FOUNDATIONS

OF

COCKPIT RESOURCE MANAGEMENT (CRM) TRAINING

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Abstract

Objectives: To provide an analysis of the foundations of cockpit resource management (CRM) for the scientific, academic, and aviation training communities through a review of CRM history, literature, and research.

Scope: This study provides a summary of what cockpit resource management (CRM) is, what its originare are, a review of contemporary research in its various components, and recommendations for selection and training to meet the objectives of improved cockpit management. It contains views on crew member skills, roles, behaviors and available resources commonly included in the analysis of CRM.

Findings: Out of the review of literature and survey activities related to this study, a descriptive analysis of CRM was constructed. This included a history of CRM development, a summary of CRM research, and an account of CRM training issues. Lack of institutional priority and absence of governmental support for funding the production of CRM training media are cited as the most important areas of concern.

Introduction

Among the reported causes of civil jet transport accidents and incidents are many factors which relate to ineffective management of available resources by the flight crew (Lauber, 1980, p. 3). Murphy (1980, p. 298) classified resource management as "the application of specialized skills to achieve a crew organization and process that effectively utilizes available resources in attaining system objectives." Lauber (1985) further refined the definition of cockpit resource management (CRM) as the utilization of all resources - information, equipment, and people - to achieve safe and efficient flight operations.

National Aeronautics and Space Administration (NASA) undertook a review of jet transport accidents occurring between 1968 and 1976 and identified sixty-two accidents which were related to improper resource management. Other such accidents have been subsequently identified. Common factors in many of these accidents involved: preoccupation with minor mechanical problems, failure to delegate tasks and assign responsibilities, failure to set task priorities, inadequate monitoring, and failure to utilize available data (Lauber, 1980, pp. 5-7). In addition to reviewing the transport accident record, a search of the Aviation Safety Reporting System (ASRS) database was conducted. The search, which covered jet transport operations only, recovered 670 incident reports that were relevant to the issue of resource management.

Resource management skills related to accidents and incidents factors cover a broad spectrum. Murphy (1980, p. 304) identified several classifications under which such skills could be placed. Among others, these classifications include: communications, leadership, planning, problem solving, and decision making. The relationship of resource management to elements of human factors research has been shown (KLM, 1980). Suggestions have been made to further identify resource management concepts as a first step in prescribing appropriate training procedures (Crump, 1980, p. 157). Cooper & White (1980) and the Flight Safety Foundation (FSF) (1985) developed lists of twenty such concepts to deal with the judgement and decision-making aspects of CRM (Figure 1).

Resource management training remains a focal point of NASA, Federal Aviation Administration (FAA), and airline interest at this time. As recently as 1986 (Orlady & Foushee, 1987), answers were being actively sought for the questions of CRM concept identification and appropriate training strategies. Although solutions other than training, such as "increasing awareness" or"setting rules" have been examined as adjuncts to training, they are not considered adequate within themselves (Lauber, 1980, p.10). In addition to the content of any CRM training curriculum developed, the sequence and format of its presentation may be important. There are also valid arguments for selection processes which emphasize acquiring resource management training prior to employment (Crump, 1980, p. 157), as well as continued

Essential CRM Skills

Listening
Assertiveness
Ability to deal with conflict
Problem-solving
Problem definition
Establishing priorities
Open mindedness
Personality awareness
Managing distractions
Fatigue management and recognition
Judgment and decision-making
Workload assessment
Managing division of attention
Stress management
Advising and critiquing
Knowledge of interdepartmental relationships
Consideration for crew
Fairness to crew
Consideration of all alternatives
Setting task priorities
Comunication of plans
Anticipation, awareness, and analysis of situation
Appreciation of captain's responsibilities
Awareness of crew's tasks
Ability to delegate
Willingness to teach or share experience
Ability to instill confidence
Professionalism
Confidence
Command presence—style—integrity
Communication of intent

Figure 1

(Adapted from Cooper et. al. 1980 and FSF, 1985)

CRM emphasis in the upgrade and recurrent training programs which span a pilot's career (Frink in Cooper, White, and Lauber, 1980, p. 188).

The Need for Cockpit Resource Management Training

As modern aircraft become more dependent upon technological advances to cope with the increasing demands of flight, managerial tasks require a higher percentage of each crew member's time. Monitoring the proper functioning of complex electronic and mechanical components overshadows the fundamental skills which were required to fly aircraft of lesser sophistication (Frink, 1980, p. 149). In addition to the increasing complexity of equipment, the flight environment is constantly making heavier demands on the crew. More traffic shares the airspace, and aircraft are operated under ever-lowering minimums of ceiling and visibility. Night flying, with its related fatigue, has been increased to meet public demand and to achieve higher rates of aircraft utilization (Glines, 1974, pp. 7-8). These demands must be balanced through nontechnical training in resource management as a supplement to existing technical training programs (KLM, 1980).

