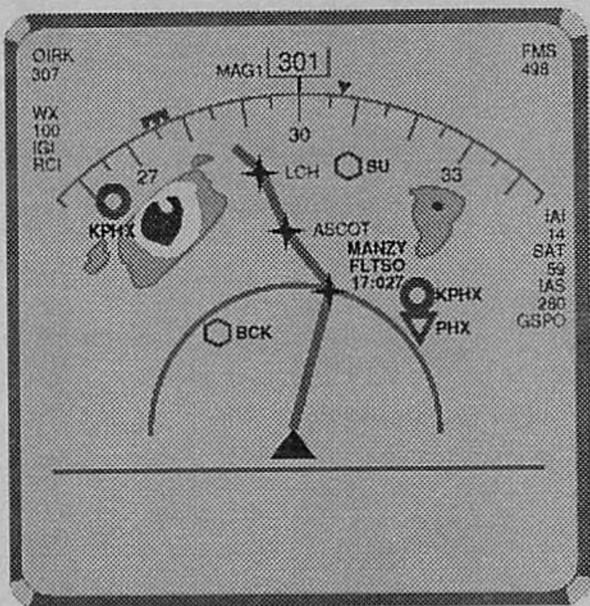
DOT/FAA/RD-92/26
DOT-VNTSC-FAA-92-8
Research and Development Service
Washington, DC 20591

Crew Resource Management: An Introductory Handbook

RSPA/VNTSC



COCKPIT HF PROGRAM

James E. Driskell
Florida Maxima Corporation

Richard J. Adams
Advanced Aviation Concepts, Inc.

Final Report

August 1992

This document is available to the public
through the National Technical Information Service
Springfield, Virginia 22161

U.S. Department of Transportation
Federal Aviation Administration

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1992	Final Report

4. TITLE AND SUBTITLE
Crew Resource Management: An Introductory Handbook

5. FUNDING NUMBERS
A1070/FA1EZ

6. AUTHOR(S)
James E. Driskell, Richard J. Adams

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Florida Maxima Corporation
147 East Lyman Avenue
Winter Park, FL 32789

Advanced Aviation Concepts, Inc.
10356 Sandy Run Road
Jupiter, FL 33478

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-FAA-92-8

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Aviation Administration
Research and Development Service
Washington, DC 20591

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FAA/RD-92/26

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the National Technical Information Service, Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Recent research findings suggest that crew resource management (CRM) training can result in significant improvements in flightcrew performance. The objectives of this handbook are to foster an understanding of the background and philosophy of CRM and to provide an overview of the development, implementation and evaluation of CRM training. Currently, CRM programs have been implemented successfully at a number of airlines, large and small, civil and military. The variety of CRM training programs suggest that there are a number of ways to achieve effective CRM.

14. SUBJECT TERMS
Crew Resource Management (CRM), Air Carrier Training, Flight Crew Performance, Air Carrier Accident Prevention, Team Coordination

15. NUMBER OF PAGES
62

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

PREFACE

Recent research findings suggest that crew resource management (CRM) training can result in significant improvements in flightcrew performance. The objectives of this handbook are to foster an understanding of the background and philosophy of CRM and to provide an overview of the development, implementation and evaluation of CRM training. Currently, CRM programs have been implemented successfully at a number of airlines, large and small, civil and military. The variety of CRM training programs suggest that there are a number of ways to achieve effective CRM.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in.) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32)(5/9)] °F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (kn^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 | 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

TABLE OF CONTENTS

Chapter 1: Introduction

Aviation Safety! This concept is readily embraced by everyone in the aviation community from flight crews to support staff to management. This was not always the case with Crew Resource Management (CRM). The concept of crew resource management has been both blessed and cursed by those in aviation. It has been cursed because the emphasis on crew resource management is relatively new, and people often have a healthy, skeptical reaction to new ways of doing things.

But CRM is also blessed by many because of what it can accomplish. Recent research findings suggest that crew resource management training can result in significant improvements in flightcrew performance. Not surprisingly, a growing number of people in the aviation community, from airline management to flight crews themselves, have embraced crew resource management as an effective approach to reducing flight errors and increasing aviation safety. Currently, CRM programs have been implemented successfully at a number of airlines, large and small, civilian and military.

Objectives of This Handbook

The objectives of this handbook are to foster an understanding of the background and philosophy of Crew Resource Management, and to provide an overview of the development, implementation, and evaluation of CRM training. This handbook is written for Part 135 and Part 121 carrier operators and management, and is designed to serve as a supplement to Advisory Circular 120-51 as revised, **Crew Resource Management.**

CRM Background and Philosophy

It is useful to distinguish between the philosophy of crew resource management and the implementation of crew resource management (CRM training). There is general agreement within the aviation community regarding the principles underlying CRM. Most agree on key CRM concepts and the need to focus on **crew** skills and performance. However, there is less consensus regarding how to implement CRM training. In fact, various training programs have appeared which meet the specific needs of individual users. The variety of CRM training programs suggests that there are a number of ways to achieve effective crew resource management.

What follows is a brief history of crew resource management, a discussion of principles, and finally, an overview of CRM training.

We've been flying for over 90 years. Why CRM now? The concept of crew resource management is not new. Anyone who thinks that the Wright brothers did not make effective use of the resources at their disposal in 1903 at Kitty Hawk is certainly mistaken. Similarly, military and civilian pilot training programs have touched on CRM topics for years. NASA's John Lauber recalls the saying that if an idea is new, it probably isn't good, and if it is good, it probably isn't new. So, while the concepts underlying CRM are not new, what **is** new is the heightened emphasis on crew resource management as one key to increased aviation safety.

From the 1950s to the 1990s we have witnessed a steady decline in aviation accidents (see Figure 1). This decline in aviation accidents has been attributed to better equipment, better training, and better operating procedures. However, this happy big picture of system safety masks some troubling data. As Figure 2 illustrates, as accidents related to equipment weaknesses have decreased, accidents attributed to human weaknesses have increased. A comparison of

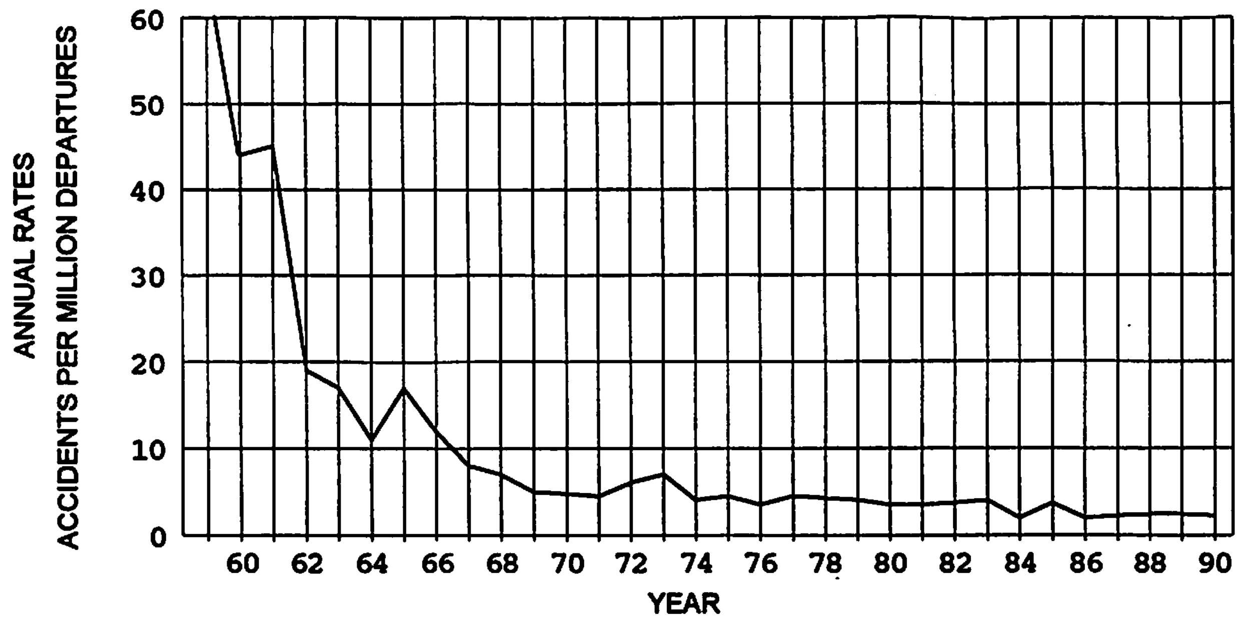


Figure 1. Total accident rate for commercial aircraft, worldwide, 1959-1990. (Excludes sabotage, military action, turbulence and evacuation injuries.) (Boeing Commercial Airplane Group, 1991)

Figure 1 and Figure 2 suggests two points. First, Figure 1 indicates that after a sharp drop in the 1960s, accident rates have leveled off from 1970 through 1990. Second, the trends in causes of accidents illustrated in Figure 2 show that human error has remained a major contributing factor in aviation accidents during these latter years.

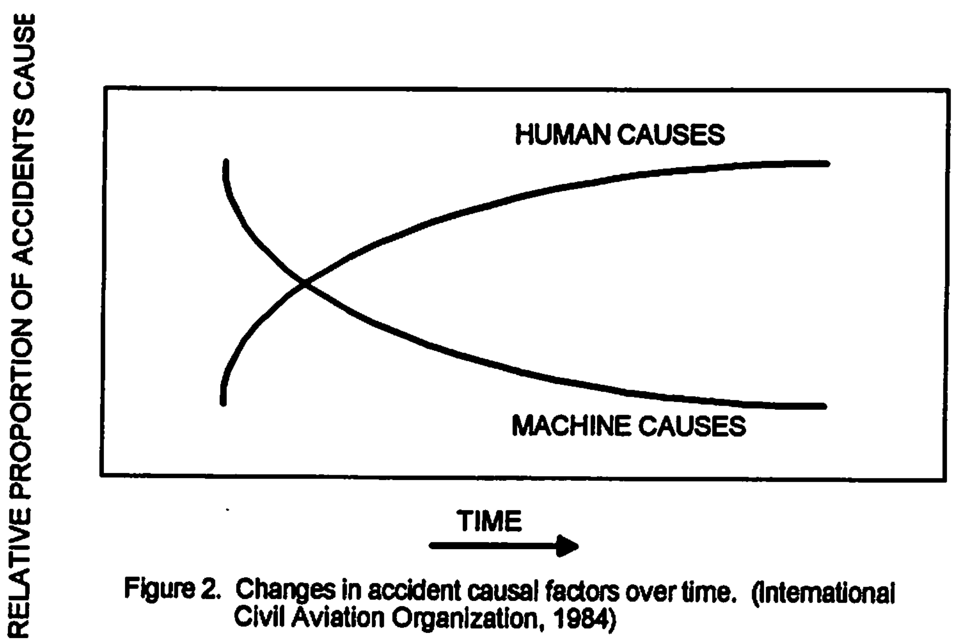


Figure 2. Changes in accident causal factors over time. (International Civil Aviation Organization, 1984)

Industry estimates of causal factors in air carrier accidents are shown in Figure 3. By a conservative estimate, well over 60% of aircraft accidents have been attributed to crew-related actions. In brief, it seems that the "human factors" contribution to aviation accidents may be a difficult problem to solve.

Primary Factor	No. of Accidents	
	Total	Last 10 yrs
Flightcrew	493	125
Airplane	124	31
Maintenance	21	7
Weather	34	9
Airport/ATC	37	12
Misc (Other)	47	23
Total with Known Causes	756	207
Unknown or Awaiting Reports	117	70
Total	873	277

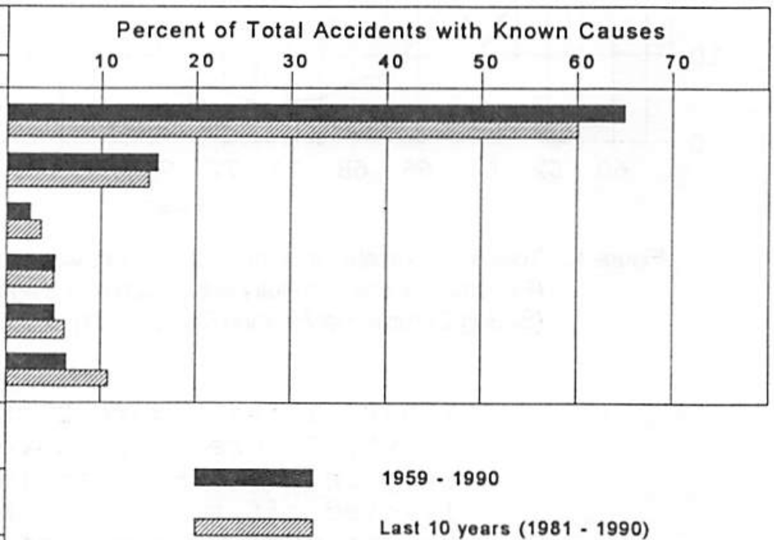


Figure 3. Primary causal factors for commercial aircraft accidents, worldwide, 1959-1990. (Boeing Commercial Airplane Group, 1991)

Concern with the factors underlying these accidents led NASA researchers in the 1970s to conduct a series of interviews with line pilots to investigate **their** perceptions of aviation mishaps. Charles Billings, George Cooper, and John Lauber found that one mishap component consistently mentioned by pilots was inadequate training. Even more interesting, these researchers found that it was not technical training that these pilots felt they lacked, but training in leadership, communication, and crew management. In other words, traditional training had done an excellent job of imparting stick and rudder skills, but these pilots felt that they needed more training in **crew coordination.** A subsequent analysis of jet transport accidents between 1968 and 1976 revealed more than 60 that involved problems with crew coordination and decision making (Cooper, White, & Lauber, 1979).

