOFT evaluation program. In J. K. Lauber & H. C. Foushee (Eds.), Guidelines for Line-Oriented Flight Training Volume II: Proceedings of a NASA/Industry Workshop (NASA CP 2184, pp. 92-102). Moffett Field, CA: NASA Ames Research Center.

This paper describes the use of LOFT in recurrent training by American Airlines. A typical scenario is described, showing where crews have typically experienced difficulty. The high-decision workload on one leg pointed out to the crew that if the captain flew this leg and tried to make all the decisions, he had a really difficult time. LOFT will not be conducted unless fully qualified line crew members are in all positions. The results of a questionnaire evaluation of LOFT are summarized. Crew acceptance was very good, and crew planning and communication were considered to be enhanced. Discussion by workshop participants follows.

Jensen, R.S. (1982). Pilot judgment: Training and evaluation. Human Factors, 24, 61-73.

An analysis of accident statistics reveals that over 50% of pilot-caused civil aviation accident fatalities are the result of faulty pilot judgment. Although the FAA requires examiners to evaluate pilot judgment, it provides no definition or criteria against which such an evaluation can be made. In spite of the statistics implicating pilot judgment in many aviation fatalities, attempts to teach it are almost nonexistent. It is but a slight overstatement to say that good pilot judgment is learned by the lucky and the cautious over many years of varied flying experiences. This paper examines some of the decision-research literature in an attempt to provide an operational definition of pilot judgment and to suggest ways that pilot judgment may be taught and evaluated in civil aviation. (A)

Johnston, A. N. (1985). Occupational stress and the professional pilot: The role of the Pilot Advisory Group (PAG). Aviation, Space, and Environmental Medicine, 56, 633-637.

This paper discusses the role of pilot peer group involvement, using the Pilot Advisory Group (PAG), in assisting pilots who manifest personal problems which derive from occupational and other stressors. Some general aspects of "background" occupational stress are discussed. Attitudes and opinions of professional aviators are identified and their role in denial of symptomatology is developed. The concept of the Pilot Advisory Group (PAG) is discussed before its role in relation to occupational stress is introduced. While some of the better-known problems associated with occupational stress in pilots are mentioned, the emphasis in this paper is on developing new perspectives regarding the identification of stress-induced dysfunction, and also in exploring the suitability of PAG involvement. The formal obligations of management and regulatory authorities are contrasted with what the author sees as the countervailing imperatives of pilot attitudes and beliefs. (A)

Johnston, A. N. (1986). Remedial training: Will CRM work for everyone? In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 108-122). Moffett Field, CA: NASA Ames Research Center.

This paper addresses the subject of those pilots who seem unresponsive to CRM training. Attention is directed to the need and opportunity for remedial action. Emphasis is given to the requirement for new perspectives and additional training resources. It is also argued that, contrary to "conventional training wisdom", such individuals do not represent a "hard core" which is beyond assistance.

Some evidence is offered that such a new perspective will lend itself to a wider appreciation of certain specific training needs. The role of appropriately trained specialists is briefly outlined, and a selected bibliography is attached for use by those interested in this area.

This paper is based on the combined experiences of several Pilot Advisory Groups (PAG's) within IFALPA [International Federation of Air Line Pilot Associations] member associations. It does not purport to describe the activities of any one PAG. Some small changes to the text have been made to preserve confidentiality. While many of the activities of PAG's have no relevance to CRM, there are clearly some very important points of intersection. The relevance of these points to diagnostic skills, and remedial training in the general domain of CRM will be obvious to the reader. (A)

Johnston, W. A. (1966). Transfer of team skills as a function of types of training. Journal of Applied Psychology, 50, 102-108.