There was a time in aviation history when complexity was minimal. Aircraft had a simplicity which was actually inappropriate to the task (Solberg, 1979, p. 130). Aviation pioneers compensated for this deficit with high levels of individual skill (LeMay & Kantor, 1965, p. 495). Eventually, pilots who entered the air transport industry had to face

operational requirements which often exceeded their individual performance limits. The two-man crew became necessary. Later, crews of up to five were needed to perform the combined functions of systems operation, navigation, and communication (Holland & Smith, 1971, p. 188). With the advances in avionics and flight automation achieved during the past twenty years, the current crew complement standard has been reduced.

Contemporary requirements for the jet transport crew member have advanced from purely psychomotor skills used in a simple application, to highly cognitive and affective skills used in a very complex, team-oriented application. Unfortunately, training has not fully recognized this changing emphasis. Basic flying ability is necessary, but these skills alone are not enough. Restrictions imposed on crew certification have emphasized individual performance and minimized the task sharing and managerial aspects of flying. As a result, the airline industry continues to witness reinforcement of the "macho pilot" stereotype who insists on demonstrating his individual ability when the other resources are available to reduce his workload (Foushee, 1980). This individualized approach to performance has also been referred to as the inappropriate "captain-does-it-all" concept cited by American Airlines (1980). Changes in training programs are necessary to emphasize group processes in complex task management.

Several attempts have been made to point out the problems and training needs related to CRM (Lauber, 1980, pp. 3-11). A

NASA resource management workshop was convened in 1979 to examine the issue in depth. Studies to identify elements of CRM have been requested by the industry, the International Air Transportation Association (IATA), and the Air Line Pilots Association (ALPA) (Cooper et al. 1980). Since that time, many papers, symposia and workshops have evolved concerning CRM issues (Lauber, 1987, p. 9). Standards for determining what concepts are essential to CRM and what training strategies to employ are still in the formative stage. When these elements are identified,more appropriate training can be developed, and improvements increw performance should result.

This study was designed to provide an overview of the CRM issue and to provide and analyze CRM research within the scientific communities. The remaining sections include the implications of CRM and contemporary CRM research activities.

The Implications of Cockpit Resource Management

If the goals of safety and crew effectiveness in scheduled airline operations are to be met, airline training programs must focus on those deficiencies which have contributed the most to accidents, incidents, and violations within the industry. When analyzing causal factors related to these events, pilot error is frequently seen as a technical deficiency in knowledge or psychomotor skills. In reality, an examination of airline accident statistics has yielded an alarming number of primary and contributing factors which relate to ineffective crew coordination (NTSB, 1976); (Lauber, 1980, pp. 5-7). The array

of skills, abilities, and characteristics needed by airline captains to deal effectively with their crew and to utilize the human and material elements of their flight environment has been categorized by the term cockpit resource management (Lauber, 1980, pp. 3-4); (Murphy, 1980, p. 298). These have been consolidated in Figure 2.

Murphy (p. 305) depicts a graphic representation of available resources in a systems context, Figure 3, and an integration of resource management skills into a systems context, Figure 4.

One of the most important aspects of research in cockpit resource management is to identify and define its components (Crump, 1980, p. 157). Only when these components are examined individually can their priority and relative importance to airline operations be determined (Cooper & White, 1980). In studying each facet of the resource management function, concepts can be developed to enhance the resource management abilities among airline crews. Once identified, resource management concepts can be evaluated for appropriate methods and training strategies (Houston, 1980, p. 162). The attainment of some of these CRM objectives, however, might be assured more effectively through the employment selection process, which would identify pre-employment skills in CRM. Allward (1967, p. 157) described a systematic approach to enhancing flight safety by emphasizing the importance of pilot education as well as training. Since

Classification of Identified Cockpit Resource Management Problems into Skill, Role, and Resources Categories

SKILLS	RESOURCES
Social and Communications Strained social relations Assertiveness Nonverification of communications Withholding communications Unnecessary communications Assumptions about message Assumptions about meaning Assumptions about other's understanding	**Human** Individual differences in knowledge, proficiency, experience, motivation, stress reaction.
Planning, Problem Solving, & Decision-making Inadequate planning Information retrieval Quality and timeliness of information Credibility of information Problem-solving strategies Staying ahead of the problem (crises prevention) Decision under stress Group think (false hypothesis)	**Material** **Facility** Availability Adequacy Human engineering **Equipment Availability** Access Adequacy Human engineering Automatic vs. manual **Textual Information** Availability Access Adequacy Human engineering **Environmental Information** Availability Adequacy
Leadership and Management Delegation of authority Erosion of authority Captain's trust-doubt dilemma Lack of decisive command Discipline and leadership in applying regulations Casualness in cockpit Crew Coordination Time structuring, priorities	**ROLE** Definition and understanding (pilot-copilot) Command responsibility of Captain when First Officer is flying Responsibility of First Officer when Captain deviates from safe or legal practices Reduced command options

NOTE: Adapted from Lauber (1980) and Murphy (1980)

education in related skills prior to employment could lead to better crew capabilities in some areas of resource management, an improved selection process based on an appropriate educational background could eventually increase the ability of flight crews in this regard (Crump, 1980, p. 157).