These preliminary results, coupled with a dogged determination to pursue answers to problems that line pilots had identified, encouraged NASA researchers to conduct further research and analysis. In one classic simulator study, B-747 flight crews were observed in a highly realistic simulated line trip from New York's Kennedy Airport to London (see inset: New York to London Minus One Engine). During this tightly-scripted scenario, an oil pressure problem forced the crew to shut down an engine. The crew had to decide where to land the plane. This decision was further complicated by a hydraulic system failure, bad weather, poor air traffic control, and a cabin crew member who demanded attention at the worst possible moments. Researchers found that there was a wide variation in the performance of crews during this simulation. Most problems arose

New York to London Minus One Engine: The Ruffell Smith Simulator Study.

Because the scenario involved a high gross takeoff weight, followed by an engine shutdown with a subsequent diversion, the crew needed to dump fuel to reduce the aircraft's weight to maximize landing weight. As in actual line operations, this was a very busy period. In one case, after the captain decided to dump fuel, the captain and the first officer together decided that 570,000 pounds was the correct target landing weight. They reached the decision without consulting the flight engineer or any aircraft documentation. The flight engineer then calculated a dump time of 4 minutes 30 seconds, which the captain accepted without comment even though it was approximately one-third the actual time required. Without prompting, the flight engineer recalculated the dump time to the nearly correct figure of 12 minutes.

Instead of dumping for 12 minutes, however, the flight engineer stopped after only 3 minutes, perhaps because he reverted to his original, erroneous estimate or because he misread the gross weight indicator. Unsatisfied, he again started to recalculate, but the failure of the No. 3 hydraulic system interrupted him.

During the next eight minutes, the flight engineer was subjected to a high work load, but then noticed that the gross weight was too high and decided to refigure the fuel. During that time, he was interrupted further and did nothing more about the fuel until the captain, noticing the gross weight indicator at 647,000 pounds, decided to make an over-gross-weight landing. A minute and a half later, the flight engineer rechecked the fuel as part of the landing checklist and became concerned about the gross weight. He spent a minute and a half rechecking calculations and announced that the aircraft's gross weight computer must be in error. Two minutes later, the simulator lands at 172 knots with only 25 degrees of flap: a 1,000 foot-per-minute descent about 77,000 pounds over the correct weight, on a short, wet runway.

During the 32 minutes between the decision to dump fuel and the landing, the flight engineer was interrupted 15 times while performing specific tasks tailoring the amount of fuel to be dumped in relation to the conditions and length of the landing runway. Nine of the interruptions came directly or indirectly from the captain, four from the cabin crew member, and two from equipment problems. The flight engineer was never able to complete and verify his fuel calculations and dump times without interruption, either by a routine part of standard operating procedure, or by a request from the captain or the cabin crew member. He thus became overloaded and his work became fragmented. The captain failed to recognize the situation and so did nothing to resolve it.

(Lauber, 1984)

not from a lack of technical knowledge or skills, but from poor resource management. Crews whose performance included a high rate of errors did a poor job of communicating, setting priorities, and sharing workload. Crews making few errors did a better job of managing available resources.

In a subsequent analysis of the cockpit voice recordings from this study, Foushee and Manos (1981) found that those crews who communicated more and who acknowledged the exchange of information made fewer errors.

Is CRM Training Necessary?

Factors related to faulty crew performance account for well over half of air carrier accidents. These include:

- Eastern Airlines, Lockheed L-1011, Miami, Florida, December 29, 1972.
- United Airlines, DC-8, Portland, Oregon, December 28, 1978.
- Allegheny Airlines, Inc. , BAC 1-11, Rochester, NY, July 9, 1978.
- Air Florida, Boeing B-737, Washington, DC, January 13, 1982.
- Air Illinois, Hawker Siddley 748-2A, Pinckneyville, Illinois, October 11, 1983.
- Galaxy Airlines, Lockheed Electra-L-188C, Reno, Nevada, January 21, 1985.
- Air Ontario, Fokker F-28, Dryden, Ontario, March 10, 1989

This early work by Lauber, Cooper, Foushee, and many others culminated in the first **NASA/Industry Workshop on Resource Management on the Flight Deck** in 1979. This event converged the efforts begun by the military and by commercial carriers in this area. Subsequently, in the early 1980s, programs were developed and implemented by some air carriers, including United Airlines, KLM, Pan Am, Trans Australia Airlines, and others. Other events, such as the 1986 **NASA/MAC Workshop on Cockpit Resource Management Training**, and the biennial aviation psychology symposia organized by Dick Jensen at Ohio State University, provided opportunities to review progress in CRM program development.

The FAA officially recognized the value of CRM types of training during this period by allowing a LOFT training period to be used as an approved period of training which could be substituted for certain pilot's recurrent proficiency checks. More recently, SFAR 58, The Advanced Qualification Program (AQP), passed into law in 1990, has given greatly expanded latitude to air carriers with regard to training. One of the conditions of the AQP training option is that CRM training be included. It is projected that CRM may one day be required in all formal aircrew certification requirements.

The CRM concept has continued to evolve over the last decade, guided by extensive federal/university/industry research and by lessons learned from the implementation of CRM programs at a growing number of airlines. FAA Advisory Circular 120-51 as revised provides a contemporary statement of CRM concepts. This document underscores several recent developments in CRM:

- CRM has come to embody the entire flight operations team, including the cabin crew, air traffic controllers, maintenance, and other groups that interact with the cockpit crew. A shift in terminology reflects this emphasis: Cockpit Resource Management is now more appropriately termed Crew Resource Management.

- A second recent initiative is the integration of CRM skills with traditional technical flying skills. Whereas CRM programs stress the acquisition of crew-related skills, it is thought that these skills should ultimately be integrated with technical skills in the normal training and evaluation process. In other words, both technical skills and CRM skills interact to determine performance on the flightdeck. Accordingly, these skills should be trained and evaluated together as part of the total training program.

- CRM programs have been in place for a time sufficient to allow a body of research evaluating CRM training effectiveness to accumulate. The research results indicate clear evidence of positive changes in aircrew performance following the introduction of CRM.

This brief look at the background of CRM has necessitated the omission of many important contributions by many people. However, it is noteworthy that CRM program development has been driven by inputs from line pilots, not dreamed up in some ivory tower. Accordingly, CRM has become widely accepted within the aviation community.

Principles of Crew Resource Management

CRM is defined as the effective utilization of all available resources--equipment and people--to achieve safe, efficient flight operations. Resources include autopilots and other avionics systems; operating manuals; and **people**, including crew members, air traffic controllers, and others in the flight system. Therefore, the concept of effective CRM combines individual technical proficiency with the broader goal of crew coordination, thus integrating all available resources to achieve safe flight.

CRM is the effective utilization of all available resources–hardware, software, and personnel–to achieve safe, efficient flight operations.

The following principles are fundamental to the CRM concept:

- Effective performance depends on **both** technical proficiency and interpersonal skills.
- A primary focus of CRM is effective **team** coordination. The team encompasses the flight crew (cockpit and cabin), dispatchers, air traffic controllers, maintenance and others.
- CRM focuses on crew members' attitudes and behaviors.
- Effective CRM involves the entire flight crew. CRM is not simply a responsibility of the captain, nor should CRM training be viewed as captain's training. All crewmembers are responsible for effective

management of the resources available to them.

- The acquisition of effective CRM skills requires the active participation of all crewmembers. Effective resource management skills are not gained by passively listening to classroom lectures, but by active participation and practice, including the use of simulations such as Line-Oriented Flight Training (LOFT).
- CRM training should be blended into the total training curriculum, including initial, transition, upgrade, and recurrent training.

CRM Training

CRM training programs come in many forms. Limited CRM training programs are now available off-the-shelf from various sources. Specific organizations develop CRM programs to meet their own particular needs and corporate culture. Therefore, someone reviewing current CRM training programs is likely to find a variety of programs and program acronyms. These include:

- Flight Operations Resource Management (FORM),
- Flight Deck Management (FDM),
- Aircrew Resource Management (ARM),
- Aircrew Coordination Training (ACT),
- Flight Team Management (FTM).

This diversity reflects the difference in size, type of aircraft, mission, training facilities, equipment, and financial resources of operators. Accordingly, no single training program is likely to meet the requirements of all operators.

All CRM training programs are built on the principles outlined above. FAA Advisory Circular 120-51 as revised may serve to build a consensus on program content by suggesting basic CRM skills to be included in any program of instruction. These skills are grouped into three clusters:

1. Communications and Decision Skills. This cluster of skills includes behaviors related to communications and decisionmaking, including:

- assertiveness
- communications
- decision making
- conflict resolution

2. Team Building and Maintenance Skills. This cluster focuses on human interaction and team management skills including:

- leadership
- team management

3. Workload Management and Situational Awareness. This cluster reflects skills related to managing stress and workload, including:

- mission planning
- stress management
- workload distribution

These skills will be examined more closely in the following chapter.

Summary

The overall goal of CRM is the blending of technical skills and human skills to support safe and efficient operation of aircraft.

Crew resource management represents an approach to improving aviation safety that was born of real life experiences of airline pilots. They realized that technical skill alone was not enough to manage safely a complex flight system. CRM emphasizes the effective utilization of **all** resources available to the flight crew, including equipment and people. In addition to respecting the importance of traditional stick and rudder skills, CRM focuses on those other skills required for effective crew performance. **The overall goal of CRM is the blending of technical skills and human skills so as to support safe and efficient operation of aircraft.**

Research and experience have both shown that the best CRM training is like other effective training - it will include three learning elements: awareness, practice, and reinforcement. CRM training should not follow any single outline, however. It is most effective when it is developed to meet each user's unique set of needs.

Overview of the Handbook

Chapter 1 has introduced CRM. The following three chapters provide suggestions and examples on what CRM is and how CRM training programs can be provided.

Chapter 2 presents an explanation of the basic CRM skills. This explanation cites cases illustrating effective and ineffective utilization of these skills.

Chapter 3 provides guidance on developing, implementing and evaluating CRM training.

Chapter 4 provides a brief summary.

Following the text, a glossary is presented as a key to the terms used in CRM training. Finally, a bibliography is included to provide supplementary reference material.

Chapter 2: CRM Skills

There are many skills required to fly an airplane safely. Some of these are referred to as technical or "stick and rudder" skills. Major categories of technical skills include:

Motor Skills: the physical control of aircraft systems, aircraft attitude, and navigation.

Procedural Skills: the execution of standard, abnormal, and emergency operating procedures.

Information Skills (Knowledge): the use of information required to conduct safe air operations in areas such as federal regulations, weather, and aircraft systems.

These skills constitute the technical proficiency of crewmembers. As noted in Chapter 1, these skills formed the primary basis for the selection and training of aviators for most of this century.

These skills are **necessary** for modern aircraft operations, but by themselves are not **sufficient** to ensure safe flight. In other words, these individual technical skills must be paired with other crew-related skills to achieve safe flight operations. For example, it is not enough that a crewmember possesses the appropriate technical knowledge; each crewmember must also have the skills necessary to receive and to transmit information efficiently in the crew setting--communication skills. The crewmember who tends to ignore input from others can be a hazard during normal flight, and can be disastrous in emergency conditions. Therefore, technical skills must be integrated with other crew-related skills, defined in Chapter 1 as CRM skills, to ensure safe flight.

The "Right Stuff" for modern-day flight operations includes both individual technical proficiency and crew resource management skills.

CRM skills, those skills related to effective crew resource management, may be grouped into the following categories:

Communication Processes and Decision Making: skills related to effective communications and crew decisions.

Team Building and Maintenance: skills related to leadership/followership and maintaining a supportive team environment.

Workload Management and Situational Awareness: skills related to operational awareness, planning, and managing stress and workload.

Figure 4 provides an overview of the skills that determine flight performance. Note that Figure 4 indicates that **both** technical skills and CRM skills are necessary for effective flight performance. This view is consistent with the recent initiative to integrate technical and CRM skills in flight operations and training.

Furthermore, each cluster of skills presented in Figure 4 is broken down into basic or primary-level skills. For example, specific skills that compose the **Communications Processes and Decision Making** cluster include communication skills, assertiveness skills, and decision making skills. The three major CRM skill clusters provide one convenient way to classify CRM skills. However, it is the primary-level skills that form the basis for CRM training.

CRM skills within each of the three skill clusters are described in the following sections. Each skill will be described briefly. Synopses of NTSB accident reports will illustrate how skills can effect crew performance. The purpose of this chapter is to provide an overview of selected CRM skills, and to demonstrate the importance of these skills to flight safety.