5 groups varying in training context (team versus individual) and skill acquisition (individual, coordination, and communication skills) were compared at transfer on team (coordination of interceptions) and individual (number of interceptions) performance of a simulated radar-controlled aerial intercept task. Individual performance was unaffected by the training variables, but team performance was a positive function of the emphasis on coordination skills during training. When acquisition of coordination skills was held constant, context had no effect on transfer performance. Intrateam communications retarded performance but prohibiting these communications during training did not lessen their disruptive effect at transfer. This inhibitory influence of team communications reflected the verbal transmittal of information irrelevant to the task or more readily obtainable from the radar scopes. (A)

Jones, D. R. (1986). Flying and danger, joy and fear. Aviation, Space, and Environmental Medicine, 57, 131-136.

U.S. Air Force flyers are all volunteers who undergo rigorous training for their profession. Their motivation may be deep rooted and emotional, or may arise from a conscious decision made in early adulthood. Some motivation is flawed and fails early. Other motivation may be eroded by a single dangerous event, by an accumulation of "close calls" (one's own or others'), or by a growing interest in nonaviation elements. Since Air Force flyers may "quit" only at some personal cost to pride or pocketbook, they may develop a fear of flying. This may be truly phobic, a situational reaction, or some awareness of personal vulnerability. Some displace anxiety about flying into somatic symptoms. The author discusses motivation to fly, its various modes of failure, and some clinical aspects of fear of flying. (A)

Kanki, B. G., Lozito, S., & Foushee, H. C. (1987). Communication indexes of crew coordination. In R. S. Jensen (Ed.), Proceedings of the Fourth International Symposium on Aviation Psychology (pp. 406-412). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory, and Association of Aviation Psychologists.

The interactive speech variations of ten two-person flight crews were explored in order to find regularities which would differentiate the low- from the high-error performances. Although a specific communication profile could be defined to characterize each crew, the overriding finding was the marked homogeneity of patterns for low-error crews and heterogeneity for high-error crews. The consistency shown by the low-error crews

was interpreted as the adoption of a standard form of communicating while the diversity shown by high-error crews indicated absence of an established convention. Because conventions are regularities which serve to validate the expectations of those involved, the ability to predict one another's behavior improves. This in turn, facilitates the coordination process. (A)

Kidd, J. S., Kinkade, R. G., & Weiner, E. L. (1958). Task stress as a factor in group formation. In Symposium on Air Force Human Engineering, Personnel, and Training Research (pp. 162-175). Washington, DC: National Academy of Science, and National Research Council.

It has been suggested that heightened stress would lead to group cohesiveness, especially if some form of task-imposed stress were applied during the group formative stages. Three different time-stress schedules were used with groups of subjects in a cooperative air traffic control type of simulation using a game board similar to Chinese Checkers. For the "increase-decrease" (I-D) group, the time-stress increased on successive trials from 5 seconds on trial one to 2 seconds on trial four, then increased back to 5 seconds on trial eight. The "constant-decrease" (C-D) group had five trials at 3 seconds followed by a more relaxed 4, 5, and 5 seconds on the last three trials. The "constant" (C) group had a constant time-stress of 4 seconds for the entire eight trials.

The results indicated that performance and group integration are relatively unaffected by differential stress schedules of the type employed here. However, there was positive evidence indicating that vital group activities such as cooperation and verbal interaction stabilize very rapidly. The additional observation of a positive relationship between measures of social interaction and task effectiveness was interpreted as an indication of a possible differentiation between task-induced interaction and member-initiated interaction.

Komich, J. N. (1985a). An analysis of the dearth of assertiveness by subordinate crew members. In R. S. Jensen & J. Adrion (Eds.), Proceedings of the Third Symposium on Aviation Psychology (pp. 431-436). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

Two reasons for a captain's performing an aberrant procedure or maneuver were identified based on interviews with a number of pilots for the major carriers. Weak captains, both in stick and rudder and in personality, will be embarrassed or humiliated by an assertive subordinate. If the copilot speaks up every time the captain is 10 knots slow, he would be asserting himself too frequently; therefore, the copilot may decide to allow 15 knots. In the case of a captain who sees himself as omnipotent, a

challenge can be construed as a threat, and the captain could greatly overreact.