According to Redding and Ogilvie (1984, p. 45), the flight crew

> ...can never be machines. They carry with them feelings, attitudes, beliefs, and values which provide them with individual personality. They also carry with them sets of values derived from their cultures. This cultural level of difference, although it is assumed not to operate in affecting professional behaviors of flying crew, may, in fact, be operating unconsciously and in ways which are difficult to perceive.

If deficiencies in resource management among crew members now employed are to be corrected, a further analysis of their training needs must be undertaken. Some of these training needs fall into the category of social and communications skills (Murphy, 1980, pp. 303-304). The ability to maintain effective coordination with others is essential in the small group environment of the flight crew (White, 1980, p. 174).

A research effort was begun at NASA's Ames Research Center in 1973 to develop a human-factors-in-aviation safety program (Lauber, 1980, p. 3). In an extensive interview program, NASA was advised by airline captains that nontechnical training in leadership, crew coordination, communications, and command was needed. Bruggink (1976) has stated, "No adult with average reasoning powers can claim ignorance of the fact that emotions,

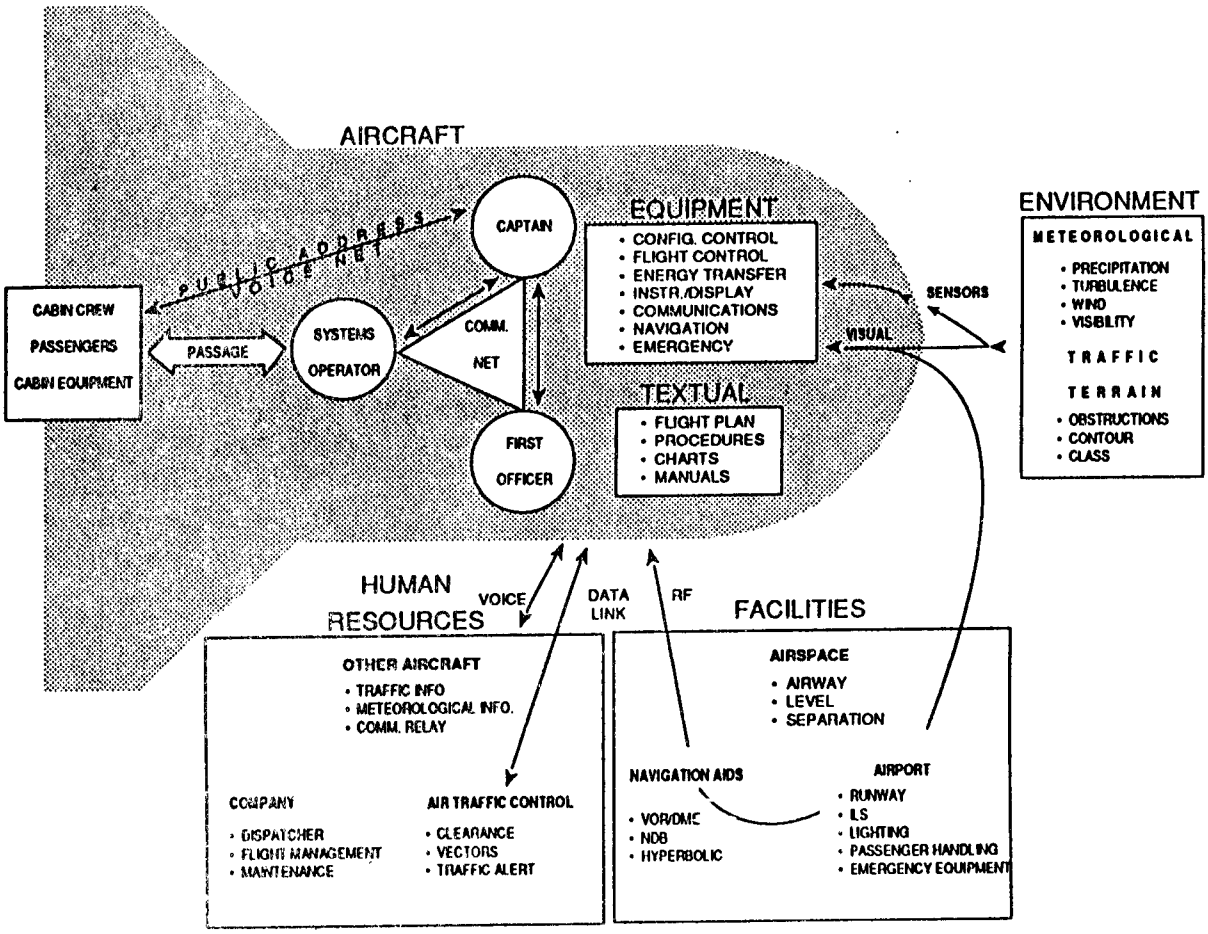

Figure 3

Systems Diagram--Categorization of Resources
(Adapted from Murphy, 1980, p. 305)