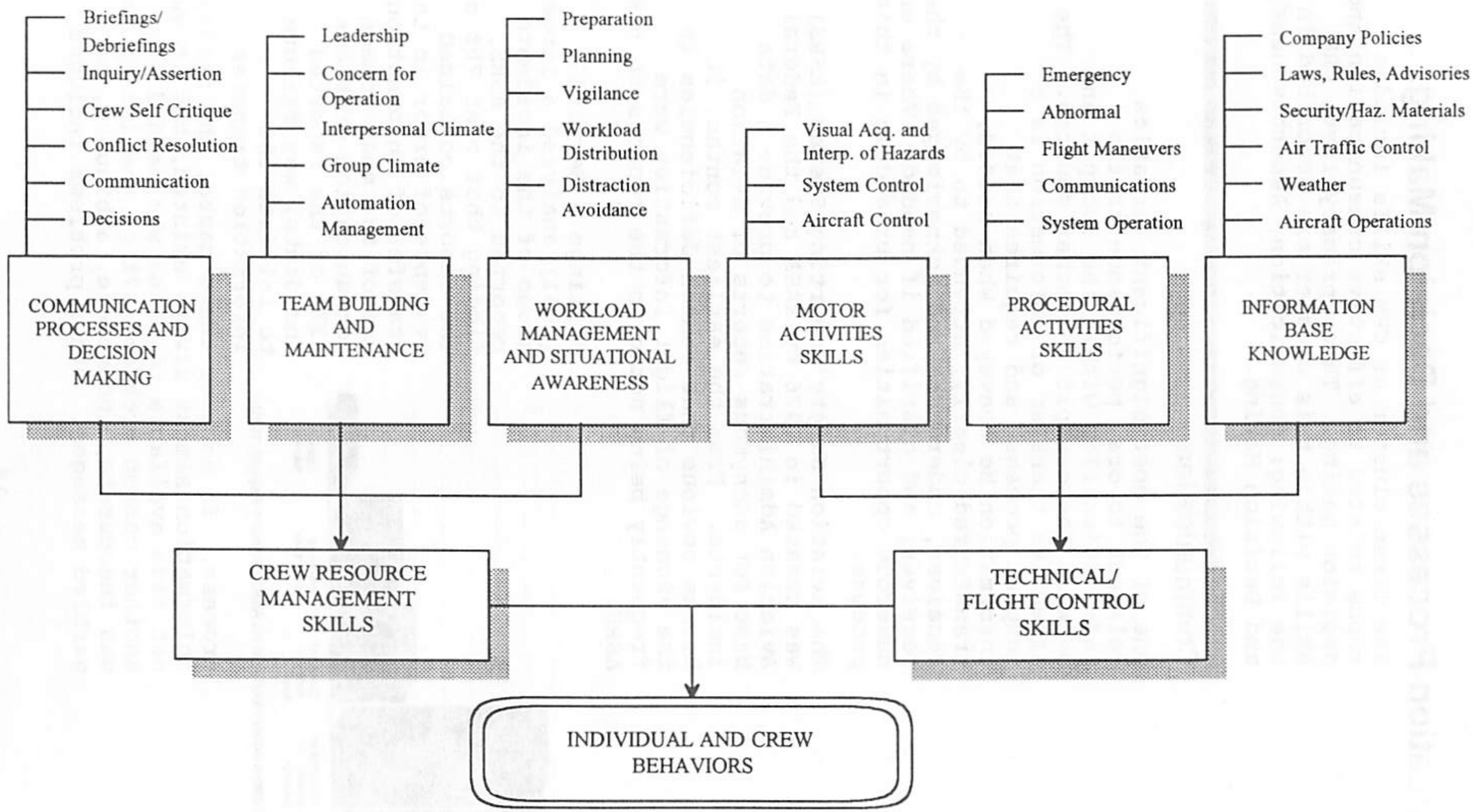


Figure 4. Skills underlying effective flight operations

Communication Processes and Decision Making.

The first cluster of CRM skills includes those related to effective communication and decision making. Three primary-level CRM skills within this cluster are described in the following: Communication, Assertiveness, and Decision Making.

Communication

One of the most significant variables relevant to crew performance is the information flow within the cockpit and between the cockpit and other sources. The effective transfer of information is a complex process, and requires that information be conveyed when needed, transferred clearly, attended to by the receiver, understood and acknowledged by the receiver, and clarified if needed. There are numerous opportunities for breakdown in this process.

The Aviation Safety Reporting System (ASRS) was created in 1976 by NASA and the Federal Aviation Administration to provide a data base for anonymous reports of aviation incidents. From the earliest months, it became obvious that common deficiencies in the exchange of flight information were frequently being noted in the reports to the ASRS.

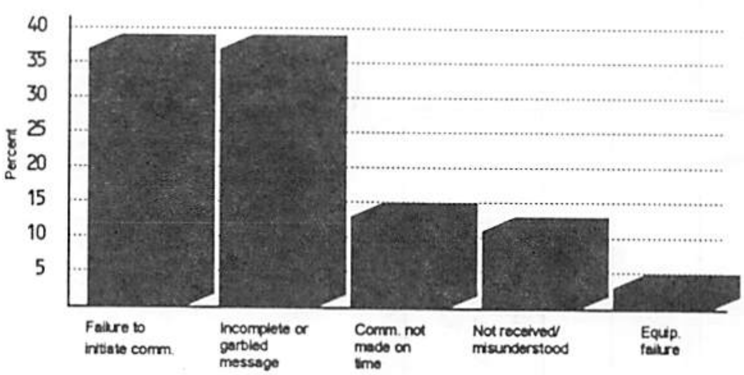


Figure 5. Communications errors reported in the ASRS (Billings & Reynard, 1981).

Billings & Reynard (1981) analyzed a large group of the incidents reported to the ASRS, finding that over 70% of the reports contained evidence of error in the transfer of information. One of the most common communication problems (37% of the reported incidents) was failure to initiate the information transfer process. In most of these cases, the needed information almost always existed, but it was not made available to those who needed it. Another common problem (37% of the incidents) was inaccurate, incomplete, ambiguous, or garbled messages. Other problems included the failure to transmit the message at the appropriate time (13%). In 11% of the cases, the message was either not received or was misunderstood. Only 3% of the information transfer problems were attributed to equipment failure.

Foushee and Manos (1981) also reviewed the ASRS data base to examine incidents involving communications problems. They observed the following communication problems:

- 35% of the reports cited problems dealing with poor understanding and division of responsibilities. Often, the lack of appropriate acknowledgments and cross-checking was a factor.
- 16% were due to interference with pertinent cockpit communications by extraneous conversations between cockpit crewmembers or between cockpit crewmembers and cabin crew.
- 15% of the incidents were due to information which one or more crewmembers believed they had transferred, but due to interference or inadequacy of the message, was not transferred successfully.
- 12% reported a total lack of communication between crewmembers. Within this category, there were numerous examples of crewmembers not communicating regarding errors even when they had access to the correct information.
- 10% of the communication problems cited were due to overconfidence or complacency. Often, crewmembers assumed that everyone else understood what was happening, when in fact, they did not.

This and related research suggests that:

- Overall, there is a tendency for crews who communicate more often to perform better than crews who communicate less.
- When more information regarding flight status is transferred, there are fewer errors related to system operation.
- Crews who frequently acknowledge commands, inquiries and observations tend to make fewer errors.

In general, effective communication is supported by the following behaviors:

- Convey information clearly, concisely, and in a timely manner.
- Use standard terminology.

- Advocate concerns and suggestions clearly and assertively.
- Acknowledge communications.
- Provide information as required.
- Repeat information.
- Ask for clarification when needed.
- Resolve conflicts constructively.

The following accident summary illustrates the importance of these behaviors.

ACCIDENT SUMMARY – On July 19, 1989, at about 3pm local time, a DC-10 operated by United Airlines as flight 232, experienced a catastrophic failure of the No. 2 tail mounted engine during cruise flight. Shortly after the engine failure, the crew noted that the hydraulic fluid pressure and quantity had fallen to zero in all three redundant hydraulic systems. The engine failure precipitated damage that severed the three hydraulic systems, leaving the flight control systems inoperative. Approximately one minute after the engine failure, the flight data recorder indicated no further movement of the flight control surfaces.

The only means of control for the flight crew was from the operating wing mounted engines. The application of asymmetric power to these engines changed the roll attitude, hence the heading. Increasing and decreasing power had a limited effect on the pitch attitude. The airplane tended to oscillate about the center of gravity in the pitch axis. It was not possible to control the pitch oscillations with any degree of precision. Moreover, because airspeed is primarily determined by pitch trim configuration and power, there was no direct control of airspeed. The crew found that despite their best efforts, the airplane would not maintain a stabilized flight condition. The airplane subsequently crashed during an attempted landing at Sioux Gateway Airport, Iowa. There were 285 passengers and 11 crewmembers onboard. One flight attendant and 110 passengers were fatally injured.

EVENT HISTORY – About 1 hour and 7 minutes after takeoff, the flight crew heard a loud bang or an explosion, followed by a shuddering of the airframe. The following sequence of events is in chronological order and is presented to summarize the type and variety of communications required.

1. The flight crew determined that the No. 2 aft (tail mounted) engine had failed. The captain called for the engine shutdown checklist. While shutting down the engine, the second officer (flight engineer) observed that the systems hydraulic pressure and quantity gauges indicated zero.

2. The first officer advised that he could not control the airplane as it entered a right descending turn. The captain took control of the airplane and confirmed that it did not respond to flight control inputs.

3. The captain reduced thrust to the No. 1 engine and the airplane began to roll to a wings level attitude.

4. A flight attendant advised the captain that a UAL DC-10 training check airman was seated in the passenger compartment and had volunteered his assistance. The captain immediately invited the airman into the cockpit.

5. At the request of the captain, the check airman re-entered the passenger cabin and performed a visual inspection of the airplane's wings. He returned and reported that the inboard ailerons were slightly up, not damaged, and that the spoilers were locked down. There was no movement of the primary flight control surfaces.

6. The captain directed the check airman to operate the throttles to free himself and the first officer to attempt to maintain command of the flight controls. The check airman advised that the No. 1 and No. 3 engine thrust levers could not be used symmetrically, so he used two hands to manipulate the throttles. Even so, he said that the airplane had a continuous tendency to turn right and it was difficult to maintain a stable pitch attitude.

7. The captain reported to the approach controller that the flight had no elevator control, they might have to make a forced landing and asked the controller for the ILS frequency, heading to the runway and length of the runway. He then instructed the second officer to start dumping fuel using the quick dump.

8. The captain asked the senior flight attendant if everyone in the cabin was ready. She reported in the affirmative and that she observed damage on one wing. The captain sent the second officer back to inspect the empennage visually.

9. The second officer returned and reported damage to the right and left horizontal stabilizers. The captain replied "that's what I thought." The captain then directed the flightcrew to lock their shoulder harnesses and to put everything away.

10. Several seconds later, the controller alerted the crewmembers to a 3,400 foot tower obstruction located 5 miles to their right and asked how steep a right turn they could make. The captain responded that they were trying to make a 30 degree bank. A crewmember commented that "I can't handle that steep of bank." The first officer stated, "we're gonna have to try it straight ahead Al..."

11. The captain reported the runway in sight and thanked the controller for his help. The controller stated that the runway the flight had lined up with was closed, but he added "that'll work sir, we're getting the equipment off the runway." The captain asked its length and the controller reported 6,600 feet. Twelve seconds later the controller stated that there was an open field at the end of the runway and that the winds would not be a problem.

12. During the final 20 seconds before touchdown, the airspeed averaged 215 knots, sink rate was 1,620 feet per minute and smooth oscillations in pitch and roll continued. The captain recalled getting a high sink rate alarm from the ground proximity warning system and that at 100 feet above the ground, the nose of the airplane began to pitch downward. First contact was made by the right wing tip followed by the right main landing gear. The airplane skidded to the right of the runway, ignited, cartwheeled and came to rest in an inverted position. (NTSB, 1990a)

The quality and efficiency of the crew communications in UAL flight 232 is one factor that minimized the loss of life in this catastrophe. Specific communications behaviors such as clarity (event #2), conciseness (event #5), timeliness (event #7) and acknowledgement (event #10) are represented in the event history.

A more intensive analysis of crew communication during this accident was performed by Predmore (1991), who broke down the Cockpit Voice Recorder (CVR) transcript into the following communication categories:

- Command-Advocacy (CMD-ADVOC)
- Inquiry
- Incomplete-Interrupted (INCOMPL)
- Reply-Acknowledge
- Observation

The following chart represents the cockpit and radio communications from flight 232 during this emergency.

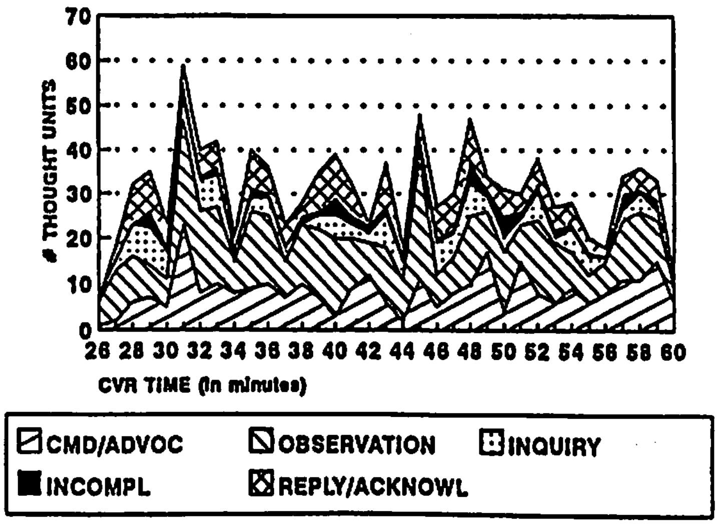


Figure 6. Communications of the UAL flight 232 crew. (Predmore, 1991)

Figure 6 reveals that the crew maintained a remarkably high level of communication overall. A second important factor is the consistent level of acknowledgement evident during this event. It is important to note that the crew of United 232 had received prior CRM training.

Assertiveness

Accident reports reveal a number of instances in which crewmembers failed to speak up even when they had critical flight information that might have averted a disaster. In most cases, this hesitancy involved a copilot or flight engineer who failed to question a captain's actions or to express an opinion forcefully to the captain. These types of incidents lead to the conclusion that crewmembers are often unwilling to state an opinion or to take a course of action, even when the operation of the airplane is clearly outside acceptable parameters.

