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7. Author(s) Lawrence L. Bailey, Ph.D. and Rogers V. Shaw, M.S.		8. Performing Organization Report No.
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This work was performed in response to the the National Transportation Safety Board's recommendation that crew resource management (CRM) training should be implemented as outlined in the Federal Aviation Administration's CRM Advisory Circular 120-51.

16. Abstract

On October 26, 1993, there was a fatal crash of a Federal Aviation Administration (FAA) flight inspection aircraft. During the accident investigation, the National Transportation Safety Board (NTSB) cited ineffective crew resource management (CRM) as one of the causal factors and recommended CRM training for flight inspection aircrews. As part of the FAA's response to the NTSB recommendation, a CRM training needs analysis was conducted. Cluster analytic results of the identified training needs suggested three categories affecting crew performance: (1) technical skills, (2) crew coordination skills, and (3) the organization context in which flight inspection crews perform. Implications for CRM awareness training are discussed. The purpose of this reort is to document the flight inspection CRM training needs that emerged from the analyses and to recommend steps for developing a flight inspection CRM training program.

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Flight Inspection Crew Resource Management Training Needs Analysis

The training of aircrews has changed markedly from the early days of aviation. Initially, the emphasis of air crew training focused on developing the technical skills of the individual crew members. The underlying assumption was that if crew members were technically proficient at their respective jobs, they would automatically be able to operate effectively as a crew (for historical reviews, see Driskell & Adams, 1992; FAA, 1993, Hartel & Hartel, 1995; Helmreich & Foushee, 1993). During the 1970s, however, evidence from airline accident reports, flight simulator transcripts, and interviews with crew members suggested that the above assumption was inherently flawed. Technical competence, by itself, did not ensure a successful mission. Instead, mission success was dependent on the manner in which technically competent crews coordinated their individual efforts (Cooper, White & Lauber, 1979; Lauber 1987; and Ruffel Smith, 1979). Training to develop aircrew coordination skills became known as Crew Resource Management or simply CRM (FAA, 1993). More recently, organizational factors (in particular those which determine the consequence of performance, and those which provide flight crews with the resources necessary to perform their jobs) have also been found to be important determinants of aircrew performance (Hackman, 1993). These findings suggest that aircrew performance depends on at least three factors: (1) technical competencies, (2) crew resource management skills, and (3) the organizational context in which crews perform.

Issues surrounding the above performance factors were identified in a National Transportation Safety Board (NTSB) report of the October 26, 1993, fatal crash of a Federal Aviation Administration (FAA) flight inspection aircraft, N82 (NTSB, 1994). This was the second fatal flight inspection aircraft accident in five years. In reviewing the factors contributing to the October crash, the NTSB issued one urgent action and seven priority action recommendations to the FAA. Included in the latter was the recommendation to institute Crew Resource Management (CRM) training, as outlined in the FAA CRM Advisory 120-51, at each of Flight Inspection Area Office (FIAO).

Prior to the accident of N82, the FAA was already in the final stages of developing a CRM training course for all FAA aircrews. With the advent of the accident, the FAA Administrator elevated the priority of this initiative, and a CRM task force led by the Civil Aeromedical Institute (CAMI) was created to guide the process of developing a CRM course specifically for the flight inspection mission. Also included in the CRM task force was the FAA's Senior Flight Safety Officer and representation from six FIAOs.

One of the first steps taken by the CRM task force was to conduct a CRM training needs analysis based on issues addressed during the November 1993 safety meetings conducted at each FIAO. These meetings were mandated by the FAA Administrator in response to the accident of N82. The purpose of the meetings was to identify organizational and crew issues that impacted the safety of all FAA flight operations.

"Flight inspection" refers to the airborne tests conducted to ensure that navigational aids are sending accurate signal-in-space guidance, and to ensure that instrument flight procedures are accurate and will safely guide aircraft to their destination. A flight inspection crew consists of a pilot in command (PIC), a second in command (SIC; co-pilot), and an electronics technician (ET). The flight inspection mission differs from other forms of flying (such as air transport) in that most flight maneuvers are conducted within the terminal area, at low altitudes, and at times running counter to the established air traffic flow pattern. This requires a high degree of traffic vigilance, as well as, coordination between the flight inspection crew, air traffic control, and a ground electronics technician.

Although generic CRM programs modeled after commercial airlines have been developed, the FAA's CRM Advisory Circular (120-51A) warns against using such programs without first customizing them to reflect the nature and needs of the specific flying mission. Following that guidance, a CRM training needs analysis was conducted to ensure that the mission-specific concerns of the flight inspection crews were addressed in their CRM awareness training. Specifically, the focus of the needs analysis was to identify: (1) the phases of the flight inspection mission that were most problematic from a CRM perspective, (2) the CRM dimensions that needed to be especially emphasized in a CRM awareness course, and (3) organizational factors that needed to be addressed to support a long term CRM initiative.