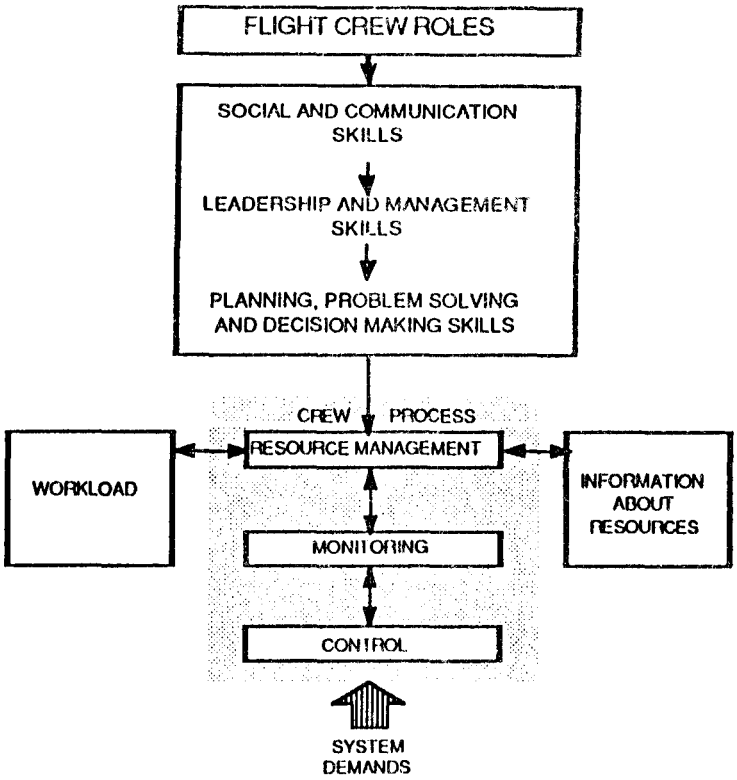

Figure 4

Resource Management Skills in a System Context
(Adapted from Murphy, 1980, p. 305)

distractions, fatigue, and a variety of other stresses affect the reliability of his performance." Gradually, a recognition of these behavioral and interpersonal elements of resource management began to take form.

In 1979, a NASA/Industry Workshop was held to focus additional attention on the resource management issue (Cooper et al., 1980). Among the seventy in attendance were representatives of the major airline training departments, NASA, and other interested agencies. Two papers were read which brought unique psychological theories to bear on the resource management issue.

Helmreich (1980, p. 17) stated that personality and situational factors intersect to determine crew responses and that assessment under full crew and mission conditions provides the most valuable performance data. Bolman (1980, p. 32) postulated that the pilot's theory of his situation often differs from reality in complex situations, and alertness to this difference is often critical to safe flight. Other papers from within the industry were presented, and a series of working group meetings convened to discuss and report on training concepts for resource management. Conference members ended the meeting with a call for additional research and a request for NASA to coordinate efforts to identify training requirements in resource management (Billings, 1980, pp. 201-202).

Research in Cockpit Resource Management

Jensen (1985, p. 12) addressed the problem of having university academic disciplines on one side of the research issue and the operational pilot and his support system on the other side. Through the influence of the first four symposia held by the Association of Aviation Psychologists, there have been opportunities to modify the extremes of each of these groups to achieve more practical and systematic inputs by all. This is a clear demonstration of how academia and industry can work together to identify and solve problems in the field of aviation.

In looking toward those research issues that relate to CRM training, Foushee and Helmreich (n.d., pp. 35-37) are concerned about the impact of mandated standards. If cockpit resource

management training is required by Federal Aviation Regulations (FAR) at some future time and this requirement encompasses evaluation, it will be essential to maintain a sharp distinction between training and the evaluation process. In addition to the operational reasons for maintaining this separation, they feel that future research on all important aspects of cockpit resource management training will be jeopardized if it is conducted in an evaluative environment.

There are few opportunities to conduct formal CRM research based on full mission simulation or Line Oriented Flight Training (LOFT), except within the training facilities of the air carrier industry. One exception to this is the simulator facility and computer complex opened in 1985 by NASA at the Ames Research Center. The facility contains both state-of-the art and advanced concept simulators. This allows the determination of flight crew behavior in both the environments of present day technology and in that envisioned for the future (Merrifield, 1985). The major areas of interest to be pursued by Ames scientists while using this new facility are work load management, decision-making, communications, and problem-solving.

The Requirements for CRM Research

The history of research in "small group" studies indicates that the complexity of the aviation environment introduces variables which can never be fully treated, given the limitations of pure academic research. This type of research is considered to be important, and is still being attempted in spite of these

limitations. In reviewing early CRM research, Murphy (1977, p. 4) concluded that suggested causal factors in crew effectiveness "have not been well-defined through systematic study or research, and proposed solutions have not been validated. Such definition and validation studies are strongly recommended." In his review of research findings and strategies related to crew coordination and performance, Murphy noted some difficulty in establishing which crew factors are responsible for ineffective crew performance. Some of those factors include role relationships, lack of decisive command, and social adjustment.

Strauch (1985, pp. 139-140) also cites the need for additional research and training program development for CRM. He points out the importance of considering the intervening variables which interact with CRM behavior.