NASA's H. Clayton Foushee reported an incident from the ASRS data base which illustrates this phenomenon. This report described a situation in which air traffic control had instructed the aircraft to level off at 21,000 feet. As the aircraft reached its assigned altitude, the copilot noticed that the captain was allowing the airplane to continue climbing. The copilot alerted the captain, but not forcefully enough for the captain to hear. The copilot tried again and pointed to the altimeter, at which point the captain stopped the climb and began descent back to the assigned altitude. The copilot summed up the reasons for his actions as follows:

The captain said he had misread his altimeter and thought he was 1000 feet lower than he was. I believe the main factor involved here was my reluctance to correct the captain. This captain is very "approachable" and I had no reason to hold back. It is just a bad habit that I think a lot of copilots have of double-checking everything we say before we say anything to the captain. (Foushee, 1982, p. 1063)

Assertiveness involves the ability to request information from others, make decisions, and carry out a course of action in a consistent and forceful manner. Assertive behavior includes:

- **Inquiry:** inquiring about actions taken by others and asking for clarification when required.
- **Advocacy:** the willingness to state what is believed to be a correct position and to advocate a course of action consistently and forcefully.

- **Assertion**: stating and maintaining a course of action until convinced otherwise by further information.

Crewmembers are often hesitant to speak up for several reasons:

- Sometimes crewmembers fail to question others' behavior because they are hesitant to point out incompetent behavior and to embarrass a captain or crewmember. Komich (1985) cites one copilot's hesitancy to correct a captain: "He's slow to catch his airspeed and if I speak up every time he's ten knots low, it'll sound like an instructional ride, so since he usually catches it at ten, I'll speak up at fifteen." Others have expressed fear of causing animosity and possibly creating a reputation as that of someone who is "difficult to work with."

- Crewmembers sometimes hesitate to speak up because they perceive the captain as too intimidating. This kind of captain sees himself as omnipotent, with the other crewmembers there only to serve his wishes, not to make any contributions to the decision-making process. Foushee (1982) cites one extreme case:

> Air traffic control had issued a speed restriction. The copilot acknowledged and waited for the captain to slow down. Assuming that the captain hadn't heard the message, he repeated, "Approach said slow to 180." The captain's reply was, "I'll do what I want." Air traffic control inquired as to why the aircraft had not been slowed, advised the crew that they had nearly collided with another aircraft, and issued a new clearance, which the captain also disregarded. Following a further advisory from the copilot, the captain responded by telling the copilot to "just look out the damn window."

- The status structure of the cockpit may contribute to non-assertiveness among crewmembers. The captain has authority in the cockpit and the responsibility for flight operations. People are naturally hesitant to question those who have higher status. Therefore, people tend to be deferential to those in command. Second, crewmembers may simply assume that, since the captain is in charge, that the captain "knows what he is doing."

However, a lack of assertive behavior on the part of crewmembers may have disastrous consequences, as the following incident illustrates.

ACCIDENT SUMMARY – About 1815 Pacific Standard Time on December 28, 1978, United Airlines Flight 173, a DC-8-61 aircraft crashed into a wooded area during an approach to the Portland International Airport. The aircraft had delayed southeast of the airport for one hour while the flightcrew coped with a landing gear malfunction and prepared the passengers for an emergency landing.

The NTSB determined the probable cause of the accident was the failure of the captain to monitor properly the aircraft's fuel state and to properly respond to the crewmembers' advisories regarding fuel. Contributing to the accident was the failure of crewmembers either to fully comprehend the criticality of the fuel state or to assertively communicate their concerns to the captain.

EVENT HISTORY – The first problem faced by the captain was the unsafe landing gear indication during the initial approach to Portland International Airport. This indication followed a loud thump, an abnormal vibration, and an abnormal aircraft yaw as the landing gear was lowered.

1. At 1712:20, Portland Approach requested, "United one seven three, contact the tower, one one eight point seven." The flight responded, "Negative, we'll stay with you. We'll stay at five. We'll maintain about a hundred and seventy knots. We got a gear problem. We'll let you know."

2. At 1746:52, the first officer asked the flight engineer, "How much fuel we got...?" The flight engineer responded, "Five thousand." The first officer acknowledged the response.

3. At 1748:00, the first officer asked the captain,"... what's the fuel show now...?" The captain replied, "Five." At 1749, after a partially unintelligible comment by the flight engineer concerning fuel pump lights, the captain stated, "That's about right, the feed pumps are starting to blink." At this point, according to air traffic control data, the aircraft was about 13 nautical miles south of the airport.

4. About 1750:20, the captain asked the flight engineer to "Give us a current card on weight. Figure about another fifteen minutes." The first officer responded, "Fifteen minutes?" To which the captain replied, "Yeah, give us three or four thousand pounds on top of zero fuel weight." The flight engineer then said, "Not enough. Fifteen minutes is gonna really run us low on fuel here."

5. From 1752:17 to about 1753:30, the flight engineer talked to Portland and discussed the aircraft's fuel state, the number of persons on board the aircraft and the emergency landing preparations at the airport.

6. At 1756:53, the first officer asked, "How much fuel you got now?" The flight engineer responded that 4,000 pounds remained, 1,000 pounds in each tank.

7. From 1757:30 until 1800:50, the captain and the first officer engaged in conversation which included discussions of giving the flight attendants ample time to prepare for the emergency, cockpit procedures in the event of an evacuation after landing, and the procedures the captain would be using during the approach and landing.

8. AT 1802:44, the flight engineer advised, "We got about three on the fuel and that's it." The aircraft was about 5 nautical miles south of the airport on a southwest heading.

9. At 1802:44, Portland Approach asked Flight 173 for a status report. The first officer replied, "Yeah, we have indication our gear is abnormal. It'll be our intention, in about five minutes, to land on two eight left. We would like the equipment standing by. Our indications are the gear is down and locked. We've got our people prepared for an evacuation in the event that should become necessary."

10. At 1803:14, Portland Approach asked that Flight 173 advise them when the approach would begin. The captain responded, "They've about finished in the cabin. I'd guess about another three, four, five minutes." At this time, the aircraft was about 8 nautical miles south of the airport.

11. At 1806:19, the first flight attendant entered the cockpit. The captain asked, "How you doing?" She responded, "Well, I think we're ready." At this time, the aircraft was about 17 nautical miles south of the airport. Almost simultaneously the first officer said, "I think you just lost number four" followed immediately by advice to the flight engineer, "Better get some crossfeeds open there."

12. At 1806:46, the first officer told the captain, "We're going to lose an engine" The captain replied, "Why?" at 1806, the first officer again stated, "We're losing an engine." Again the captain asked, "Why?" The first officer responded, "Fuel."

13. At 1807:12, the captain called Portland Approach and requested, " Would like clearance for an approach into two eight left, now." The aircraft was about 19 nautical miles south-southwest of the airport and turning left. This was the first request for an approach clearance from Flight 173.

14. At 1813:21, the flight engineer stated, "We've lost two engines, guys." At 1813:25, he stated, "We just lost two engines - one and two."

15. At 1813:38, the captain said, "They're all going. We can't make Troutdale." The first officer said, "We can't make anything."

16. At 1813:46, the captain told the first officer, "Okay. Declare a mayday." At 1813:50, the first officer called Portland International Airport Tower and declared, "Portland Tower, United one seventy three heavy, Mayday. We're - the engines are flaming out. We're going down. We're not going to be able to make the airport." This was the last radio transmission from Flight 173.

(NTSB, 1979)

In this accident, the flight engineer was increasingly concerned about the critical fuel situation, making several observations to the captain that were not acknowledged. In its report, the NTSB stated:

Admittedly, the stature of a captain and his management style may exert subtle pressure on his crew to conform to his way of thinking. It may hinder interaction and adequate monitoring and force another crewmember to yield his right to express an opinion. (NTSB, 1979)

Decision Making

Decision making is a topic that may at first glance seem to be an individual matter. After all, the captain is the final authority and responsible for flight decisions. However, aircrew decision making is a group process, and clearly illustrates the collective nature of crew resource management. There are a number of hardware, software, and human resources available in the cockpit, including other crewmembers, ATC, dispatch, and various sources of information. The decision maker who does not rely on input from other crewmembers and from other flight team members outside the cockpit is more likely to make poor decisions.

Although decisions are certainly founded on aeronautical knowledge, flying skills, and experience, it is often difficult to describe how decisions are made in actual flying situations. It has generally been assumed that learning to make good decisions could be attained only through experience. However, research has shown that aircrew decision making skills can be shaped through training.

The decision making process may be broken down into the following five steps:

1. **Recognizing or identifying the problem.** Does a problem exist that requires action?

2. **Gathering information to assess the situation.** This step requires determining what information is needed, who has the needed information, and whether the information is verified by other crewmembers and resources.

3. **Identifying and evaluating alternative solutions.** This step includes evaluating

the advantages as well as the risks associated with each alternative identified, and selecting the optimum alternative.

4. **Implementing the decision.** This step includes executing the decision and providing feedback on actions taken to crewmembers.

5. **Reviewing consequences of the decision.** This step involves evaluating the consequences of the decision and revising the decision if consequences are not as anticipated.

Some decisions, especially those that must be made under extreme time pressure, must be seat-of-the-pants decisions. In these cases, there is very little time to gather all available information or to evaluate alternative solutions. These situations call for **intuitive** decision making, which is based on gut reactions, or more specifically, is based on past experience and training. However, these emergency situations are relatively rare. Most situations allow sufficient time to make a more deliberate or **analytical** decision. This decision more closely follows the steps outlined above. Analytical decision making uses the resources available to the decision maker and results in more informed decisions.

Team Building and Maintenance

Team Building and Maintenance skills include those skills related to fostering effective team performance.

Leadership

The term "leadership" implies that this skill is relevant only to the captain. There are two reasons why this is not true. First, a flightcrew is a team with a clearly designated leader: the captain. The captain as **designated leader** retains the authority and responsibility for flight operations. However, there are times when other crewmembers must play functional leadership roles. A **functional leader** may carry out leadership duties for a specialized task on a temporary basis, such as a takeoff or landing. In this case, the crewmember must direct task activities and serve as a functional leader to carry out that task.

Second, leadership would more properly be called **leadership/followership**. Leadership is a reciprocal process, and there are behaviors that both a leader and a follower must apply to ensure effective performance. For example, one leader behavior might be to provide direction for carrying out a task; correspondingly, one follower behavior might be to provide feedback on performance of the task. In other words, leader behaviors are less effective without complementary follower behaviors.

Leadership is not just "captain's" material. All crewmembers must perform leadership duties in some situations. Furthermore, leadership is not a one-way process, but requires both leader actions and effective crewmember responses.

Understanding the leadership role requires an understanding of what it is that leaders do. Effective leaders perform four primary functions:

1. **Regulating Information Flow.** The leader must regulate, manage, and direct the flow of information, ideas, and suggestions within the cockpit crew and between the cockpit crew and outside sources. This function includes the following behaviors:

- Communicating flight information
- Asking for opinions, suggestions
- Giving opinions, suggestions
- Clarifying communication
- Providing feedback
- Regulating participation

2. **Directing and Coordinating Crew Activities.** The leader must function as crew manager to provide orientation, coordination and direction for group performance. This function includes:

- Directing and coordinating crew activities
- Monitoring and assessing crew performance
- Providing planning and orientation

- Setting priorities
- Delegating tasks

3. **Motivating Crewmembers.** The leader must maintain a positive climate to encourage good crewmember relations and to invite full participation in crew activities. This function includes:

- Creating proper climate
- Maintaining an "open" cockpit atmosphere
- Resolving/preventing conflict
- Maintaining positive relations
- Providing non-punitive critique and feedback

4. **Decision-making.** The leader is ultimately responsible for decisions. This function includes:

- Assuming responsibility for decision making
- Gathering and evaluating information
- Formulating decisions
- Implementing decisions
- Providing feedback on actions

The following excerpt from an NTSB accident report illustrates the errors that can occur when certain leadership and followership behaviors are applied poorly or not at all.

ACCIDENT SUMMARY – On October 11, 1983, Air Illinois Flight 710, a Hawker Siddley 748-2A was being operated between Chicago, Illinois and the Southern Illinois Airport, Carbondale, Illinois, with an intermediate stop at Springfield, Illinois. At 2020 central daylight time (CDT), Flight 710 departed Springfield with seven passengers and three crewmembers on board. About 1.5 minutes later, Flight 710 called Springfield departure control and reported that it had experienced a slight electrical problem but that it was continuing to its destination about 40 minutes away.

The flight toward Carbondale was conducted in instrument meteorological conditions. The cloud bases in the area were at 2,000 feet MSL with tops at 10,000 feet. Visibility below the cloud bases was 1 mile in rain, and there were scattered thunderstorms in the area.

The Cockpit Voice Recorder transcript showed that shortly after takeoff, Flight 710's left generator suffered a complete mechanical failure and that in responding to the failure of the left generator, the first officer mistakenly isolated the right generator from the airplane's d.c. electrical system. All subsequent attempts to restore the right generator to the airplane's d.c. distribution system were unsuccessful, and the airplane proceeded toward Carbondale relying solely on its batteries for d.c. electrical power.

EVENT HISTORY – The flight was about 45 minutes behind schedule when it arrived at Capitol Airport, Springfield, Illinois. The flightcrew remained on board while the airplane was fueled. At 2011:44, when Flight 710 requested its IFR clearance, it also requested 5,000 feet for its enroute altitude, as opposed to the IFR flight plan of 9,000 feet stored in the ARTCC computer. At 2019:40, Springfield tower cleared Flight 710 for takeoff.