Four roots of the problem are listed: (a) Crews understand and value the maintenance of cockpit harmony; (b) once outside the published limits, there is nothing the subordinate can monitor to decide when to speak up; (c) there is not always sufficient time for a lengthy discussion; and (d) as part of the "captain mystique," it is generally accepted that the captain can do no wrong.

Komich, J. N. (1985b). When should pilot discipline end and pilot savvy begin? In R. S. Jensen & J. Adrion (Eds.), Proceedings of the Third Symposium on Aviation Psychology (pp. 367-371). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

An analysis of aircraft accident reports indicates that many of those accidents attributed to pilot error also involved a lack of pilot discipline, a failure to follow a checklist or a prescribed procedure. Consequently, any pilot who wishes to ensure a safe flight will strictly adhere to the published procedures and checklists. However, analysis of recent accidents indicates that perhaps strict adherence to these published procedures is not always going to guarantee a safe flight. Under certain extenuating circumstances, the pilot might require knowledge above and beyond the checklist or flight manual to assure that desired margin of safety.

Krey, N. C., & Rodgers, D. (1986). CRM for Part 91 and 135 operators (SimuFlight, Inc.). In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 158-169). Moffett Field, CA: NASA Ames Research Center.

The Flight Deck Management program presented by SimuFlight, Inc. for corporate and private operators of multicrew aircraft is described. The concepts of the Flight Deck Management Cycle are discussed as expansions of the triangle of planning, challenge, and response. A flow chart of subtasks within this triangle is provided.

Opportunities for improvement suggested in client feedback critiques include: first, greater personal commitment on the part of the pilots and greater acceptance of their own human limitations; second, industry commitment to train crews instead of individuals; and third, development of clearly defined criteria for measuring crew performance.

Lauber, J. K. (1980). Resource management on the flight deck: Background and statement of the problem. In G. E. Cooper, M. D. White, & J. K. Lauber (Eds.), Resource Management on the Flight Deck: Proceedings, NASA/Industry Workshop (NASA CP 2120, pp. 3-16). Moffett Field, CA: NASA Ames Research Center.

One of the principal causes of incidents and accidents in civil jet transport operations is the lack of effective management of available resources by the flight-deck crew. Present aircrew training programs could be augmented to improve flight-deck management. This paper discusses previous research, as well as accident and incident narratives, and proposes candidate solutions to the problem to provoke discussion during the workshop that follows.

Lauber, J. K. (1986). Cockpit resource management: Background and overview. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 5-14). Moffett Field, CA: NASA Ames Research Center.

This paper provides a brief history of cockpit resource management problems, along with some definitions and principles, and a status report of present cockpit resource management training programs. The earliest NTSB observation regarding cockpit procedures, crew discipline, and flight management was noted in their report of a Convair 580 accident in 1968. The first direct reference to flight deck resource management occurred in the report of a DC-8 accident in Portland, OR, in 1979. During a study of the interaction of workload with errors by H. P. Ruffell Smith, the idea emerged to apply classical business management concepts to cockpit operations.

The author defines cockpit resource management as the effective utilization of all available resources--hardware, software, and liveware--to achieve safe, efficient flight operations. Some of the major principles related to CRM include: delegation of tasks and assignment of responsibilities, establishment of priorities, monitoring and cross-checking, use of information, problem assessment, leadership, communications, and the avoidance of preoccupation.

Reference is made to many of the courses developed by airlines and other organizations by way of introduction to the workshop presentations which follow.

Lozito, S. C., Kanki, B. G., & Foushee, H. C. (1987). "But captain, I've been doing this a lot longer than you have," The effects of "role-reversal" on crew interaction. In R. S. Jensen (Ed.), Proceedings of the Fourth International Symposium on Aviation Psychology (pp. 413-418). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory, and Association of Aviation Psychologists.