In the recommendations of the cockpit resource management committee of the AOPA/FSF symposium, Jensen (1985, p. A50) proposed scientific studies using control groups to compare the communications and management styles of those pilots who have had CRM training with those who have not.

In discussing the existence of research evidence on any change of crew coordination patterns resulting from CRM training, Helmreich and Wilhelm (1987, pp. 440-446) answer with an unequivocal "no." They state simply that data meeting the requirements of scientific rigor and rules of evidence are lacking.

Topics for CRM Research

In addition to generalized research in the behavioral disciplines and in human factors, the aviation community has seen the necessity for more specialized research in specific areas related to cockpit resource management. These include areas of CRM skill, CRM characteristics, and CRM processes. A discussion of behavioral research outside these specific areas is beyond the scope of this study.

A brief overview of important research categories will be covered including research accomplished and, in some cases, research which has been called for. Research on personality and attitudes, communications/role/coordination, human factors/workload, and needs analysis is reviewed.

Needs analyses. Kaufman (1983, p. 54) refers to "need" as the gap between current results and desired results. When used in this context, the gap refers to the difference between "what is" and "what should be" in a training program. Need exists at different levels. One level relates to the identification of training objectives and goals. Another level involves the process or method of training to obtain these desired goals.

A needs analysis study of the Air Canada line pilots was accomplished in 1984 and 1985 by Westerlund (1985, p. 236). A significant portion of this report was devoted to a discussion of command, leadership, and cockpit resource management training. This statistically based study attempted to identify the managerial, interpersonal, developmental, and appropriate

technical training needs of pilots in Air Canada. The results of this survey indicated that 96 percent of responding line pilots agreed that effective crew concepts are essential to operational success. The pilots accused airlines of continuing to focus on achievement of individual pilot proficiency while paying relatively little attention to fostering skills and coordinated action among crew members. One of their statements was (p. 235), "A collection of qualified individual pilots does not guarantee an effective team in the cockpit."

One of the most interesting responses quoted by Westerlund from his research dealt with the very essence of the CRM problem (p. 256):

> The best captains are the most well-liked because the rest of the crew works hard to please him and feels bad if they make a mistake... The biggest liability is the captain with a personality problem because, no matter how good he is, he polarizes the crew socially. There is no training in this area. Personalities are hard to change and there is no hard direction in this area from hiring time on. They train a captain to rattle off checks and drills like a machine, but they don't teach him how to command. Command is the artful skill of reading a man's personality and tiptoeing through his social land mines so that, in the end, he accepts you and hopefully likes you. Then, he will give you his best.

Additional insights concerning CRM training design should be explored. By pursuing a more formal "needs analysis" procedure, each airline could define important objectives while allowing a range of CRM concepts and training strategies to be assessed.

Personality and attitude. Helmreich (1984, p. 583) draws major distinctions between personality traits and attitudes with respect to cockpit resource management ability. As a corollary to his research, he developed a "management attitudes"

questionnaire which revealed a number of significant differences in attitudes about flight deck management. In this study, crew position was used as his dependent variable. He concluded that the observed variability in CRM attitudes stems from basic differences in belief rather than in ambiguities of interpretation. This divergence in attitudes about cockpit management indicates that there are many experienced pilots who are either unaware or unconvinced of current findings regarding effective flight deck management (pp. 588-589). Data suggests that these attitudes toward CRM are, in fact, independent of personality traits. This supports the conclusion that training in cockpit resource management may improve these attitudes and subsequently improve observable performance in line operations. Since personality traits are so resistant to change, it was considered important by Helmreich that the dimension of attitude change for cockpit resource management should be exploited. By enhancing CRM attitudes, he feels it is possible to compensate for adverse personality characteristics which frequently persist in the exercise of cockpit resource management.

The element of personality may play a much larger role as a determining factor in flight deck behavior than has been realized. Helmreich (1987) reveals in his recent research that any observable change in personality as a result of training in cockpit resource management may be illusory. He states (p. 16):

> After the honeymoon effect of the training task is over, the facade of cooperativeness and eagerness may crumble, revealing hostility and arrogant insensitivity. Prior studies on this have been faulty in that they examine those

personality traits and their effect on performance during training, rather than in application at some later time.

Pre-employment attitude and personality characteristics important to pilot selection were also discussed by Beach (1980, p. 170). The airline pilot applicant should bring more to the airline than his flying experience.

1. He should have effective interpersonal communication skill.
2. He should be a team player.
3. He should be a good follower as well as a good leader.
4. He should operate cooperatively within the system.
5. He should have a stable personality.
6. He should be flexible [and] adaptable.
7. He should have proper motivation.

These characteristics may be measurable using existing instruments described in the psychological literature. If none can be found, they should be developed. Beach emphasized, however, that the final selection process for airline pilots cannot be accomplished simply by testing. The selection process should be influenced heavily by in-depth interviews conducted by carefully selected line crew managers. The importance of "selecting in" the proper personality and related interpersonal attributes, prior to hiring, emphasizes the need for further CRM research to determine the most effective and predictive selection processes. Longitudinal studies on recently hired pilots now being conducted by American Airlines may provide a partial resolution to these needs (American Airlines, n.d.).