1. At 2021:14, Flight 710 contacted departure control and informed the controller that it was climbing through 1,500 feet. The departure controller advised the flight that he had it in radar contact, cleared it to climb to and maintain 5,000 feet, and cleared it to proceed direct to Carbondale after it received the Carbondale VOR.

2. At 2021:34, Flight 710 informed the departure controller that it had experienced a "slight electrical problem..." The controller asked the flight if it was going to return to Springfield, and the flight reported that it did not intend to do so.

3. At 2022:10, the flight told departure control that "We'd like to stay as low as we can," and then requested and was cleared to maintain 3,000 feet. The controller asked the flight if he could provide any assistance, and the flight responded, "We're doing okay, thanks."

4. At 2023:54, the first officer told the captain that "the left (generator) is totally dead, the right (generator) is putting out voltage but I can't get a load on it." About 30 seconds later, he reported "zero voltage and amps on the left side, the right is putting out 27.5 volts but I can't get it to come on the line." At 2025:42, he told the captain that the battery power was going down "pretty fast."

5. At 2027:24, the captain called Kansas City center and stated that he had an "unusual request." He asked clearance to descend to 2,000 feet "even if we have to go VFR." He also asked the controller "to keep an eye on us if you can." The controller told the flight that he could not clear it to descend. The captain thanked the controller and continued to maintain 3,000 feet.

6. At 2028:45, the captain said, "Beacons off... and Nav lights are off." At 2031:04, the first officer reminded the captain that Carbondale had a 2,000 foot ceiling and that the visibility was 2 miles with light rain and fog. There was no reply or acknowledgement from the captain.

7. At 2033:07, the flight attendant came forward and the captain asked her if she could work with what she "had back there." The flight attendant reported that the only lights operating in the cabin were the reading lights, the lights by the lavatory, the baggage light and the entrance lights. The captain instructed her to brief the passengers that he had turned off the excess lights because the airplane had experienced "a bit of an electrical problem..." but that they were going to continue to Carbondale.

8. At 2038:41 (17 minutes after the initial failure), the first officer told the captain, "Well, when we... started losing the left one I reached up and hit the right (isolate button) trying to isolate the right side because I assumed the problem was the right side but they (the generators) both still went off."

9. At 2044:59, in response to the captain's request, the first officer reported that the battery voltage was 20 volts. At 2049:23, Kansas City center requested Flight 710 to change radio frequencies. The flight acknowledged the request, which was the last radio communication from Flight 710.

10. At 2051:37, the first officer told the captain, "I don't know if we have enough juice to get out of this." At 2052:12, the captain asked the first officer to "watch my altitude, I'm going to go down to twenty-four hundred (feet)." He then asked the first officer if he had a flashlight and to have it ready. At 2053:18, the first officer reported, "We're losing everything, ...down to about thirteen volts," and at 2053:28, he told the captain the airplane was at 2,400 feet.

11. At 2054:00, the captain asked the first officer if he had any instruments. The first officer asked him to repeat, and at 2054:16, the captain asked "Do you have any instruments, do you have a horizon (attitude director indicator)?" Flight 710 crashed near Centralia, Illinois VORTAC located about 40 nautical miles north of the Southern Illinois Airport. Three crewmembers and seven passengers were killed in the crash.

(NTSB, 1984)

This accident involved an HS-748-2A aircraft which experienced a generator failure at night. Proper procedures were not followed, causing disconnection of the second generator. A series of poorly managed actions followed, including an attempt to make the destination on battery power alone. Several behaviors related to leadership/followership are identifiable:

- Poor monitoring and assessment of crew activities (Event 8)
- Little feedback or acknowledgement of actions (Event 6, 8)
- Utilization of critical information unknown (Event 6)

Furthermore, a crucial error occurred when the co-pilot reminded the captain of IFR weather at the destination, got no response from the captain, and did not press the issue until it was too late.

This accident shows that it is sometimes difficult to apply vital team behaviors required in the cockpit such as leadership, planning, problem solving, delegating, motivating, and setting priorities. This difficulty reinforces the importance of CRM training.

Workload Management and Situational Awareness

These skills reflect the extent to which crewmembers maintain awareness, prepare for contingencies, and manage workload and stress.

Workload Management

Workload management includes preparation, vigilance and avoidance of distractions and complacency. Pilots interviewed about workload management offered the following tips:

Preparation – "Commit SOP' (Standard Operation Procedures), limitations and emergency procedures to memory, to free up mental capacity to deal with unforeseen events."

Planning – "Before each flight, I typically spend about one hour at home reviewing the route and airport information."

Vigilance – "Be especially vigilant when everything is going well." and "Never assume anything, but verify and cross-check all critical information."

Complacency – "Avoid complacency. The minute you think something won't hurt you, it will."

Distractions – "Maintain a terrain awareness and a general knowledge of the topography over which you are flying."

(from Kelly, 1991)

Workload varies according to the phase of an operation, from the routine of preflight planning and enroute cruise to the high workload of a low visibility instrument approach. Either workload level can be dangerous.

Accidents often occur when workload demands exceed crew capabilities. Figure 7 illustrates the phases of flight in which most accidents occur. Note that takeoff, approach, and landing phases account for most aircraft accidents. These phases are also periods of high crew workload. If any distraction or irregularity occurs during these phases, an accident is much more likely to occur than at other times.

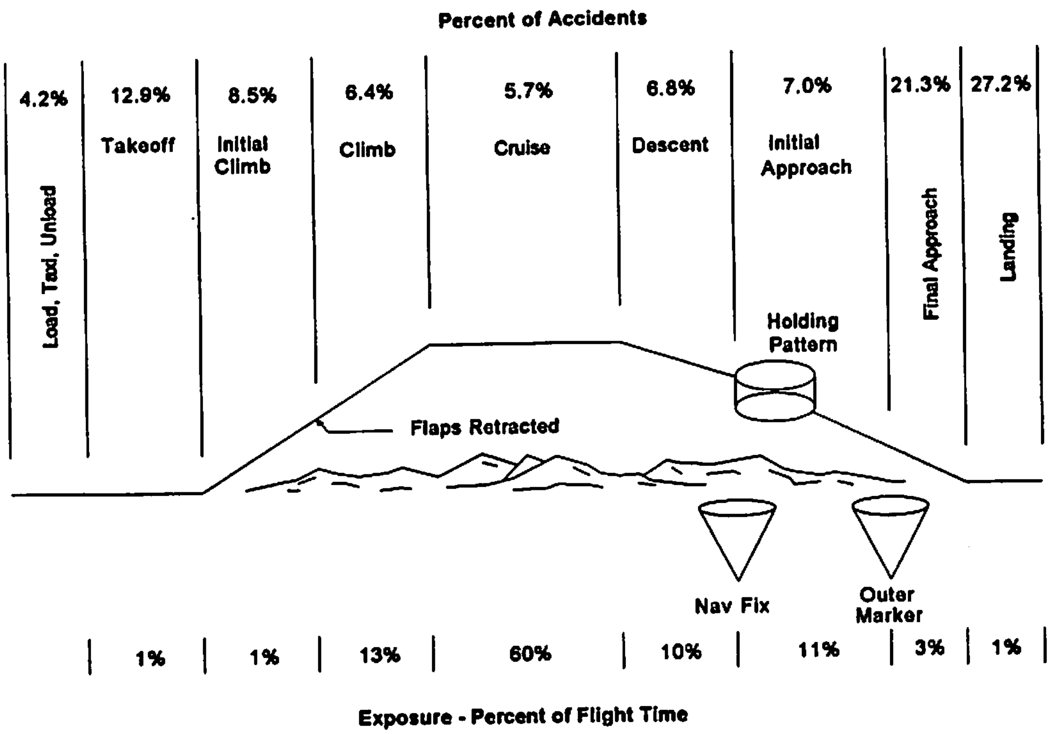


Figure 7. Percent of total commercial aircraft accidents by phase of flight, worldwide, 1959-1990. (Boeing Commercial Airplane Group, 1991)

Paradoxically, **low workload** can also be a hazard to safety. Crews may be less alert during long cruise segments. These low workload periods are times when complacency, forgetfulness and drowsiness are most common. Examination of the errors associated with low and high workloads reveals that performance follows a YERKES DODSON arousal curve like the one depicted in Figure 8.

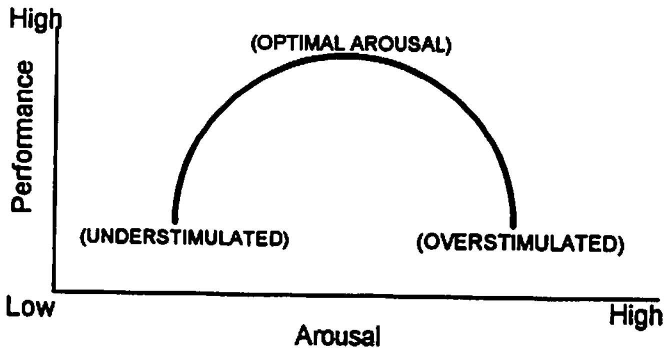


Figure 8. Very low or very high arousal can degrade performance.

The following accident emphasizes the relationship between arousal and performance. Crucial elements identifiable in this excerpt include the importance of unbroken attention to instrument scan and the insidious role of distractions.

ACCIDENT SUMMARY -- On December 29, 1972, an Eastern Airlines Lockheed L-1011 crashed in the Everglades about 18 miles west-northwest of Miami International Airport (MIA). There were no major mechanical problems, severe weather phenomena or crew incapacitation. The flight diverted from its approach because the nose landing gear position indicating system of the aircraft did not indicate that the nose gear was locked in the down position. The aircraft climbed to 2,000 feet MSL and followed a clearance to proceed west from the airport at that altitude. During that time the crew attempted to correct the malfunction and to determine whether or not the nose landing gear was extended. Unfortunately, during that period, workload management in terms of flying, navigating and communicating was totally ignored due to fixation on the relatively minor failure.

The flight was conducted in clear weather conditions with unrestricted visibility. However, the accident occurred in darkness with no moon. The flight was uneventful until the approach to MIA. The landing gear handle was placed in the "down" position during the preparation for landing, and the green light, which indicates to the crew that the landing gear is fully extended and locked, failed to illuminate. The captain recycled the landing gear, but the green light still failed to illuminate.

The National Transportation Safety Board determined that the probable cause of this accident was failure of the flight crew to monitor the flight instruments during the final four minutes of flight, and to detect an unexpected descent soon enough to prevent impact with the ground. Preoccupation with a malfunction of the nose gear position indicating system distracted the crew's attention from the instruments and allowed the descent to go unnoticed.

EVENT HISTORY – Eastern Airlines Flight 401 was a scheduled passenger flight from the John F. Kennedy International Airport in Jamaica, New York to the Miami International Airport in Miami, Florida.

1. At 2334:05, EAL 401 called the MIA tower and stated, "Ah, tower, this is Eastern, ah, four zero one, it looks like we're gonna have to circle, we don't have a light on our nose gear yet."

2. At 2334:14, the tower advised, "Eastern four oh one heavy, roger, pull up, climb straight ahead to two thousand, go back to approach control, one twenty eight six."

3. At 2335:09, EAL 401 contacted MIA approach control and reported, "All right, ah, approach control, Eastern four zero one, we're right over the airport here and climbing to two thousand feet, in fact, we've just reached two thousand feet and we've got to get a green light on our nose gear."

4. At 2336:04, the captain instructed the first officer, who was flying the aircraft, to engage the autopilot. The first officer acknowledged the instruction. Subsequently, the captain took over the flying responsibilities. The first officer successfully removed the nose gear light lens assembly, but it jammed when he attempted to replace it.

5. At 2337:08, the captain instructed the second officer to enter the forward electronics bay, below the flight deck, to check visually the alignment of the nose gear indices.

6. At 2337:48, approach control requested the flight to turn left to a heading of 270 degrees magnetic. EAL 401 acknowledged the request and turned to the new heading. Meanwhile, the flightcrew continued their attempts to free the nose gear position light lens from its retainer, without success. At 2338:34, the captain again directed the second officer to descend into the forward electronics bay and check the alignment of the nose gear indices.

7. At 2340:38, a half-second C-chord, which indicated a deviation of +/- 250 feet from the selected altitude, sounded in the cockpit. No crewmember commented on the C-chord. No pitch change to correct the loss of altitude was recorded. A short time later, the second officer raised his head into the cockpit and stated, "I can't see it, it's pitch dark and I throw the little light, I get, ah, nothing." The flightcrew and an EAL maintenance specialist who was occupying the forward observer seat then discussed the operation of the nose wheelwell light. Afterward, the specialist went into the electronics bay to assist the second officer.

8. At 2341:40, MIA approach control asked, "Eastern, ah, four oh one how are things coming' along out there?" This query was made a few seconds after the controller noted an altitude reading of 900 feet in the EAL alphanumeric block on his radar display. The controller later testified that momentary deviations in altitude information on the radar display were not uncommon; and that more that one scan on the display would be required to verify a deviation requiring controller action.

9. At 2342:05, the first officer said, "We did something to altitude." The captain's reply was "What?" The first officer asked, "We're still at two thousand, right?" The captain immediately exclaimed, "Hey, what's happening here?"

10. At 2342:10, the first of six radio altimeter warning "beep" sounds began; they ceased immediately before the sound of initial ground impact. The aircraft crashed while in a left bank of 28 degrees. The aircraft was destroyed. There were 163 passengers and a crew of 13 aboard the aircraft. Ninety-four passengers and five crew members received fatal injuries. All other occupants received injuries which varied from minor to critical.

(NTSB, 1973)

The distraction shown in this accident report was an operational one. Ironically, the distraction itself was not serious. The crew's mismanagement of the distraction caused it to be fatal.