Legislation providing for airline deregulation has, among other things, created some ambiguity with respect to cockpit role structures. With the demise of some airlines, the absorption of others, the merging of seniority lists, and a new shortage of pilots, individuals with experience equivalent to or greater than that of the pilot in command may be placed in roles of lesser status. A formerly senior captain may be flying in the right seat as a first officer with an individual very much "junior" in terms of both age and experience. Moreover, the mandatory retirement of airline pilots at age 60 does not apply to flight engineers, and some are "down-grading" to fly in that capacity. The effects of this "role-reversal" phenomenon on the crew coordination process have not been explored. The purpose of this study was to begin investigating this phenomenon using data obtained from a previous "short-haul" full mission study conducted by Foushee, Lauber, Baetge, and Acomb (1986). (A)

Margerison, C., McCann, D., & Davies, R. (1986). Aircrew team management program (Trans Australia Airlines). In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 90-107). Moffett Field, CA: NASA Ames Research Center.

This paper describes the development, implementation, and evaluation of the Aircrew Team Management Workshop used at Trans Australia Airlines. A consultative network was established among the crew force which engendered a commitment to the course because it was designed with them rather than for them. This network included all facets of the airline, from management and check airmen to line crews and union representatives. A list of key problem areas to be addressed included: lack of support, standard operating procedures ignored, stress, judgment, emotional problems, get-home-itis, management pressure, discipline, leadership, and communication. The key training elements derived were: understanding of oneself and others, communication skills, and team skills.

Results of a questionnaire assessment are included and show a strong acceptance by the flight crews.

Murphy, M. R. (1980). Analysis of eighty-four commercial aviation incidents: Implications for a resource management approach to crew training. Proceedings of the Annual Reliability and Maintainability Symposium (pp. 298-306). New York: The Institute of Electrical and Electronics Engineers, Inc.

A resource management approach to aircrew performance is defined and utilized in structuring an analysis of 84 exemplary incidents from the NASA Aviation Safety Reporting System. The distribution of enabling and associated (evolutionary) and recovery factors between and within five analytic categories suggest that resource management training be concentrated on: 1) interpersonal communications, with Air Traffic Control (ATC) information of major concern; 2) task management, mainly setting priorities and appropriately allocating tasks under varying workload levels; 3) planning, coordination, and decision-making concerned with preventing and recovering from potentially unsafe situations in certain aircraft maneuvers. Problem-solving and leadership skills were implicated as factors in a sufficient number of incidents to require further study. Leadership, social skills, and role-issue effects may be under-reported in voluntarily submitted incident data; more systematic study is recommended. Some problem areas are identified for which design changes are apparently in order, particularly the ATC interface.  
(A)

Murphy, M. R., & Awe, C. A. (1986). Aircrew coordination and decisionmaking: Peer ratings of videotapes made during full mission simulation. In Twenty-First Annual Conference on Manual Control, (NASA CP 2428, pp. 23.1-23.33). Moffett Field, CA: NASA Ames Research Center.

Six professionally active, retired captains rated the coordination and decisionmaking performances of sixteen aircrews while viewing videotapes of a simulated commercial air transport operation. The videotapes displayed a composite of four views of crew members and the cockpit, from cameras located inside the simulator. The scenario featured a required diversion and a probable minimum fuel situation. Seven-point Likert-type scales were used in rating variables on the basis of a model of crew coordination and decisionmaking. The variables were based on concepts of, for example, decision difficulty, efficiency, and outcome quality; and leader-subordinate concepts such as person- and task-oriented leader behavior, and competency motivation of subordinate crew members. Five front-end variables of the model were in turn dependent variables for a hierarchical regression procedure. The inclusion of decision efficiency and command reversal as variables in the model appear to be useful advances in conceptualizing the crew performance process. The rating of videotapes appears to have considerable promise in developing crew performance models. It is suggested that addition of flight

and system information to the display format would reduce error variance in crew process ratings. Crew members for this study were diverse with respect to airline of origin and recency, or currency on the Boeing 707--the aircraft simulated. Some retired personnel were used. The results should be interpreted accordingly. (A)

Nunn, H. T. (1981). Line-oriented flight training--Northwest Airlines. In J. K. Lauber & H. C. Foushee (Eds.), Guidelines for Line-Oriented Flight Training Volume II: Proceedings of a NASA/Industry Workshop (NASA CP 2184, pp. 26-37). Moffett Field, CA: NASA Ames Research Center.