Research by Gerathewohl (1978) also emphasizes the importance of personality. In his research (p. 48), he states

that personality was the most ambiguous characteristic of the factors he studied. It consisted of "confidence level, self-discipline, apprehension, mood, conscientiousness, security, risk-taking, rigidity, adaptability, motivation ... and interpersonal relations." With respect to impact of personality in the work place, he states, "In work that requires continuous close cooperation with other crew members, interpersonal relationships probably contribute more to success or failure than minor deviations from acceptable performance in an individual's task."

Chidester agrees that in the personality factors that contribute to qualities of leadership and suitability for captaincy, formalized training appears to have a minimal effect. Since these are important issues for cockpit resource management, he stresses that pilot selection based on personality attributes may be necessary to achieve the desired cockpit resource management training results (1987, p. 478). An appropriate resolution to this problem, in his view, is to combine training and selection processes to serve as complementary approaches.

Communications, role, and crew coordination. In examining the research related to cockpit resource management, Murphy (1977, p. 4) considers that crew coordination is an important but little understood factor in commercial aircrew performance. Citing typical examples of pilot/copilot role relationships, he noted that lack of decisive command and strained social relations were typical problems. He stressed that causal factors in crew

effectiveness and command deterioration have not been well defined through systematic studies, nor have any proposed solutions been validated.

Bolman (1980, p. 32) agrees with this deficiency. He states, "There is a need to understand the dynamics of the role system, how to create an effective and mutually understood set of role relationships, and how to modify those relationships quickly, without creating confusion, overlaps, and gaps." To accomplish this, the "10 Commandments of Good Crew Coordination" (American Airlines, 1978, p. 12) can be put to good use. These are:

1. Think people!
2. Set the tone!
3. Solicit information!
4. Use other crew member's experience!
5. Don't be shy!
6. Be persistent!
7. Remember who's in command!
8. Be tactful!
9. Reinforce good coordination!
10. Don't shirk your responsibility!

American Airlines (Ehman, 1980) also established a well-recognized set of principles for CRM. These include:

1. Appropriate delegation of tasks and assignments of responsibilities.
2. Establishment of a logical order of priorities.
3. Continuous monitoring and cross checking of essential instruments and systems.
4. Careful assessment of problems and avoidance of preoccupation with minor ones.
5. Utilization of all available data to conduct an operation.
6. Clear communication among crew members of all intentions.
7. Assurance of sound leadership by the pilot in command.

Judgment and Decision-Making. Norman and Edmunds (1980)

indicate that the relationship of judgment to decision-making is considered to be essential to cockpit resource management training. Components of this process are problem recognition, information gathering, and information integration. Diehl and Buch (1986, p. 9) illustrate a decision-making process in Figure 5. In determining an appropriate course of action, prompt