This report presents the results of the needs analysis, along with a discussion of the CRM training implications that emerged. However, before proceeding, the reader may find helpful the following background information about CRM, the FAA's prior CRM training initiatives, and information concerning the flight inspection aircraft accidents that highlighted the need for flight inspection CRM awareness training.

CRM Background

Crew Resource Management (CRM) refers to the "effective utilization of all available resources-hardware, software, and personnel-to achieve safe, efficient flight operations" (p. 8, Driskill & Adams, 1992). CRM differs from other forms of team work training both in the nature of decisions that must be made, as well as the consequences of those decisions. Typically, aircrews must make CRM related decisions in a matter of seconds and the results of those decisions have life and death consequences. Although CRM training began with aviation, it now has extended into such other fields as operating rooms (Howard, Gaba, Fish, Yang, & Sarnquist, 1992), nuclear power plants (Gaddy & Wachtel, 1992), and combat units (Andrews, Wagg & Bell, 1992).

The need for specialized training in CRM stems from the developmental tract that many technical fields require of their professionals. For the most part, the emphasis of technical training is on the development of individual knowledge, skills, and abilities. Teamwork is often represented as the simple aggregation of individual efforts. Because of the lack of formal training in teamwork, technically proficient individuals may have well developed strategies for working by themselves, but these same strategies may not be the most effective for use in a group (Salas, Dickinson, Converse, & Tannenbaum, 1992). For example, persons who are used to making decisions on their own may not take the time to inform others of the rationale behind those decisions. Whereas the individual may understand what is going on, others may have only a limited view of the situation, a view that can also be colored by their own perspective.

One of the main emphases, then, of CRM training is to develop the resource management skills necessary to ensure that all group members are operating from a common frame of reference and that this reference is consistent with what is actually occurring. Specific skills developed in CRM awareness training commonly include: (1) communication skills, such as inquiry, advocacy, and assertion; (2) methodologies for identifying problems and making decisions under severe time constraints; (3) self-monitoring skills for critiquing decisions and actions of the crew; (4) conflict resolution skills; (5) skills associated with crew leadership, followership, and concern for the task; (6) interpersonal skills necessary for maintaining a professional crew climate; (7) situational awareness and distraction avoidance skills; (8) workload planning and distribution skills; and (8) identifying personal stressors and developing effective stress reduction techniques (FAA, 1993).

As an organizational intervention, CRM typically involves a three-phase approach (FAA, 1993). This includes formal classroom training, practice and feedback, and organizational reinforcement. In the first phase, the *awareness phase*, CRM principles are taught in a classroom setting and are reinforced through the use of accident recreations, case history discussions, role-playing exercises, etc. The purpose of this training is to provide crew members with a common understanding of how CRM principles apply to their mission, and to practice some basic skills. Once general principles are acquired, they are further refined during the second phase of training, *practice and feedback*. Ideally, this phase of training should be conducted on an annual basis in a simulated mission training environment. Crews then perform mission oriented tasks while being video-taped. Afterwards, crew members view the video playback of their performance and perform a self critique of their CRM skills. Finally, in the third phase, the *reinforcement phase*, the organization ensures that CRM principles become part of the organization's culture by adopting policies, procedures, and practices that are consistent with, and reinforce, CRM principles. Among other actions, this involves incorporating CRM principles in all forms of training, requiring managers to become effective role models for CRM behaviors, and establishing CRM criteria for use in selection, promotion, and performance appraisal decisions. For a more complete review of CRM training and its history, see Driskell & Adams (1992), Hartel & Hartel (1995), and Wiener, Kanki & Helmreich (1993).

FAA CRM Training

Two flight inspection CRM training initiatives preceded the accident of N82. In early 1990, CRM awareness training was delivered to all flight inspection pilots. The course was developed and conducted by United Airlines. Although the course exposed participants to CRM principles, it was not customized to the mission needs of flight inspection crews. Furthermore, electronic technicians were not included in the training. Finally, the course itself was delivered as a stand-alone program, with no formal attempts made to integrate it into a long-term CRM program as described in the previous section.

To address the above weakness, in 1992, under the sponsorship of the FAA's Flight Safety Program, a CRM initiative began, with the goal of developing a long-term CRM training effort for each of the five FAA aircraft programs: (1) flight inspection, (2) flight standards, (3) Washington flight program, (4) research and development, and (5) training academy. The Flight Safety Program targeted the flight inspection aircrews as having the most pressing need for CRM training. Thus, work began to develop a prototype flight inspection CRM training effort that would serve as a guide for the remaining aircraft programs. Guiding this effort was an informal taskforce, consisting of the FAA Senior Flight Safety Officer, CAMI, and representation from flight inspection crews. Throughout 1993, the taskforce reviewed existing aircarrier CRM programs, as well as the results from published CRM research. With the advent of the N82 accident, a formal CRM taskforce was developed and charged to deliver flight inspection CRM awareness training during the second quarter of fiscal year 1994. The new taskforce agreed to developed a one-day post-accident CRM awareness training course which would be followed by a three-day course following the completion of a CRM needs analysis.