This paper describes development of the LOFT concept by Northwest Airlines in 1974. The concept of LOFT came from discussions among the flight training staff of ways to create simulator training which would be closely related to the actual line environment and provide for total crew participation in realistic flight experiences.

Conceptual bases are identified. Crew interaction is the essential focus of LOFT training. Although full-mission simulation may be used in checking situations, it is essential that a training environment be maintained. The key issue for instructors is not that errors were made but whether the pilots recognize and understand why the errors were made. The instructor should permit the participants to exhaust their evaluation before proceeding with the instructor-noted items. If any crew members have exhibited the need for further training, they would be called aside privately and the matter discussed. Discussion by workshop participants follows.

Ruffell Smith, H. P. (1979). A simulator study of the interaction of pilot workload with errors, vigilance, and decisions (NASA TM 78482). Moffett Field, CA: NASA Ames Research Center.

This research comprised a full mission simulation of a civil air transport scenario that had two levels of workload. Twenty fully qualified three-man crews took part in the study. The actions of the crews and the basic aircraft parameters were observed and heart rates were recorded.

Reduction of these data permitted the enumeration of errors, vigilance, decisions, and their association with heart rate to be investigated.

The results showed that the number of errors was very variable among crews, but the mean increased in the higher workload case. The increase in errors was not related to rise in heart rate but was associated with vigilance times as well as the days since the last flight.

The recorded data also made it possible to investigate decision time and decision order. These also varied among crews and seemed related to the ability of captains to manage the resources available to them on the flight deck.

Error rates and heart rates were essentially the same as those found in actual flight operations, indicating the quality of the simulation. It is suggested that similar levels of full-mission simulation could benefit training and accident investigation. (A)

Schwartz, D. (1986). CRM training for FAR Parts 91 and 135 operators (Flight Safety International, Inc.). In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 170-177). Moffett Field, CA: NASA Ames Research Center.

This paper describes the CRM training offered by Flight Safety International (FSI) to air taxi operators. This course focuses on the concepts of the "safety window" between the surface and 2,000 feet above the ground, and situational awareness. The Cockpit Management Concept (CMC) developed by FSI incorporates the skills and attitudes which might optimize situational awareness. Five elements that contribute to situational awareness and ten clues as to when the crew has lost situational awareness are discussed. The training is delivered in four sections taught at subsequent training intervals.

Siem, F. M. (1986). The effect of aircrew member personality on interaction and performance. In G. E. Lee (Ed.), Proceedings, Psychology in the Department of Defense, Tenth Annual Symposium (pp. 284-288). Colorado Springs, CO: U.S. Air Force Academy.

Eighty pilots whose responses to a personality questionnaire identified them as having characteristics associated with either superior or inferior flight deck performance were selected to work in two-person crews operating a microcomputer-based flight simulator program. Raters viewed tapes of the simulator sessions and evaluated performance and communication styles. Analyses indicated that crews in which the pilot was highly competitive and low in an expressive, interpersonal orientation tended to communicate more with their copilots and that higher levels of interaction were associated with poorer performance, in contrast with studies of airline pilots (e.g., Foushee & Manos, 1981). (A)

Shroyer, D. H. (1986). The development and implementation of cockpit resource management in UAL recurrent training. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 47-49). Moffett Field, CA: NASA Ames Research Center.