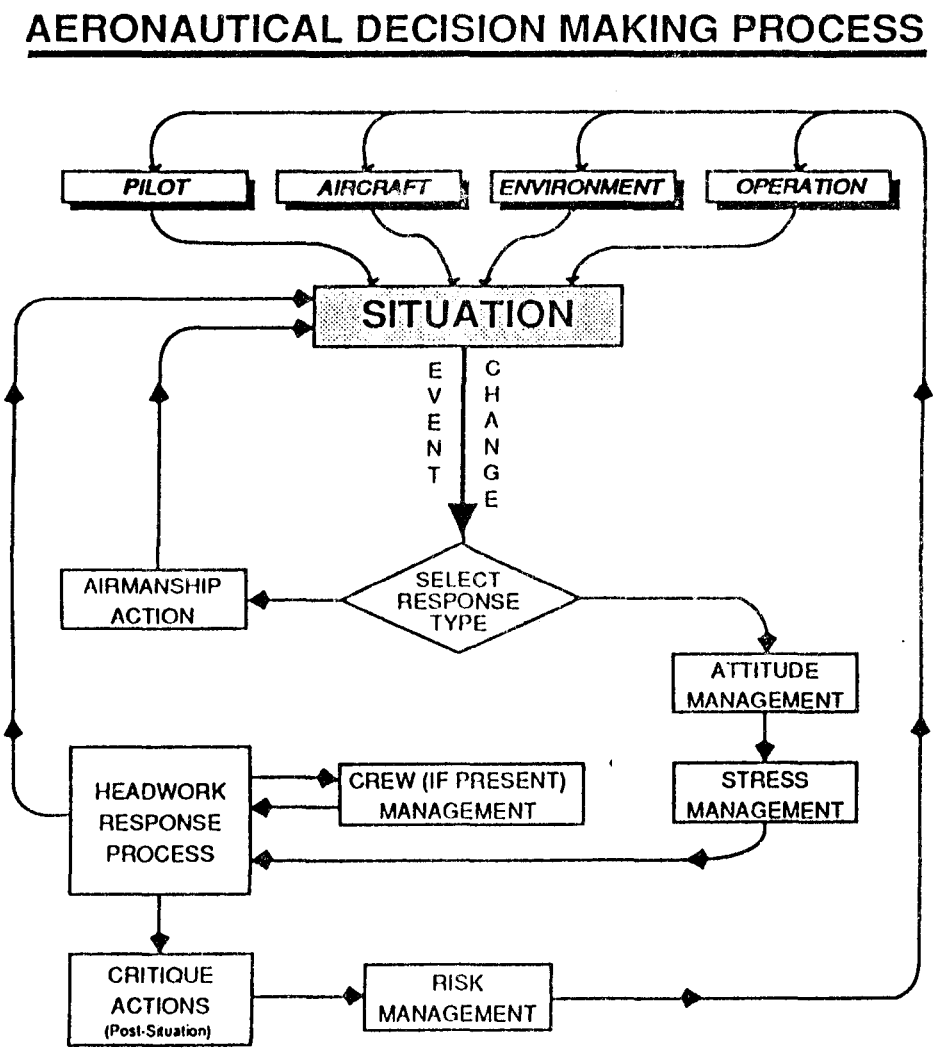

Figure 5
(Adapted from Diehl and Buch, 1986, p.9)

analysis of an appropriate number of alternative courses must be accomplished and compared for relative effectiveness. A best course of action must then be derived for the present situation, given the information, resources, and time available to the pilot. The action may be airmanship (psychomotor) or headwork (cognitive/ affective). Attitude, stress, and teamwork are brought to bear during headwork responses. During the implementation of this derived course of action, a feedback loop consisting of additional information or a change in information, allows the reevaluation of current conditions, risk assessment, and a concomitant change in the decision making process. Each course of action determined through this means requires constant monitoring during the progress toward the desired goal.

Human factors and workload. Barnhard et al. (1975, p. 13) described a method of study for human factors in aircraft operations. This research was accomplished prior to the full development of the cockpit resource management concept. As a result, in the initial illustration of the information processing algorithm, cockpit resource management was not graphically addressed. In a modification of their model, the elements of interpersonal relationship and crew coordination have been added. After adapting the model to accommodate this resource management philosophy, one can follow the segmented portion of Figure 6 to convey the essential CRM elements of such an adaptation.