Distractions can also come from outside the cockpit in the form of traffic, weather, unexpected rerouting, etc. The keys to dealing with distractions in order to avoid catastrophic consequences lie in the crew's ability to focus on aircraft control and hazard avoidance.

The crew should be prepared to avoid distractions. The captain can fly the aircraft and delegate tasks that might interfere. Or vice-versa. While the distraction in the L-1011 accident demanded immediate attention, it was the captain's responsibility to set priorities and to delegate responsibilities or make work assignments. Tragically, the entire crew became absorbed in the distraction at the expense of aircraft control.

Stress Management

There are two types of stress that can degrade flight performance. One type has been called **background** stress. Background stressors are chronic stress factors that are in the background of our everyday activities. They include job stress, stress to maintain schedules, fatigue, family stress, and the stresses imposed by organizational requirements. Sometimes no single source of stress may seem very serious, but the combined or cumulative effects of stressors can lead to degraded performance. In other instances, major life stressors such as divorce or death of a loved one can have ill effects on one's performance. Counseling on coping skills has proven effective in controlling background stressors.

A second type of stress is **acute** stress. Acute stress is the overload that occurs in a high intensity event, such as an unfamiliar flight irregularity. This type of stress occurs all at once, and the results can be catastrophic. Acute stress results in several negative consequences:

- "Tunnel vision", or the restriction of attention to only part of a task
- Rigidity of response, or maintaining a single course of action even though conditions have changed
- A tendency to scan alternatives less effectively during decision making, and
- "Ballistic" decision making; making decisions without thinking through the consequences of a decision.

The intense time pressure, unfamiliarity, and overload inherent in acute stress conditions result in a narrowed view. In turn, awareness is reduced regarding the hazards of the task, and the resources available to meet those hazards.

Chapter 3: Implementing CRM Training

Early versions of CRM training were largely attempts to adapt existing training materials that had been developed for other purposes, such as management training. But it became clear that a more complete method was needed.

The Systems Approach to Training

The **systems approach to training** has been used successfully in a variety of settings, including the military, airlines, and other industries. While the systems approach to training exists in many forms, it generally provides guidelines for training in three steps: DEVELOPING the training, IMPLEMENTING the training, and EVALUATING the training. It is not a rigid rule book but rather a general process for building training programs.

What follows is a simplified scheme for CRM training, using the systems approach.

STEP 1: Developing CRM Training

Training program development activities may be grouped in three areas: (1) Needs Assessment; (2) Setting Performance Objectives; and (3) Preparing a Training Plan.

1. Needs Assessment

The first step in the development of a successful CRM training program is to assess the organization's training needs. There are many ways to assess training needs, including surveys, reviews of incidents, and studies by special advisory committees.

The scope of the needs assessment depends on the specific organization's size and complexity. A comprehensive needs assessment can help an organization identify training needs most vital to its operations and to arrange other needs by priority.

An organization may not be entirely receptive to the new training that it needs. One useful tool for assessing an organization's attitudes toward CRM training is the "Cockpit Management Attitudes Questionnaire", developed by Helmreich (1984). (See Appendix) This questionnaire can provide useful readings on embedded attitudes toward training. Further, this type of measurement encourages people to get involved in the development of the training program.

Training needs exist on at least three levels: the individual, the group, and the organization. We have mentioned the individual in focusing on the group. But we have said little about the organization. Is the organizational culture supportive of CRM training? Is management on board? A CRM program has to be supported from the top of the organization to the bottom. Therefore, some training program may be needed for management. Management training may consist of distributing materials on crew-related incidents; posting information on CRM successes such as the United Airlines flight 232 story; or running a seminar for management describing the nature and value of a CRM program. In any case, it is essential to build management support early in program development.

Management support is essential to effective CRM training.

To assist in the assessment of needs, a set of practical questions can be asked. A variety of answers are appropriate. The specific answers depend on the unique characteristics of the user organization. However, there have been some valuable general lessons learned from the CRM training programs that have been implemented at various airlines. Some of these lessons follow.

WHO?

Who should develop the training? Various people can and do develop CRM training programs. Programs can be bought off the shelf or developed from scratch. They can be developed by outside consultants or by in-house experts. Some sort of compromise among these options often provides the best approach.

Two hints have proven helpful in CRM program development. First, there are excellent models of CRM training available, including programs developed by several airlines and by the military aviation community. And many publications are available covering lessons learned over the last decade on building a successful CRM training program.

Second, most organizations have found that a team approach is effective in developing a CRM training program. Many organizations do not have training specialists on staff. In this case, the design and development team should include both outside training consultants and in-house representatives. In-house representatives should comprise a wide array of managers, flightcrew, check airmen, and instructors. This team approach avoids the pitfall of having an outside expert design a program in isolation--a program that later proves not to fit an organization's needs. Perhaps even more important, this team approach ensures that flightcrews are involved in the CRM training program from the beginning--a critical factor in securing acceptance and commitment by users.

CRM training is crew training, and may include all groups that work with the cockpit crew and are involved in decisions that impact flight safety.

Who should be trained? The CRM concept has evolved from an initial narrow focus on the cockpit crew. It has broadened to include all other groups who interact with the cockpit crew and who are involved in decisions that affect flight safety. These groups include cabin crewmembers, air traffic controllers, dispatchers, maintenance people, customer service agents, and even specialized crisis teams such as bomb threat and hijack teams. Although CRM training has focused primarily on cockpit crewmembers, some airlines have begun to develop CRM training programs that include flight attendants, dispatchers, and maintenance people.

Central to the CRM concept is that CRM training is for the whole crew, not just for the individual; that while individual excellence is always desirable, teamwork is the focus; and that a good blend of resources is the best bet for a safe flight.

WHAT?

What should be trained? Early CRM training programs borrowed heavily from management training practices. Conveniently, management training had traditionally dealt with topics like teamwork and leadership. Management concepts were often applied broadly to the aircrew setting, with varying degrees of success. One characteristic of more recent CRM training programs is a shift from broad concepts to specific aircrew skills and behaviors. While no set curriculum is necessarily appropriate for all airlines, the CRM primary-level skills identified in Figure 4 provide one useful framework for CRM training. These primary-level skills can be used in developing performance objectives later in Step 2: Setting Performance Objectives.

HOW?

How should training be introduced? Machiavelli wrote in The Prince that "There is nothing more difficult to arrange, more doubtful of success, and more dangerous to carry through than initiating changes." Resistance to change can take many forms, from passive disinterest to outright sabotage. (The term sabotage, in fact, stems from the French sabot or shoe, referring to the wooden shoes thrown by workers into machinery to jam gears). Because people tune out what they are not motivated to hear, many a training program has been scuttled because of a lack of user acceptance. This problem is sometimes called lack of "buy-in" or "sign-up."

The goal of successful implementation is that the new training "disappears" into the organization: it becomes an accepted and routine part of the normal training program.

Usually, introducing change in an organization invites problems; but not always. Sometimes the need for change is so glaringly obvious that buy-in is almost automatic.

In the early 1900s, for example, statisticians at American Telephone and Telegraph identified two powerful growth trends: telephone use and population growth. Projecting these trends, they forecast that by 1920 every female in the United States would have to be employed as a switchboard operator in order to meet demand. Within two years, AT&T had developed the automatic switchboard. Everyone from overworked switchboard operators to impatient telephone customers welcomed the new system. And today, of course, the automatic telephone switchboard is one of the key elements of our so-called information age.

The trends in crew-related airline accidents (shown in Figure 3) are almost as obvious. And the consensus within the airline community strongly favors CRM training. But a program known to be beneficial will not necessarily be accepted. Even the best of programs may fail if the introduction of the training program is managed poorly. People often become accustomed to doing things in a certain way, and resistance to change is normal. But some steps can be taken to promote acceptance of "new" training. Those steps are covered later in this chapter under "Implementing CRM Training".

WHERE?

Where should training take place? Initial CRM training can take place in any setting that is conducive to learning. Many organizations hold initial training in off-site facilities in order to avoid disruptions. However, the location of initial CRM training is less important than the process of bringing crew members together.

CRM focuses on **crew** interaction. And CRM training is most effective in groups large enough to include entire crew units. Later phases of training are most effective when trainees are broken out into crew units and trained in simulators or other cockpit mock-ups.

HOW MUCH?

CRM training must be integrated into the total training program.

How much training is required? Initial CRM training can be accomplished in as little as two or three days. But continual CRM training should become part of the total training program. CRM skills should be considered a major element of the overall skills package that produces safe flight. CRM training never really ends. More on continual training follows in this chapter under "Preparing a Training Plan."

2. Setting Performance Objectives.

Performance objectives specify what is to be learned.

The next step in the development of a CRM training program is to set performance objectives. **Performance objectives** are the desired outcomes of training. They answer the question, What will trainees be able to do at the end of a training session that they could not do before training? Objectives must be simple. It must be clear if they have been met at the end of training. Usable performance objectives include the specific behaviors desired and standards for measuring satisfactory performance. A performance objective for classroom training might be:

- Given a written scenario describing accident No. xxx, crewmembers will be able to state in writing at least three barriers to communication present in this situation.

By expressing objectives in this manner, those people designing the training program are forced to identify exactly what each lesson should accomplish. Later these performance objectives serve as guidelines for the evaluation of training. The basic CRM skills were discussed in Chapter 2, CRM Skills, and can be used to develop CRM performance objectives.

There are different **types** of learning objectives. Trainees may learn:

- Intellectual skills, such as problem solving
- Factual information (knowledge)
- Attitudes
- Motor skills

Therefore, any one training session or training module may have a mix of training objectives.

CRM depends upon support from the entire organization, not just the aircrew. The phrase "organizational shell" has been coined to describe the organizational culture in which flight crews operate. One aviation psychologist writes:

> *Imagine, if you will, a beautifully designed and professionally executed CRM program that helps crew members learn and practice precisely the skills that they need to operate well as a team in a demanding flight environment. Now place that program in an organization where lines of flight are badly constructed and constantly changing at the last minute, crews are poorly composed and short-lived, norms of conduct reinforce individual order giving and taking rather than team-level planning, excellent crew performance goes wholly unrecognized, and crews often are unable to obtain information, technical assistance, or material resources when they need them to proceed with the work.*
>
> *To complete a good CRM course in an organization that has...an unsupportive organizational context is like getting all dressed up for a dance and having the car break down halfway there. Cockpit resource management simply cannot take root and thrive unless organizational conditions also foster and support effective teamwork. (Hackman, 1987, p. 37)*

The point is well made that performance objectives must be set for the organization as well as the individual.

3. Preparing a Training Plan.

A training plan provides a blueprint for CRM training development.

The third step in the development of CRM training is **preparing a training plan.** A training plan provides a complete description of a course of instruction including sequenced lessons. Lesson details provide a description of training objectives, content, methods, training aids, and other elements required for instruction. A sample of an abbreviated training plan is shown on the following page.

A training plan identifies training objectives, provides an outline of course content, specifies training methods, and even provides an estimate of the time required for each topic.

A variety of **training methods** may be chosen to present course content. Since people learn in a variety of ways--by listening, by seeing, by discussing, and by doing--it follows that there are a number of training methods available. Training methods include lectures, training tapes, seminars,

SAMPLE LESSON PLAN

Session Title: Communication Skills

Objectives:

1. Given a written scenario describing incident No. XXX, the crewmembers are able to state in writing three barriers to communication present in this situation.
2. Crewmembers acknowledge communications from others during role-play.
3. Crewmembers use standard terminology throughout a LOFT simulation.
4. ...

Topic	Content	Training method	Time
Introduction	A. Barriers to effective aircrew communication	Videotape demonstration Lecture with viewgraphs	10 minutes 20 minutes
Verbal and nonverbal communica-tion	A. Giving and receiving feedback B. Acknowledging communications C. Using standard terminology D. Nonverbal communications	Classroom demonstration Lecture with viewgraphs Role-play communications exercise	10 minutes 20 minutes 20 minutes
Recognition	A. How to recognize ineffective communication skills in self and others	Role-play exercise with self and instructor critique.	30 minutes

demonstrations, role-playing, and simulation. In general, it is preferable to use a variety of training methods in order to enhance learning and to sustain the trainees' interest.

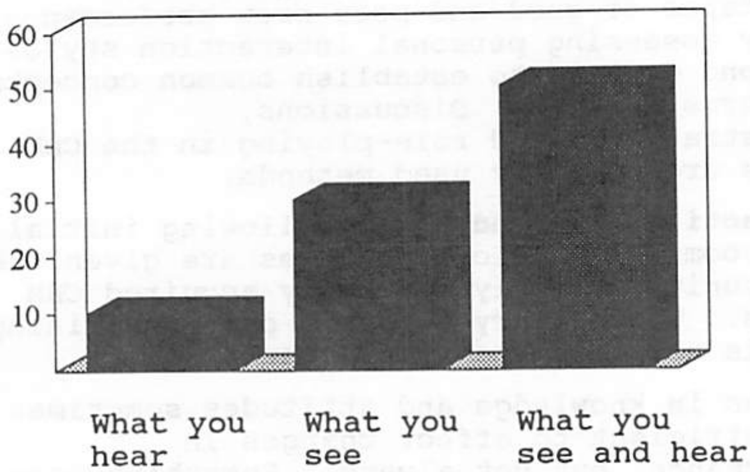
Lesson developers may find the following points helpful. First, education specialists have identified **nine critical instructional events** that support learning:

1. Gain the trainee's attention.
2. Describe the objectives of training.
3. Stimulate recall of prerequisite skills.
4. Present content to be learned.
5. Provide guidance and support.
6. Elicit the performance.
7. Provide feedback.
8. Assess performance.
9. Enhance retention and transfer.