As early as 1955, United Airlines realized that they had a problem in their cockpits, but could not specifically identify the problem. The Portland DC-8 accident in 1978 was the catalyst for the effort to develop training in cockpit resource management.

Line-Oriented Flight Training (LOFT) allows the final proof that skills and attitudes addressed in academic cockpit resource management exercises actually operate in the cockpit. Several important requirements involving the LOFT process have emerged. First, all scenarios need to be tightly scripted. Secondly, the content must be rigidly controlled. The third requirement is the formulation of a plan for updating and continuing progress of the system.

The importance of a well-trained instructor cannot be overemphasized. He must be schooled in the seminar and pre-work process, have good equipment qualifications, understand the instructor manual, be highly trained as a LOFT administrator, have substantial training in observational skills, and be able to conduct the all-important critique process.

Sommerville, J. (1981). Texas International Airlines LOFT program. In J. K. Lauber & H. C. Foushee (Eds.), Guidelines for Line-Oriented Flight Training Volume II: Proceedings of a NASA/Industry Workshop (NASA CP 2184, pp. 71-78). Moffett Field, CA: NASA Ames Research Center.

This paper describes a variation on the concept of LOFT used by Texas International Airlines. A Line-Oriented Check Ride (LOCR) has been implemented as opposed to Line-Oriented Flight Training. A scenario is structured such that the average pilot will complete the checkride without complication. Pilots are checked every 6 months, and are expected to perform with perfection. This is viewed as a disadvantage since some pilots become bored due to the lack of challenge. The company believes that the advantages of greater realism in training and elimination of the requirement for a line-check in the airplane overshadow any disadvantages. Discussion by workshop participants follows.

Thiagarahan, S. (1979). Transition evaluation: Correcting and confirming planned change. In National Society for Performance and Instruction Journal, 18(3), 5.

Transition evaluation provides a procedure to channel energy spent in complaining about change into providing objective bases for informed decision-making. Two major decisions can be made during the evaluation process: a summative decision about whether or not to continue the installation of the new system, and a formative decision as to different ways to improve the new system. Transitional evaluation will immediately expose a decision based on subjective, unjustifiable whims of the decision maker.

Title 14, U.S. Code of Federal Regulations, Section 121, Certification and Operations: Domestic Flag and Supplemental Air Carriers and Commercial Operators of Large Aircraft.

This section of the U.S. Code contains Federal Aviation Regulations affecting the operation and management of all U.S. airlines.

Traub, W. (1979). Flight crew selection at United Airlines. In G. E. Cooper, M. D. White & J. K. Lauber (Eds.), Resource Management on the Flight Deck: Proceedings, NASA/Industry Workshop (NASA CP 2120, pp. 61-75). Moffett Field, CA: NASA Ames Research Center.

This article discusses hiring practices at United Airlines. They consider attitude and personality traits important and prefer individuals who (a) are motivated by an aviation career itself, (b) show a congruent interest pattern, (c) are confident of their ability to control their environment, (d) have a realistic outlook that is free from abnormal anxiety reactions, (e) are conscientious and goal-directed, (f) are cooperative, (g) are consistent, and (h) possess a high startle threshold. Discussion by workshop participants follows.

White, L.C. (1986). Cockpit resource management training. In H.W. Orlady & H. C. Foushee (Eds.), Cockpit Resource Management Training: Proceedings of NASA/MAC Workshop (NASA CP 2455, pp. 123-125). Moffett Field, CA: NASA Ames Research Center.

The 6th General Flight Crew Training Meeting in 1984 was, for most International Air Transport Association member airlines, their first exposure to resource management training. Because very few airlines had implemented a program or even understood the term "resource management," a member airline survey was conducted.

Responses were received from 17% of the 140 member airlines. Courses had been implemented by 14 of those responding. Six airlines planned to introduce the training. Four airlines had no plans to do so. Three were investigating the possibility. Typical syllabus content focused on leadership, communication, decision-making and crew cooperation. Four airlines gave the course to captains only, and seven airlines provided this training to all flight crew members.