Flight Inspection Aircraft Accidents

Although CRM training can be viewed as a proactive means for an organization to ensure the safety of its flight operation, some organizations wait until they have experienced an aircraft accident before they initiate a CRM training program (Helmreich & Foushee, 1993). Described below are the three flight inspection aircraft accidents (two fatal and one non-fatal) that preceded the development of the FAA's CRM awareness training for its flight inspection aircrews. Information concerning these accidents is documented in the NTSB accident report on N82 (NTSB, 1994).

On October 26, 1993, N82, a Beech Super King Air 300/F, crashed into mountainous terrain near Front Royal, Virginia. All three crew members died in the crash. The plane was owned by the FAA and operated by the Atlantic City, New Jersey, Flight Inspection Area Office (FIAO). The NTSB determined that the most probable cause of the accident was the failure of the pilot-in-command to operate under visual flight rules over mountainous terrain. Subsequent investigations conducted by the NTSB revealed that the PIC had a history of ignoring visual flight rules, failing to adhere to checklists, and not acknowledging inquiries by the second-in-command when such matters were brought to his attention. Furthermore, when crew members reported these infractions to the Atlantic City flight operations/scheduling supervisor (FO/SS), the supervisor failed to take corrective action (NTSB, 1994).

In addition to the formal report on N82, two earlier flight inspection aircraft accidents also involved problems with situational awareness, communications, and overall crew coordination. On November 2, 1988, a Rockwell Jet Commander (1121A) operated by the Atlantic City FIAO crashed near Oak Grove, Pennsylvania, killing all three crew members. Based on their investigation, the NTSB determined that the aircraft had entered an area of moderate icing conditions and was in a holding pattern while the crew checked on flight inspection equipment malfunctions. The crew apparently noticed ice accretion and activated the surface de-icing system. Ice broke lose and entered engine intakes, causing both engines to flame out. During emergency descent, the crew attempted to restart engines with no success. In addition, both pilots were reported to have experienced stress in their private lives that could also have affected their performance (NTSB, 1994).

An earlier, non fatal accident occurred on September 29, 1986, when a Rockwell Sabreliner (NA-265) operated by the Oklahoma City FIAO was destroyed while landing near Liberal, Kansas. The NTSB determined that the flying pilot (in this case the SIC) touched down 21 feet short of the runway. Due to the impact the landing gear collapsed and the aircraft traveled the full length of the runway before stopping on a golf course a quarter of a mile away. Also cited as contributing to the accident was the PIC's failure to follow proper flight procedures.(NTSB, 1994).

All three of the above accidents contained elements of ineffective crew resource management. Thus, the accident reports themselves, served as one means of identifying CRM training needs. In addition to accident reports, CRM training needs were also identified by analyzing the results of safety meeting discussions following the N82 accident, and by asking subject matter experts to provide narratives of problematic situations that they had encountered while performing a flight inspection mission. This report summarizes the training needs derived from the last two sources.

METHOD

Participants

Subjects matter experts (SMEs) were recruited during a one-day post accident CRM awareness training course conducted at each of the FIAO. Training participants were advised that they could participate individually in the data collection for the training needs analysis, or they could provide their input to their FIAO's CRM representative. Fifty-eight flight inspection SMEs chose to provide their individual input. This represented 30% of the flight inspection workforce. Subjects consisted of PICs, SICs, and electronics technicians. To protect the anonymity of the individuals and their respective FIAOs, no demographic data were collected. In addition, all surveys were destroyed following data entry and analysis. These measures were taken to assure the participants that they could be candid with their responses, and that no punitive action could result from their participation in the survey.

Instruments

Two written questionnaires were used to collect data for the training needs analysis. The purpose of the first questionnaire (Safety Survey) was to identify: (1) CRM dimensions that needed to be addressed in awareness training; and (2) the organizational factors that needed to be addressed to support a long term CRM effort. The Safety Survey presented SMEs with 109 issues, extracted verbatim from written summaries of the November 1993 safety meeting discussions. For each safety issue, SMEs indicated which of 13 performance categories most applied (see Table 1). Multiple categories could be assigned to a given safety issue. Definitions for the first 10 categories were derived from commonly accepted CRM dimensions (Bowers, Morgan, Salas, & Converse, 1993; FAA, 1993). These categories represented potential CRM awareness training modules. Categories 11 and 12 (skill proficiency and organizational factors) were included, based on the literature previously reviewed. Category 13 (CRM Dimension Not Specified) was included for completeness.