(from Gagne, Briggs, & Wager, 1988)

Second, research shows that people remember about 10% of what they hear, 30% of what they see, and 50% of what they see and hear.

WHAT YOU REMEMBER



It follows that the more of the trainee's senses are involved, the greater the learning experience. Hands-on training (hearing, seeing and feeling) is better than watching a training tape. A training videotape with a soundtrack is better than a training audio tape alone.

Third, it is always desirable to mix instructional methods and actively involve the learner. More than young people, adults are known to respond to training that can be readily applied in their work. Instruction should not be limited to lectures and training tapes, for example. Role-playing, workshops and other practical exercises that involve the trainee promote the sense that the training is relevant and useful.

Finally, all effective training, including CRM training, comprises three essential components:

1. Indoctrination/Awareness

2. Practice and Feedback

3. Operational Reinforcement

Initial training focuses on introducing CRM skills and fostering awareness of the need for CRM training.

1. Indoctrination/Awareness. Initial training is conducted in a classroom setting with the goal of laying a foundation for skills acquisition. One goal of training at this stage is to convince the crewmember that he or she can benefit personally from CRM training. This goal can be met by reviewing data on crew-related accidents, by describing crew coordination problems, by viewing videotapes of good and poor crew performance, and by assessing personal interaction styles. A second goal is to establish common concepts and terms for CRM. Discussions, demonstrations, and role-playing in the CRM skills are commonly used methods.

2. Practice and Feedback. Following initial classroom instruction, trainees are given the opportunity to apply the newly acquired CRM skills. The primary emphasis of CRM training at this stage is **crew performance.**

Learning new skills requires active practice and feedback.

Changes in knowledge and attitudes sometimes are sufficient to effect changes in performance, but not always. Something more is usually required. Practicing skills and receiving feedback on performance are proven to be effective in completing the learning of desired behaviors.

Effective practice may be achieved through high, medium, or low fidelity simulations. Realistic high fidelity simulations may be achieved through blending CRM training into Line Oriented Flight Training (LOFT). LOFT provides the ideal setting for skills practice, because it presents a full-crew, full-mission scenario in which CRM skills can be evaluated along with technical skills.

CRM practice may range from full-mission simulation to role-playing using cockpit procedures trainers (CPTs) or even cruder cockpit mock-ups.

Feedback on performance may also be provided by a number of means. Videotape provides a clear and vivid record of performance, and is widely used. Replay, fast forward, slow motion, and freeze frame are some of the valuable videotaping functions that can be used during debriefings.

Under the guidance of a skilled instructor, the crew's critique of its own performance during debriefing can effectively build CRM skills. Other feedback valuable to the individual comes from a pilot's fellow crewmembers. And often the most lasting benefit to the pilot comes from his own self-assessment. Each of these assessments is vastly improved by the use of videotaping and other audio-visual aids.

3. **Operational Reinforcement.** All of us have hit ourselves on the finger with a hammer. We experienced what is known as one-trial learning. We immediately grasped the concept of hammer/finger interaction, and probably vowed immediately never to do that again. However, the term "one-trial learning" is actually misleading. If we never practice even a simple skill like hammering, we are more likely to hit our fingers again.

Behavior that is not rehearsed and reinforced decays over time.

Sustaining the sophisticated skills of crew coordination requires continual repetition and reinforcement. Studies have shown that the initial benefits of CRM training dissipate within a relatively short period if training is not reinforced over time. Thus, CRM training should be included as a regular part of recurrent training. Since people tend to forget both facts and skills over time, continual training should include refresher seminars reinforced by practice and feedback exercises such as LOFT.

Training method selection may vary according to the component of CRM training being taught. The purpose of the **indoctrination/awareness** component of CRM training is to provide concepts and terms for crew coordination problems, and to address CRM skills. Indoctrination/awareness commonly begins in a classroom setting. Methods of instruction include lectures, seminars and guided discussions.

The purpose of the **practice and feedback** component of CRM training is to apply newly acquired CRM skills. Accordingly, emphasis is placed on exercises, demonstrations, role-playing, and simulations. Trainees are given an opportunity to try out these behaviors and to receive feedback on their performance.

The purpose of **operational reinforcement** is to prevent the loss of CRM skills once they are acquired. CRM training must be included as a regular part of the recurrent training requirement. Continued reinforcement of CRM skills will require a mix of training methods, including seminars, active practice, and feedback.

The mission of CRM training is to promote changes in behaviors related to crew coordination in order to prevent accidents. The bottom line is **crew performance.** Performance starts with awareness of appropriate knowledge, attitudes, and behaviors. But awareness is not enough. Like the athlete with great potential, crewmembers need an opportunity to hone their performance through realistic learning experiences. The practice and feedback component of CRM training meets this need.

LOFT provides realistic, full-mission simulation to enhance skill transfer.

The best training method known for CRM practice and feedback is simulated line operations using flight simulators. Line Oriented Flight Training (LOFT) is the best known of these programs. LOFT blended with CRM training provides several advantages:

- It embeds CRM into the total training program.
- It provides a full mission scenario in which crews are evaluated for both CRM skills and traditional technical skills.
- It allows crew training in a full crew context.
- It invites the use of video recording and playback during debriefing, providing an excellent means of evaluating performance.

- It is accepted by most crewmembers and provides an effective means of reinforcing CRM skills.

If LOFT is not available, CRM practice and feedback can be accomplished with lower-level simulations. Realistic demonstrations, problem-solving scenarios, and role-playing exercises, complemented by audiovisual aids, can provide an effective means of reinforcing CRM skills. Keys to effective practice include direct learner involvement, hands-on training experience, and immediate feedback with the opportunity for further practice.

STEP 2: Implementing CRM Training

It is important to develop an implementation plan early in the training development process. Determine who should be involved in the implementation; anticipate user reactions and consider ways to overcome possible negative responses; and develop a timetable for implementation. Finally, introduce the training carefully and deliberately. Some organizations have tried out new training programs on test groups, then asked for input. They have then revised the programs before implementing them on a widespread basis.

Getting key personnel involved in the design and development of CRM training is one way to enhance commitment.

Seek participation. When a change occurs in a corporate setting, it is crucial to encourage buy-in and discourage resistance. In the extreme, resistance can become outright rejection, sometimes called the Not Invented Here syndrome. Not Invented Here is most likely when people do not feel involved. Get as many key people as possible involved in the development of the CRM training. As early as possible sign up the opinion leaders within your organization and any other significant group such as the pilots' association. Seek their participation early, and maintain their involvement while the CRM element is worked into the total training program.

Demonstrate program support. In 1961, a major American corporation established a school for managers to teach a new approach to company operations. The new approach was based on an innovative marketing philosophy centered on customer needs. After completing the course, 85% of the management trainees left the company within a short time. The reason? The company had not changed, and management had retained its habitual way of doing things. In this case, the corporate culture did not support the very change that upper management had tried to introduce. This example illustrates that all levels in an organization must be on-board or a new program may quickly die for lack of support.

Thus, it is critical that CRM program support be conspicuous from top management through to line operations. Similarly, the support of the pilots' association can provide a valuable program endorsement.

Communicate. Commitment can't be assumed; it must be earned. Therefore, it is vital to communicate the reasons for a CRM program. People need to know what CRM is and what it isn't, what it can accomplish, and why CRM training is important. Communication can be accomplished through meetings, seminars, newsletters, and posters. The following is a useful guide to effective communications.

The Seven C's of Effective Communication

- **Credibility:** The messenger must be seen as credible and competent by the receiver.
- **Context:** The message should be delivered in a context that is comfortable to the receiver and invites his participation.
- **Content:** The message must be relevant and important to the receiver.
- **Clarity:** The message must be clear and must be delivered in terms the receiver will understand. Jargon is to be avoided.
- **Continuity and consistency:** The message should be reinforced often and should be consistent from all voices within the organization.
- **Channels:** Channels of communication should be familiar and relevant to the receiver.
- **Capability:** The message should be suited to the capabilities of the receiver.

Follow-up. The most valuable guidance comes from the student, not from the instructor. Monitor program implementation through feedback from CRM trainees. Be prepared to address their concerns, and to revise the program as appropriate.

The Key Role of Check Airmen and Instructors

The success of any CRM training program rests on the skills of the people who administer the training. Thus, it is vital that check airmen and instructors be carefully chosen. Although check airmen and instructors are often chosen for their proficiency in technical matters, proficiency in teaching and evaluating CRM skills is an additional credential, not always easily earned.

Check airmen and instructors must be highly skilled in all areas of CRM performance.

Check airmen and instructors are especially important for two reasons. First, they are directly responsible for instruction, observation, feedback, and program evaluation. Second, they are in a strategic position to "sell" CRM and are likely to be opinion leaders within the organization. Because of their high profile, any attitude short of conspicuous support on their part can undermine the entire CRM program, which depends upon voluntary buy-in at every level of the organization.

There are at least three ways to encourage check airmen and instructors to support CRM and to become proficient in CRM skills. For one, they can be given CRM training before anyone else. For another, they can be given **more** training than anyone else. Finally, check airmen and instructors can be signed up for the CRM program at an early point. They can then provide input into the development of the CRM program and develop a sense of ownership of it. That sense of ownership, in turn, sets an example and encourages buy-in by others.

STEP 3: Evaluating CRM Training

Ex-Mayor Koch of New York was known for asking "How am I doing?" as he strolled New York's boroughs. This habit was not only good for public relations, but it also provided Koch with immediate feedback on his performance.

There are several reasons why the question "How are we doing?" needs to be asked continually during CRM training:

- To determine if the training meets objectives. For example: After completing the training module on Effective Communications, are trainees actually communicating any better?
- To determine if results from courses meet overall program goals. For example: After mastering the Communication lesson objectives for individuals, are crews communicating any better?
- To provide feedback to trainees.
- To provide feedback to instructors.
- To review and improve the training program itself.

The consideration of how training will be evaluated should begin in the early stages of training design.

Preparations for training program (CRM) evaluation should be made during the training design phase, while training objectives are being set. Objectives should be clear and measurable. Objectives that are vague or difficult to measure invite trouble in evaluating the success of the program. A clear plan for program evaluation should be developed early in the training design process because evaluation activities should begin **before** training is implemented.

As mentioned earlier, it is likely that a variety of outcomes will come from training, including changes in knowledge, attitudes, and behavior. It is appropriate to use multiple measures of effectiveness in evaluating training. As an example, researchers at the Naval Training Systems Center have adopted the following measures of effectiveness for a Navy aircrew coordination training program:

Type of Evaluation	Sample Item/Measure
Pre-Training Assessment	1. Aircrew coordination is critical to flight safety (agree/disagree). 2. List four barriers to effective communication in the cockpit.
Trainee Reaction	1. This training was relevant to my flight performance.
Learning	1. List four barriers to effective communication in the cockpit.
Performance	1. Crew requests clarification of garbled communication during simulated exercise.
Organizational Outcome	1. Data on incidents involving crew coordination.

Adapted from Cannon-Bowers et al. (1989).

Pre-training assessment is done before training begins. Its purpose is to provide a pre-training baseline measure of skills and attitudes. This pre-training baseline is used as a reference against which post-training improvements are measured.

Trainee reaction measurements can be taken to assess trainees' reactions regarding training program relevance, content, methods, or other features. "The Cockpit Management Attitudes Questionnaire" is one evaluation tool that is used to assess pre-training and post-training attitudes toward crew coordination (See Appendix).

Tracking various reactions to CRM training is valuable for several reasons. First, **negative reactions** signal a lack of acceptance by users. But they often point to specific areas where small adjustments may make a big difference immediately. Second, **positive reactions** probably point the way to further program improvements. Third, **other groups' reactions** to the training program may provide valuable cues for improvements; groups like flight attendants, agents, mechanics, and dispatchers. And finally, **reactions tracked over time** can reveal much about changes within the corporation.

Evaluation can be used to assess reactions to training, learning, changes in performance, and the degree to which organizational goals are met.

Learning is measured against learning objectives, which are just the flip-side of training objectives. The most familiar kind of measurement is probably the question and answer test. Answers may be oral or written. As an example, one objective might be that trainees be able to describe barriers to communication in the cockpit. Measurement might take the form of a simple question requiring the trainee to describe four barriers.

Performance is measured against performance objectives. Typically, instructors receive special training in conducting performance evaluations, and then observe and rate crew performance against performance objectives during simulation exercises.

Organizational outcome measures include comparisons of data on crew-related accidents. Although increased safety is a simple enough ideal, attaining a valid measure of the effect of CRM training on safety is very difficult. One reason is that it is difficult to analyze events that seldom occur--aviation accidents. Another reason is that it is often difficult to measure whether changes in the accident rate are related to CRM training or to other events, such as equipment upgrades or industry-wide changes. The difficulty in using such comparisons to measure training program effectiveness points to the need for multiple measures.

Using multiple measures of training effectiveness permits a comprehensive and informative training evaluation.

Multiple measures of effectiveness are useful in documenting program successes and shortfalls. For example, trainees may fail because they have not learned the skills, do not clearly understand CRM concepts, or fail to see the training as meaningful or relevant. Using multiple measures of a program's effectiveness allows the evaluator to isolate specific areas for program improvement.

Finally, evaluation should not be punitive. The purpose of CRM training evaluation is to measure program effectiveness and to provide specific guidance for improvements to the program. Training evaluation should not be used to assess an individual's fitness for duty.

CRM skills are crew skills. CRM evaluation should focus on crew or team performance. Individual crewmembers should receive clear feedback on their own performances, but the emphasis should remain on crew performance.