Whitehead, J. (1981). Delta Airlines LOFT training. In J. K. Lauber & H. C. Foushee (Eds.), Guidelines for Line-Oriented Flight Training Volume II: Proceedings of a NASA/Industry Workshop (NASA CP 2184, pp. 79-91). Moffett Field, CA: NASA Ames Research Center.

This paper describes the use of LOFT in recurrent training by Delta Airlines, and variations of the concept described by the FAA in Advisory Circular 120-35 in other courses. Shortly after Advisory Circular 120-35 was issued, Delta instituted LOFT training in their DC-9 training program, which served as a model for other aircraft. It offers line crews an opportunity to exercise their problem solving skills and develop insights into crew coordination and resource management. As a side benefit, instructors have the opportunity to observe the appropriateness of procedures in normal, abnormal, and emergency situations and suggest changes to the flight manual. Debriefing offers an opportunity to provide the real instruction of the program. The instructor is aware of the scenario objectives and subtleties. The instructor must advise the crew of these objectives and then review their performance in fulfilling them. LOFT is used to supplement other training. Initial DC-9 training incorporates a LOFT profile to increase familiarity with line operations.

A tangential problem has surfaced, in that flight engineers feel that LOFT is inadequate to provide the necessary in-depth systems review to maintain proficiency. Discussion by workshop participants follows.

Williges, R. C., Johnston, W. A., & Briggs, G. E. (1966). Role of Verbal communication in teamwork. Journal of Applied Psychology, 50, 473-478.

A simulated radar-controlled aerial intercept task was used to examine verbal communication between teammates under verbal (communication necessary) and verbal-visual (communication unnecessary) conditions. Communication facilitated team performance only in the verbal condition. Team performance, however, was best in the verbal-visual condition. A transfer-of-training paradigm was employed to determine if verbal skills developed in one condition would transfer to the other condition. Differential transfer occurred neither in communication behavior nor in team performance. It was concluded that verbal

communication, when not required by the task, plays an insignificant role in teamwork, and that this role apparently is not enhanced by verbal training. (A)

Wilhelm, J. (1986). Considerations in evaluation of cockpit resource management training. In G. E. Lee (Ed.), Proceedings, Psychology in the Department of Defense, Tenth Annual Symposium (pp. 279-283). Colorado Springs, CO: U.S. Air Force Academy.

A short history of cockpit resource management training is given. "Macro" evaluation strategies as well as strategies for evaluation of individual CRM programs are discussed. Changes in pilot and crew performance on the line are argued as the best indicators of CRM effectiveness. (A)

Woelfel, J., & Stover, B. (1985). Cockpit communication and aircraft safety: An empirical study. In R. S. Jensen & J. Adrion (Eds.), Proceedings of the Third Symposium on Aviation Psychology (pp. 387-401). Columbus, OH: The Ohio State University, Aviation Psychology Laboratory.

Several investigators have recently put forward the possibility that members of the flight crew may have been aware of problems before accidents, but that difficulties in communication may have prevented them from taking appropriate corrective actions. This has led to an increased interest in the process of cockpit communication and the group dynamics of flight crews.

Although early studies have been useful; nonetheless, the study of cockpit communication is still relatively undeveloped. Accordingly, the present study was designed as a preliminary effort to identify the principle concepts which control cockpit communication.

The study consisted of two phases. In the first phase twenty-four in-depth interviews were conducted with flight crews of general aviation aircraft. The major concepts identified in these unstructured interviews were then incorporated into a very precise Galileo(tm)-type questionnaire which was administered to additional flight crews.

Although this study should be considered preliminary, several strategies for improving cockpit communication were identified. Should further research confirm the usefulness of these types of strategies, they might be appropriately included in flight crew training programs to increase the likelihood that flight crew members would report unusual or hazardous circumstances early enough for corrective actions to be taken. (A)