Two kinds of analysis were planned for the Safety Survey. First, safety issues would be sorted by the performance categories to which they most applied. Second, cluster analytic techniques would be used to determine the hierarchical structure of the safety issues and how they related to overall mission success. Whereas the first analysis would identify specific training needs, the second analysis would provide a broader structural context for interpreting those needs.

The purpose of the second questionnaire (Incident Survey) was to identify the phases of flight that were most problematic from a CRM perspective, as well as to provide insight concerning the cause of those

TABLE 1
Performance Categories

1. **Mission Analysis*** - includes monitoring, allocating, and coordinating the resources of the crew and the aircraft; prioritizing tasks; setting goals and developing plans to accomplish the goals; and creating contingency plans.
2. **Situational Awareness*** -refers to identifying the source and nature of problems, maintaining an accurate perception of the aircraft's location relative to the external environment, and detecting situations that require action.
3. **Decision Making*** - includes identifying possible solutions to problems, evaluating the consequences of each alternative, selecting the best alternative, and gathering information needed prior to arriving at a decision.
4. **Communication*** - includes sending, receiving, and acknowledging information among crew members in a way that facilitates the accurate transfer of information
5. **Crew Interpersonal Climate** (CC)** - Refers to the overall interpersonal atmosphere of the crew. It includes the way interpersonal conflicts are resolved, the degree to which members enjoy working together, the shared values they have about their profession, and the degree of comfort the crew has with the way crew activities are coordinated.
6. **Leadership*** refers to directing the activities of others, monitoring and assessing the performance of crew members, motivating members, and communicating mission information.
7. **Adaptability*** - refers to the ability to alter one's course of action as necessary, maintain constructive behavior under pressure, and adapt to internal or external changes.
8. **Assertiveness*** - refers to the willingness to make decisions, demonstrating initiative, and maintaining one's position until convinced otherwise by facts.
9. **Workload Management***** - refers to the ability to schedule, structure, and coordinate mission activities so as not to jeopardize situational awareness during any phase of the mission.
10. **Life Stress***** - refers to stressors outside of the context of work which interfere with a person's ability to perform as expected by self and crew members.
11. **Skill Proficiency**- refers to technical skills, the absence of which adversely impacts the crew's confidence in their ability to carry out the mission.
12. **Organizational Factors** - refers to formal (regulations) and informal (imposed by a given manager) policies and procedures which constrain the way a crew should ideally function.
13. **CRM Not Specified** - refers to any CRM principle not specified in the above list.

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* After Bowers, et al. (1993) definitions of crew coordination demands.

** After Feldman (1968), 3-factor model of cohesion.

*** After FAA Crew Resource Management Training Advisory Circular, 120-51A (1993).

problems. SMEs were given written instructions asking them to describe problematic situations that they had experienced while performing a flight inspection. The instructions were modeled after Flanagan's (1954) critical incidence methodology, commonly used to identify behaviors that differentiate between varying levels of performance. In describing their situations, SMEs were instructed to include: (1) the specific problem that was encountered, (2) the phase of the flight in which the problem occurred, (3) what led up to the incident, (4) what crew members did that was effective or ineffective, and (5) the impact that the problem had on the success of the overall mission. Data from this survey were subject to content analyses by the authors.

Procedures

Both the Safety and Incident surveys were administered during the one day post accident CRM awareness training conducted at each of the FIAOs. The training seminar had a five fold purpose: (1) to present an overview of what was meant by CRM, (2) to outline the steps that would be used to develop a three day flight inspection CRM awareness course, (3) to establish trust and rapport with the flight inspection crews, (4) to deliver a training module on aeronautical decision making, (5) to conduct small group discussions after viewing an aircraft accident scenario similar to the N82 accident. After outlining the CRM course development process, time was set aside for volunteers to participate in the identification of CRM training needs.. Volunteers were briefed on the purpose of the training needs analysis and the part it would play in the course development process. Afterwards, a question and answer period was conducted to alleviate any doubts or concerns participants had about the two surveys. Verbal and written instructions were then provided before administering each survey. A survey administrator was present to answer any additional questions. No time limit was imposed.

RESULTS

Safety Survey

The first step in analyzing the Safety Survey was to construct a 109 by 13 frequency matrix in which the rows contained the 109 issues extracted from the safety meetings, and the columns contained the 13 performance categories identified in Table 1. Cell values represented the frequency with which a given safety issue was matched to a particular category. The maximum value for any cell was 58, corresponding to the number of people who participated in the survey. From this frequency matrix, each column was sorted based on cell values. This produced a priority listing of safety issues associated with each training category. The results of this analysis appear in Table 2.