A Final Note on CRM Training

Setting up a CRM training program is not as difficult as it might seem to the CRM newcomer. Using a systems approach the process can be broken into three steps: Development, Implementation, and Evaluation. Each of these steps can be further broken down into manageable units such as Needs Assessment, Setting Performance Objectives, and Preparing a Training Plan. And these units can be further broken down as necessary.

Furthermore, good CRM training can be accomplished with a conservative budget by blending it with existing training, using existing resources.

A well-conceived CRM training package can blend nicely with existing training and meet with little resistance. While the CRM element is perceived as new, it is often treated as a stand-alone training product. Over time, as the blending becomes complete, CRM should become indistinguishable from other training. At that point it has become "seamless", or "invisible" to the trainees, the most desirable state.

Airlines that do not yet have CRM programs are in the enviable position of being able to build on the lessons learned from more than a decade of CRM program development. There is now a wealth of materials available to support CRM program development. Each developing CRM program can be custom-fitted to the unique needs of the organization while drawing on the abundant resources already available.

Chapter 4: Summary

Commercial aviation is one of the safest forms of transportation, with a safety record that is excellent by any standards. The number of commercial jet aircraft in service worldwide has climbed steadily over the past three decades to a total of 9,530 in 1990, while annual departures have increased to 13,298,000 for 1990 (Boeing, 1991). Remarkably, over this same period, the total accident rate has declined from over 60 accidents per million departures to about 2.5 -- less than one twenty-fourth the accident rate in 1959! (see Figure 1) This fortunate trend can be attributed to advances in equipment technology, to a high level of individual technical proficiency, and to improved operating procedures.

Despite the record, one challenge has not been met: Breakdowns in crew performance have remained **the** primary factor in commercial jet accidents. Two out of three accidents are attributable to flightcrew error.

In the early years, when equipment reliability was the biggest problem, the aviation community responded with ingenuity and resolve. Engines and other aircraft components became more reliable, and related accidents declined. Today, with crew performance the most significant threat to aviation safety, the industry has responded with an ambitious program to support effective crew coordination and performance: Crew Resource Management training.

One aviation observer has projected that this industry focus on crew performance has the potential to **double** system safety. Data on the effectiveness of existing CRM programs indicate that this challenge is being met.

Glossary

ACTIVE LISTENING: the skill of hearing and understanding other people and checking the accuracy of one's understanding by communicating with the sender.

ACTIVE LEARNING: physically performing the essential movements or a skill or displaying behavior that has been taught (as opposed to passive learning, or simply listening to instruction).

ATTITUDE: a way of thinking or feeling; a mental disposition towards something that determines that person's response.

BEHAVIOR: a person's observable responses to a stimulus.

COMMUNICATION: the transfer of information and/or messages between or among people by the use of words, letters, symbols, or nonverbal communication.

COMMUNICATIONS PROCESS AND DECISION BEHAVIOR SKILLS: a cluster of CRM behaviors related to effective communications and decision making.

CREW RESOURCE MANAGEMENT: the effective utilization of all available resources--hardware, software and personnel--to achieve safe, efficient flight operations.

DECISION-MAKING: the process of selecting a course of action from available options, based on information available at the time.

FEEDBACK: response messages which clarify and ensure that meaning is transferred.

INDOCTRINATION/AWARENESS: the first phase in CRM training, which provides a conceptual framework for other phases. It typically consists of classroom instruction focusing on identification of CRM skills and concepts.

INQUIRY/ASSERTION: the skill of actively seeking out relevant information and showing a concern for both self and others' rights.

LEADERSHIP: the ability to utilize appropriate interpersonal skills to motivate, manage, and direct crew activities to achieve a task.

LINE-ORIENTED FLIGHT TRAINING (LOFT): a full mission simulation presented in real-time which is usually videotaped for later crew self-critique.

NEEDS ASSESSMENT: the process of determining where training is needed in an organization, what a trainee must learn in order to perform their job effectively, and who needs training.

ORGANIZATIONAL CULTURE: the larger organizational environment in which the flightcrew operates. Structure, standards, and reward policies are part of organizational culture. Management or organizational support for CRM training is a critical component of effective program implementation.

PASSIVE LEARNING: training that does not actively engage the trainee in the instructional process; the trainee is expected to passively "absorb" instructional material.

PERFORMANCE OBJECTIVES: statements which describe the desired outcomes of training in specific, behavioral terms.

PLANNING: the ability to establish an appropriate course of action for self and others to accomplish a specific goal.

PRACTICE AND FEEDBACK: the second phase of CRM training, in which participants actively employ newly acquired CRM skills and receive feedback on their effectiveness.

REINFORCEMENT: the final phase of CRM training. This phase is ongoing and involves ensuring that CRM becomes an inseparable part of the organization's culture by garnering top management support, identifying and reinforcing effective behavior in normal line operations, and instituting CRM training as a regular part of the recurrent training requirement.

ROLE-PLAYING: a training technique in which trainees are told to imagine themselves in the situations presented by the trainer. Trainees are free to act out different behaviors and reactions as long as they stay "in role" throughout the session.

SITUATIONAL AWARENESS: an active awareness of internal and external conditions that affect flight safety. It includes a realization of current, past and future contingencies that may affect flight performance.

STRESS MANAGEMENT: any of a variety of techniques, methods, or general strategies which have been developed to help people cope with the adverse consequences of stress.

SYSTEMS APPROACH TO TRAINING: a systematic approach to training development which provides guidelines for training design, development of instructional activities, implementation, and evaluation of training.

TEAM BUILDING AND MAINTENANCE SKILLS: a cluster of CRM skills focusing on interpersonal relationships and effective team practices.

TEAM MANAGEMENT: command and leadership by the captain and supportive behavior by crewmembers.

TEAM REVIEW: skills involved in pre-mission planning and analysis, ongoing synthesis and evaluation of information, and post-mission debriefing.

TRAINING PLAN: an outline of what will take place during a training session, including training objectives, content, training methods, and training media.

USER ACCEPTANCE: the extent to which a training program is accepted and endorsed by users.

WORKLOAD MANAGEMENT AND SITUATIONAL AWARENESS SKILLS: a cluster of CRM skills which reflect the extent to which crewmembers maintain awareness of the operational environment; anticipate contingencies; and plan and allocate activities that manage stress and workload.

Reference Materials

General Articles

The following references include documents cited in the text, plus other relevant articles and documents of general interest.

Boeing Commercial Airplane Group (1991). Statistical summary of commercial jet aircraft accidents, worldwide operations, 1959-1990. Seattle, WA: Product Safety Organization, Boeing.

Billings, C. E., & Reynard, W. D. (1981). Dimensions of the information transfer problem. In C.E. Billings & E.S. Cheaney (Eds.), Information transfer problems in the aviation system (NASA Technical Paper No. 1875). Moffett Field, CA: NASA-Ames Research Center.

Cannon-Bowers, J. A., Prince, C., Salas, E., Owens, J. M., Morgan, B. B., & Gonos, G. H. (1989, November). Determining aircrew coordination training effectiveness. Paper presented at the 11th annual meeting of the Interservice/Industry Training Systems Conference, Ft. Worth, TX.

Foushee, H. C. (1984). Dyads and triads at 35,000 feet: Factors affecting group process and aircrew performance. American Psychologist, 39, 885-893.

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.

Foushee, H. C., & Manos, K. L. (1981). Information transfer within the cockpit: Problems in intracockpit communications. In C. E. Billings & E. S. Cheaney (Eds.), Information transfer problems in the aviation system (NASA TP-1875). Moffett Field, CA: NASA-Ames Research Center.

Gagne, R. M., Briggs, L. J., & Wager, W. W. (1988). Principles of instructional design. New York: Holt.

Hackman, J. R. (1987). Organizational influences. In H. W. Orlady & H. C. Foushee (Eds.), Cockpit resource management training: Proceedings of the NASA/MAC workshop (NASA CP-2455) (pp. 23-39). Moffett Field, CA: NASA-Ames Research Center.

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

Helmreich, R. L., Chidester, T. R., Foushee, H. C., Gregorich, S., & Wilhelm, J. A. (1989). How effective is cockpit resource management training? Issues in evaluating the impact of programs to enhance crew coordination (NASA/UT Technical Report 89-2).

Helmreich, R. L., Chidester, T. R., Foushee, H. C., Gregorich, S. E., & Wilhelm, J. A. (1989). Critical issues in implementing and reinforcing cockpit resource management training (NASA/UT Technical Report 89-5).

International Civil Aviation Organization (1984). Accident prevention manual (1st. Ed.). ICAO Doc 9422-AN/923.

Jensen, R. S. (1989). Aeronautical decision making - Cockpit resource management (DOT/FAA/PM-86/46). Arlington, VA: Systems Control Technology.

Kelley, W. (1991). Safety tips from the pros. Aviation Safety, 11, (21).

Lauber, J. K. (1984). Resource management in the cockpit. Airline Pilot, 53, 20-23, 38.

National Transportation Safety Board. (1973). Aircraft accident report: Eastern Airlines, Inc. L-1011, N310EA Miami Florida (NTSB/AAR-73/14). Washington, DC.

National Transportation Safety Board. (1979). Aircraft accident report: United Airlines Flight 173, DC-8-61, N8082U (NTSB/AAR-79/12). Washington, DC.

National Transportation Safety Board. (1984). Aircraft accident report: Air Illinois Hawker Siddley HS 748-2A, N748LL (NTSB/AAr-84/10). Washington, DC.

National Transportation Safety Board. (1989). Aircraft accident report: United Airlines B-737-200 structural failure (NTSB/AAR-89/03). Washington, DC.

National Transportation Safety Board. (1990a). Aircraft accident report: United Airlines DC-10-10 engine explosion and landing at Sioux City Iowa (NTSB/AAR-90/06). Washington, DC.

National Transportation Safety Board. (1990b). Aircraft accident report: United Airlines B-747-122 cargo door failure and explosive decompression (NTSB/AAR-90/01). Washington, DC.

Predmore, S. C. (1991). Microcoding of communications in accident analyses: Crew coordination in United 811 and United 232. In R. S. Jensen (Ed.), Proceedings of the sixth annual international symposium on aviation psychology. Columbus, OH: Ohio State University.

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

Books and Conference Proceedings

Cooper, G. E., White, M. D., & Lauber, J. K. (Eds.). (1979). Resource management on the flight deck (NASA Conference Publication 2120). Moffett Field, CA: NASA-Ames Research Center.

Jensen, R. S. (Ed.). (1987). Proceedings of the fourth annual international symposium on aviation psychology. Columbus, OH: Ohio State University.

Jensen, R. S. (Ed.). (1989). Proceedings of the fifth annual international symposium on aviation psychology. Columbus, OH: Ohio State University.

Jensen, R. S. (Ed.). (1991). Proceedings of the sixth annual international symposium on aviation psychology. Columbus, OH: Ohio State University.

Komich, J. N. (1985). An analysis of the dearth of assertiveness by subordinate crewmembers. In R. S. Jensen and J. Adrion (Eds.), Proceedings of the third symposium on aviation psychology (pp. 431-436). Ohio State University, Columbus, OH.

Orlady, H. W., & Foushee, H. C. (Eds.). (1987). Cockpit resource management training (NASA Conference Publication 2455). Moffett Field, CA: NASA-Ames Research Center.

Wiener, E. L., & Nagel, D. C. (Eds.). (1988). Human factors in aviation. San Diego: Academic Press.

CRM Training Applications

Bruce, K. D., & Jensen, D. (1986). Cockpit management training at People Express. In Orlady, H. W., & Foushee, H. C. (Eds.). Cockpit resource management training (NASA Conference Publication 2455). Moffett Field, CA: NASA-Ames Research Center.

Christian, D., & Morgan, A. (1986). Crew coordination concepts: Continental Airlines CRM training. In Orlady, H. W., & Foushee, H. C. (Eds.). Cockpit resource management training (NASA Conference Publication 2455). Moffett Field, CA: NASA-Ames Research Center.

Davidson, J. (1986). Introduction to Trans Australia Airlines CRM training. In Orlady, H. W., & Foushee, H. C. (Eds.). Cockpit resource management training (NASA Conference Publication 2455). Moffett Field, CA: NASA-Ames Research Center.

Scott-Milligan, F., & Wyness, B. (1986). CRM training and human factors training: what Air New Zealand is doing about it. In Orlady, H. W., & Foushee, H. C. (Eds.), Cockpit resource management training (NASA Conference Publication 2455). Moffett Field, CA: NASA-Ames Research Center.

Sellards, R. (1986). Cockpit resource management at USAir. In Orlady, H. W., & Foushee, H. C. (Eds.), Cockpit resource management training (NASA Conference Publication 2455). Moffett Field, CA: NASA-Ames Research Center.

Vandermark, M. J. (1989). A comprehensive crew management program for the America West Airlines pilots and attendants. In R. S. Jensen (Ed.), Proceedings of The Fifth Annual Symposium on Aviation Psychology (pp. 640-645). Columbus, OH: Ohio State University.

Wilkinson, D. (1989). Cockpit resource management training - The Qantas experience. In R. S. Jensen (Ed.), Proceedings of The Fifth Annual Symposium on Aviation Psychology (pp. 456-461). Columbus, OH: Ohio State University.

Wilson, T. (1989). Aircrew team management - The Australian experience. In R. S. Jensen (Ed.), Proceedings of The Fifth Annual Symposium on Aviation Psychology (pp. 462-467). Columbus, OH: Ohio State University.

Yocum, M., & Monan, W. (1986). CRM training in corporate/regional operations (Group V). In Orlady, H. W., & Foushee, H. C. (Eds.), Cockpit resource management training (NASA Conference Publication 2455). Moffett Field, CA: NASA-Ames Research Center.