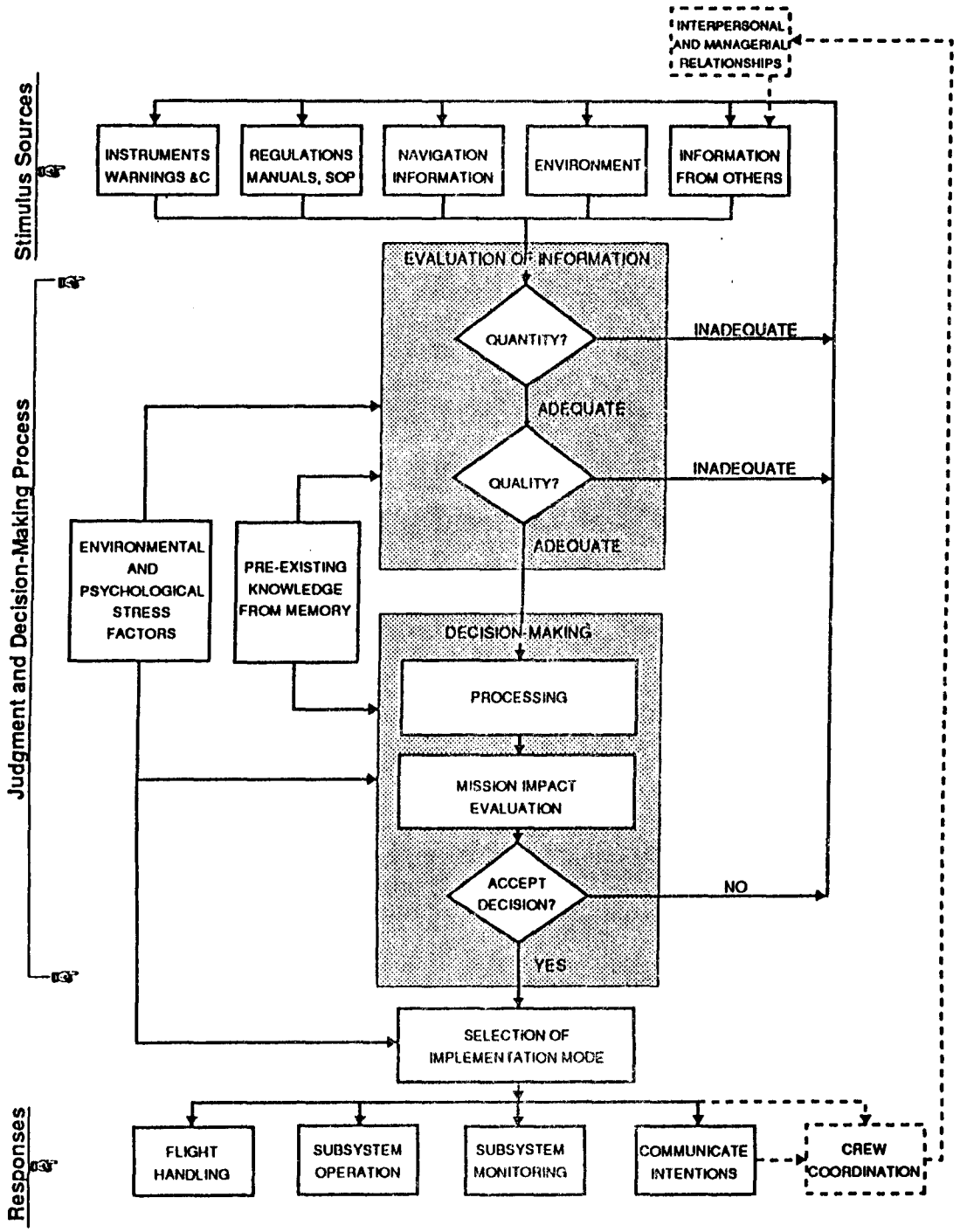

Figure 6

Processing Model for Cockpit Behavior and Resource Management
(Adapted from Barnhart et al., 1975, p. 73)

Wiener (1985, p. i) discussed the results of a two-year study to determine the factors affecting the transition of airline pilots from traditional to highly automated aircraft. Implications of cockpit resource management insufficiency were found in some of the difficulties that pilots had in adapting to the new systems. The general view of pilots toward cockpit automation was favorable, but some findings reported a degree of skill loss through automation. He concluded (p. 91) that concern for psychological disenchantment among professional pilots as a result of these technology advances was unwarranted.

In partial contrast to Wiener's findings, Curry (1985) described the results of a questionnaire on pilot attitudes toward new technology cockpits. An important element of cockpit resource management emerged (p. 29) concerning distractions encountered during high levels of cognitive activity. When abnormal or unexpected functions of the automated systems were encountered requiring intervention by the crew, that need frequently went unnoticed in the two-man cockpit. In that environment, the frequency of high cognitive activity and workload curtailed the normal amount of cross-checking. In such a situation, the immediate need for pilot intervention can easily go unnoticed.

Problems of this nature are frequently encountered during the departure and arrival segments of a flight. Typical of the high cognitive level of the distractor task would be the simultaneous requirements for programming the flight management

computer while the other pilot is responding to radio communications. If unselected mode changes or inappropriate responses occur in the flight management system, inordinate exposure to unwanted and hazardous modes of flight can be encountered.

There is no way to avoid the additional stress and monitoring workload related to the contingency operations of automated systems. The element of risk attributable to this additional subjective workload in the two-man crew may not have been given its appropriate level of importance by the MacLucas committee on crew complement in new technology aircraft (President's Task Force, 1981). In reaching their conclusions concerning the safety and efficacy of the two-man cockpit, the committee chose to disregard a 1964 jet transport cockpit study by the Civil Aeronautics Board (CAB). In that study (President's Task Force, 1981, Appendix E), the CAB concluded that the minimum flight crew manning determination should be based on aircraft operational complexity and the resulting workload. A major contributing factor to the tragic 1987 Northwest MD-80 crash could be the McLucas Committee's failure to observe that CAB conclusion. The development of effective CRM training may help to alleviate the consequences of that committee's ruling against the three-man crew.

Summary

In studying 28,000 reports submitted by pilots and air traffic controllers to the ASRS program during a four-year

period, Billings and Cheaney (1981) discovered numerous problems in the transfer of information which subsequently degraded flight safety. Items contributing to these deficiencies were distraction, failure to monitor, complacency, high workload, and ambiguous procedures, all of which can respond to improvements in cockpit resource management. In spite of the recognition that many crew error accidents are avoidable, little effort has been devoted to determining what factors are involved in human error, or what CRM training concepts could be effectively applied. Shaw states (IATA, 1981, p. 1):

> A lack of knowledge [exists] about the [human factors] discipline, including its goals, methods, techniques, needs, timing, training, applications,...[CRM] skills and knowledge are only vaguely understood. The objectives... are a fundamental understanding of human factors for airline personnel and prompt organizational actions to produce training and informational programs which help to develop that awareness.

In reviewing the history of cockpit resource management as it has emerged from the fields of aviation safety and human factors, some successes and some failures have been noted. Additional research has been called for, but very little CRM research has been accomplished. Requests for support have been frequently made, but responses to those requests have been slow to materialize. CRM has been discussed at great length in a wide range of settings over an inordinate length of time. Philosophically, most participants in these dialogues have maintained a favorable and sympathetic point of view toward the resolution of the CRM problem. There are, as in all issues, some elements of dissension. The economics of CRM training program

development, instructor manning, and crew manpower requirements make the CRM issue difficult to resolve. Non-standardization of CRM objectives, lack of a CRM media pool, and other training priorities within the airline industry have contributed to this difficulty. Only recently (Jensen, 1987) has the FAA directed specific attention to CRM training issues. Many questions remain on training methods and effectiveness. With the proper ingredients of cooperation and support between all individuals and agencies affected by this issue, a more rapid and favorable resolution to program development in cockpit resource management and its subsequent adoption into the aviation system may yet be achieved.

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