In the first column of Table 2, training categories are presented in descending order based on the frequency with which they were endorsed. The percentages of endorsement are indicated in parenthesis. Over half of the problems discussed during the safety meetings concerned problems associated with management (20%), crew interpersonal climate (11%), situational awareness (10%), and leadership (10%). Decision making, life stress, adaptability, and assertiveness together accounted for the bottom 11% of the endorsements. Presented in the second column of Table 2 are the training needs that were identified for each training category. These include both training for management to support CRM (indicated under Organizational Factors) as well as training for crew members themselves. Notice that no training needs were identified under the "assertiveness" category. This does not suggest that there is no need for assertiveness training. It simply means that survey respondents did not indicate that assertiveness was related to the issues raised during the safety meetings.

To determine the hierarchical structure of the Safety Survey, the frequency matrix was converted into a proximity matrix, using squared Euclidean distances as a measure of similarity. Clusters were then formed using Ward's method in SPSS for Windows version 6.0. Ward's method forms subgroupings (clusters) based on maximizing the ratio of between-cluster variance over within-cluster variance. The resulting dendogram depicting the hierarchical relationship of five interpretable clusters is shown in Figure 1. These clusters include: (1) technical skills, (2) organizational stressors, (3) crew stressors, (4) situational awareness, and (5) planning and decision making. Training themes associated with each of five clusters are shown in Table 3.

TABLE 2

Crew Resource Management Training Needs

Performance Categories Ranked by Percentage of Endorsement (%)	Training Needs
Organizational Factors (20%)	Need for management to: "walk the talk;" develop and enforce well defined policies and procedures; understand the nature of the flight inspection mission and how managerial performance affects crew performance; establish standardization; and create an atmosphere in which candid exchanges about safety can occur.
Crew Interpersonal Climate (11%)	Need for the entire crew to participate in creating a safe flying environment; to be clear on their respective team roles; and to resolve interpersonal conflicts before flying.
Situational Awareness (10%)	Need for the entire crew to participate in altitude and aircraft position awareness.
Leadership (10%)	Need for the Pilot In Command to clarify roles each crew member will play prior to flying the mission; and to distribute the workload so that the PIC is not over tasked.
Communications (9%)	Need for a pre-flight briefing highlighting the major phases of the mission so that the entire crew is prepared, and the need to create a professional climate for open communication exchanges among crew members.
Mission Analysis (8%)	Need to include organizational factors affecting the mission, in particular, the scheduling of flight inspections, the availability of aircraf and the conduct of pre-flight briefings
Skill Proficiencies (8%)	Need to maintain currency and the need to train to standardization.
Workload Management (7%)	Need to coordinate with air traffic control, and to reduce scheduling pressures.
CRM Dimension not specified (6%)	No training needs identified.
Decision Making (4%)	Need for the crew to take charge of decisions affecting the success of the mission, in particular deciding on whether or not it is safe to fly.
Life Stress (3%)	Need to quickly resolve organizational uncertainty (office closings and relocations).
Adaptability (2%)	Need to adjust to flight check restrictions imposed by air traffic control without creating an adversarial situation, and to adapt to itinerary changes rather than being distracted by them.
Assertiveness (2%)	No training needs identified.

Figure 1 shows that mission success consists of two clusters, one that deals with Technical Performance, and one that deals with Crew Participation. Technical performance is further divided into issues related to technical flying skills, as well as stressors that act to interfere with the performance of those skills. This interference consists of factors residing within the organization and factors that reside within the crews. Crew participation is comprised of issues related to maintaining situational awareness, and planning and decision making.

Table 3 shows that the training needs that emerge from the cluster analysis may be further divided into two categories: (1) areas of personal concern, and (2) areas of personal control. This division is also shown in Figure 1 by the dashed line. Contained in areas of personal concern are those issues that concern flight inspection crews, such as technical skills and organizational stressors, but are outside their personal control. For example, flight crews can request changes in the kind of training that they receive, however, they do not have the power to make those changes. In contrast, areas of personal control, such as crew stressors, situational awareness, planning, and decision making, are more strongly associated with factors that crew members themselves have the power to change.

Incident Survey

In analyzing the results of the Incident Survey, a problem arose due to incomplete data. Of the five factors that SMEs were asked to include in their narratives, only the first two were reported with any degree of clarity. Subsequent discussions with the SMEs revealed they were more comfortable talking about problems than writing about them. Because of problems with incomplete data, the results of the content analyses are reported for heuristic purposes only, and should not be construed as representing scientific rigor.

Data from the CRM Incident Survey were coded by the authors according to the phase of the mission in which problems occurred, as well as the most probable cause of the problem (i.e., weather, person, or equipment failure). This information is provided in the first four columns of Table 4. The numbers recorded in each cell refer to the frequency with which a probable

Figure 1
Hierarchical Classification of Training Needs

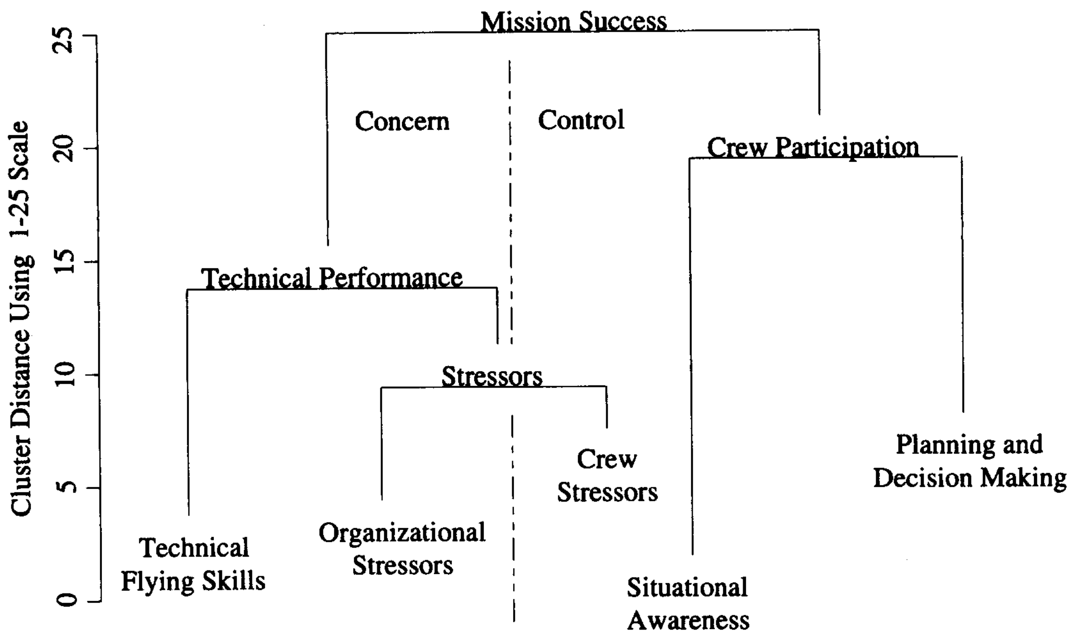

TABLE 3

Cluster Themes

Clusters	Dominant Themes
Areas of Concern	
Technical Skills	Train to a standard, and maintain currency with equipment
Organizational Stressors	Mission-safety conflict, aircraft maintenance problems, and lack of organizational support
Areas of Control	
Crew Stressors	Role conflict, role ambiguity, low morale
Situational Awareness	Altitude and position awareness
Planning and Decision Making	Preflight briefings, aircraft safety

TABLE 4

Probable Cause of Problems Encountered at Each Phase of the Flight Inspection Mission

Mission Phase	Number of People Problems	Number of Weather Problems	Number of Equipment Problems	Row Frequencies	Row %
Pre-Departure	4	0	0	4	6.9%
Take-off	8	0	2	10	17.2%
Enroute	5	5	3	13	22.4%
Inspection	20	3	2	25	43.2%
Landing	2	2	2	6	10.3%
Column Frequencies	39	10	9	58	
Column %	67.2%	17.3%	15.5%		100%

cause occurred within a given phase of the mission. In addition, Table 4 also shows column and row frequencies and percentages.

The most probable cause of the problems reported in Table 4 was associated with people-related issues (67.2%) involving interactions among crew members and with air traffic control and airway facilities ground maintenance. This was followed by weather-related problems (17.3%), and equipment malfunctions (15.5%). Most of the incidents occurred while performing the flight inspection (43.2%), followed by enroute (22.4%), take-off (17.2%), landing (10.3%), and pre-departure (6.9%). A content analysis of the people-related problems suggested three problematic areas involving: (1) errors in information processing (e.g., situational awareness, and decision making); (2) errors in information transfer (i.e., communications); and (3) factors associated with the way crew members related to each other (e.g., interpersonal climate).

A second content analysis of the CRM incidents was conducted to identify the CRM performance dimensions associated with a given incident. Following the same procedures used by SMEs in the Safety Survey, the authors identified the performance categories (see Table 1) that most applied. Percentages of incidents associated with a given performance category were then derived as reported for the safety survey. This information is presented in column two of Table 5. For comparison purposes, the results of the Safety Survey are also shown in column 3. For the most part, the rank order (based on percentage values) of the CRM categories are the same for both surveys. Notice, however, that there is an extreme difference associated with two CRM categories, decision making and organizational factors. Whereas decision making was a significant factor (22%) associated with the CRM incidents, it played a relatively minor role in the CRM safety issues (4%). Similarly, organizational factors were the dominant issues discussed in the CRM safety survey (20%), but they contributed little (1%) to the factors associated with the CRM incidents. These differences have important implications for CRM training and will be discussed later in this report.

TABLE 5

Performance Category Comparisons between Incident Survey and Safety Survey

Performance Categories	Incident Survey Percentage of Occurrences	Safety Survey Percentage of Endorsements
Decision Making	**22%**	**4%**
Crew Interpersonal Climate	22%	11%
Situational Awareness	20%	10%
Communications	15%	9%
Mission Analysis	8%	8%
Assertiveness	7%	2%
Leadership	3%	10%
Workload Management	2%	7%
Organizational Factors	**1%**	**20%**
Skill Proficiencies	0%	8%
Life Stress	0%	3%
Adaptability	0%	2%
CRM Dimension not specified	0%	6%

DISCUSSION

The cluster analytic results of the training needs analysis support earlier findings that flight crew performance is dependent on three factors: (1) technical skills, (2) resource management skills, and (3) the organizational context in which flight crews operate. As shown in Figure 1, technical performance and crew participation form two distinct classifications of training needs, with organizational and crew contextual factors acting as stressors that interfere with the technical performance of flight inspection crews. Furthermore, the training needs that emerge from this classification may be further divided into two categories: (1) those factors over which flight crews have control, and (2) factors that concern flight crews, but control of which resides within the organization. Using the structural framework of Figure 1, several training implications are especially worth noting.

First, crew members reported problems with the technical training they received. In particular, pilots complained that some of them were not getting enough flying time which made them feel not as technically proficient as they would have liked. In addition, pilots were not always checked out on equipment modifications prior to conducting a flight inspection mission. Since the single most important resource that crew members possess is technical skill, technical training deficiencies, such as these, must first be addressed for crew resource management training to have a positive effect on crew performance.

Second, the results of the needs analysis suggested that crews would benefit by more active crew participation, particularly with regard to three areas: (1) pre-mission briefings, (2) decisions about safety, and (3) maintaining aircraft situational awareness. The importance of a pre-mission briefing cannot be over emphasized. It is during this briefing that crews develop what Cannon-Bowers, et al. (1993) and others have called a shared mental model of the mission (for a review of the literature see Klimoski & Mohammed, 1994). A shared mental model may be thought of as a common set of expectations about what will occur during a mission. Included in this mental model are expectations concerning the time-sequencing of mission events, the tasks to be performed, and how individual efforts will be coordinated (Cannon-Bowers, et al., 1993). When a pre-mission briefing is lacking, crew members must rely on past experiences to guide their performance. The implicit assumption is that everyone is operating with the same set of expectations. Unfortunately, it is usually under non-routine conditions that the fallacy of this assumption surfaces (Orasanu, 1994).

In addition to establishing a shared mental model of the mission, the pre-mission briefing is an excellent time to address the leadership, communications, and crew climate concerns, as indicated in Table 2. How a PIC conducts a pre-mission briefing sets the stage for the communication patterns that will emerge among crew members (Hackman, 1993). If the PIC provides a well organized briefing and solicits input, then he or she establishes an atmosphere of professional competency in which crew members feel free to voice concerns. Furthermore, to the extent that crews can resolve differences of opinions prior to flight, they are less likely to be distracted by those differences during the course of the mission. By involving all three crew members (PIC, SIC, and ET) in decisions regarding flight safety, crews create a climate in which flight safety is a shared responsibility. The need for such involvement is reflected in the decision making and situational awareness CRM training needs presented in Table 2.

A third implication derived from the needs analysis concerns the effects that organizational and crew stressors have on the technical performance of a flight inspection mission. Crew stressors, such as role ambiguity and role conflict, have already been addressed as issues that should be clarified during a pre-mission briefing. Organizational stressors, however, require further elaboration.

Flight inspection crews are mission oriented. Their job is to fly the aircraft over a prescribed course under the guidance of ground-to-air flight navigation equipment, while onboard electronic equipment records the aircraft's relative position in space. The ground facility is certified when the recorded data indicate the aircraft flew the desired course within specific tolerances. Facilities must be flight checked and certified prior to use when ground navigation aids or equipment are installed, repaired, removed, or replaced and when required periodic inspections are due. Navigational aids may also be flight checked following aircraft accidents.

Due to a variety of reasons (such as a facility outage at O'Hare International, a high density traffic airport), there can be increasing pressure on flight crews to perform flight checks during marginal weather or during off peak traffic hours late at night when crews tend to be fatigued. Crews consider these conditions to be unsafe, and problems can arise when flight crews perceive (correctly or incorrectly) that their management is more concerned about getting the job done than they are about their safety.

In a study conducted by Witt, Hilton, & Helman (1994), workplace safety perceptions were found to be directly related to perceived managerial support for safety. Moreover, management was perceived to be most supportive of safety when employees experienced a work climate that was "relatively free from politics and unfairness, and in which everyone shared a common view regarding the importance of safety." The authors concluded that how managers deal with everyday problems sets the tone for how they will deal with safety related issues. This conclusion is further supported by the organizational factor concerns reported in Table 2. In particular, flight crews expressed the need for management to understand how managerial performance affects crew performance, as well as the need for management to create an atmosphere in which candid exchanges about safety can occur.

Concerns about organizational stressors are valid and need to be addressed by the organization; however, caution is advised when addressing these issues during CRM awareness training. The inclusion of organizational factors is likely to shift the focus of CRM training from what Covey (1989) calls "areas of control" to "areas of concern." Areas of concern are those issues in which crews have a vested interested, but little personal control over the outcome. In contrast, areas of control represent issues in which the crews, themselves, have the power to effect change. Covey further notes that there is a tendency for people to spend a considerable amount of time attempting to address areas of concern while neglecting areas of control. This division is shown in Figure 1 and is reflected in the frequency that organizational factors were discussed during the safety meetings. Of all CRM categories, organizational factors was the most frequently discussed, but it is the area over which crews have the least personal control.

One way of keeping CRM awareness training focused on areas of control is to develop training scenarios around situations that crews have actually experienced while in flight. This can be seen by the Table 5 comparison between the rank ordering of CRM categories derived from the Safety Survey, and those derived from the CRM Incidents. Whereas organizational factors represented 20% of the issues discussed in the safety meetings, they represented only 1% of the CRM incidents reported by flight inspection crews.

The above results further suggest that by simply changing the field of reference from problems in general (as discussed in the November 1993 safety meetings) to problems in the air (as reported in the Incident Survey), crew members are more apt to take personal responsibility for their actions. This projected outcome forms the basis of the practice and feedback phase of CRM training (FAA, 1993). In this phase, instead of evaluating the performance of others (as in watching accident recreations), crews are videotaped while performing under mission simulated conditions. Afterwards, crews view the video playback of their performance and critique themselves on their resource management skills. Factors affecting crew performance are often self-evident, however, a trained facilitator may be necessary to ensure that crews perform a self critique on more than just their technical performance (Butler, 1993).

Finally, in support of developing CRM awareness training, data from the CRM incident survey (see Table 4) suggest that most flight inspection CRM-related problems (43.2%) occurred while performing aircraft maneuvers during the airborne testing phase of flight (i.e., the actual flight inspection). These problems involve communication errors, errors in information processing, and factors associated with the crew's interpersonal climate. Although generic CRM training materials in those areas exist, the FAA CRM Advisory Circular (120-51A) cautions against using such material without first adapting it to reflect the nature and needs of the organization.

The most successful CRM training programs are those which are internally developed (Captain J. E. Carroll, retired United Airlines Vice President of Safety and Training, personal communications, May 17, 1994). This is because crew resource management is more than just a course, it is a philosophy or way of knowing and thinking about flying a mission. This philosophy is manifested in an organization's culture. By developing an internal course, organizations must address such questions as: (1) what is the purpose of the flying mission and what are its priorities, (2) how do organizational policies and practices affect the flying mission, (3) what really takes place when a flight crew flies a mission, (4) how prepared are flight crews for accomplishing their mission, and (5) what habits have flight crews developed that enhance or impede the success of a mission? When a generic course is used to deliver CRM training, there is a tendency for organizations to side-step many of these harder questions, and instead just implement a course as a "quick fix." As a consequence, such CRM programs tend to fade over time.

There is a down side to developing a CRM program, however, when internal resources are used: it takes time, and mistakes will be made. Thus, unless an organization is willing to commit the necessary resources to improve upon initial efforts, its CRM program is likely to fall below expectations. In addition, flight crews should understand that their CRM program will evolve over time, with its success dependent upon the degree to which flight crews are actively involved in course development, program implementation, and program evaluation. For these reasons, the following recommendations are made: (1) develop a CRM awareness course from within the FAA, rather than trying to fit AVN to a generic CRM course; (2) create a CRM program that can be sustained over the long term, rather than attempting to implement a "quick fix;" (3) involve the flight crews in the course development process; (4) develop a common language between the flight crews and AVN management for discussing CRM issues; (5) develop a mission-based flight inspection simulation training environment for the practice and feedback phase of CRM training; and (6) adopt organizational reinforcers to support the principles of CRM.

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