



National Transportation Safety Board
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Safety Recommendation

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U.S. air carrier operations are extremely safe, and the accident rate has declined in recent years. However, among the wide array of factors cited by the National Transportation Safety Board as causal or contributing to airplane accidents, actions or inactions by the flightcrew have been cited in the majority of fatal air carrier accidents. Recognizing that deficiencies in various aspects of the aviation system may underlie the errors made by flightcrews, the Safety Board conducted a study¹ to learn more about flightcrew performance by evaluating the characteristics of the operating environment, the flightcrews, and errors² made in major accidents of U.S. air carriers.

The Safety Board selected for study the accidents³ of U.S. air carriers operating under Title 14 Code of Federal Regulations Part 121 that occurred between 1978 and

¹ National Transportation Safety Board. 1994. A review of flightcrew-involved, major accidents of U.S. air carriers, 1978 through 1990. Safety Study NTSB/SS-94/01. Washington, DC.

² As used in the Safety Board's study, "error" means a specific instance in which a crewmember responded inadequately to the existing situation. It does not connote improper motivation or intentions on the part of the crewmember.

³ One case was classified as an incident by the Safety Board. Because it was the subject of a major investigation, equivalent to those received by the accident cases, the incident produced a substantial amount of human performance data; thus, it was included in the study. For convenience, it is referred to as an accident.

1990, for which the Board had conducted major investigations and cited the actions of the flightcrew as causal or contributing factors. Although the 37 accidents that fulfilled the selection criteria are not necessarily a representative sample of all air carrier accidents and flights, they do represent all of the flightcrew-involved, Part 121 air carrier accidents for which the Safety Board has conducted a major investigation during the 12-year period.

Measures of flightcrew characteristics, the operational environments within which these accidents occurred, and the specific errors associated with flightcrew performance during these accident flights were extracted from the Safety Board's investigation records and accident reports. Characteristics of the accidents and the circumstances associated with the accident sequences were evaluated to establish the operational context of the accident.

Previous accident investigations have identified a large set of operational and human performance factors as being related to the occurrence or seriousness of errors. The data from the accident investigation dockets were sufficient to examine 24 variables. The variables pertaining to characteristics of the accidents' operating environments were local time of day, type of operation, type of aircraft, phase of operation, weather factors, mechanical factors, other (non-flightcrew) personnel factors, and flight delay status. The variables pertaining to characteristics of the crewmembers were time since awakening, duty hours, off-duty hours prior to flight, time zone change, total flight hours, hours in crew position, years in crew position, hours in aircraft type, hours in aircraft type and crew position, hours in certain numbers of days prior to the accident, past unsatisfactory rating, crew assignment (who was flying), captain/first officer first day together, and captain/first officer first flight together.

The distributions of the operational context variables and crew characteristics in the accidents were examined and, when feasible, compared with illustrative examples of non-accident flights. Associations between the operational context variables and the number and types of errors were also examined. Despite the inherent limitations of accident data, the study identified a number of potentially interesting associations. The findings of the study, as well as the subject areas that could not be evaluated in the study, may suggest areas for further human factors research and underscore the importance of the National Plan for Aviation Human Factors,⁴ a program that the Safety Board believes should receive a high priority from the Federal Aviation Administration (FAA).

⁴ The National Plan for Aviation Human Factors was established by the Aviation Safety Research Act of 1988 (P.L. 100-591).

Errors: Definition, Classification, and Distribution

For the Board's study, an error was defined as a discrete instance in which a crewmember (1) did something that should not have been done, (2) did something inadequately, or (3) did not do something that should have been done. For example, "Did not extend takeoff flaps."

The definition of error was restricted in the study by the limited information that investigators can obtain reliably from an accident. Investigators can infer an inadequate action or inaction by analyzing various components of the accident airplane: the CVR, flight data recorder, control surfaces, instruments, and switches. This type of information was available to accident investigators and used to identify specific errors of action or inaction. But an error in perception, comprehension, attention, knowledge, memory, or reasoning—which may have led to an error of action or inaction—rarely leaves a trace in the wreckage and is difficult to determine conclusively in retrospect. Consequently, these types of errors were not identified.

The 37 accidents were reviewed to identify the specific errors that flightcrews made during the accident sequences. The Safety Board identified specific errors from the following sources of information: (1) cause/factor statements in the brief format accident report; (2) statement of probable cause and conclusions in the aircraft accident report; and (3) factual material and Safety Board analytical statements in the aircraft accident report. A brief narrative was produced to describe each error identified in the 37 accidents.

A total of 302 specific errors were identified in the 37 accidents. Names of air carriers and crewmembers were removed from data records prior to analyzing the errors and their operational contexts.

Each of the 302 identified errors was classified into one of nine types of errors adapted from an error classification scheme used by NASA.⁵

The nine error types are defined below.

Primary Errors.—Eight of the nine descriptive types of errors⁶ are considered primary errors; that is, they are not dependent on making a prior error.

1. Aircraft handling: Failure to control the airplane to desired parameters.

⁵ 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.

⁶ Examples of the types of errors are provided in the text of the study.

2. Communication: Incorrect readback, hearback; failure to provide accurate information; providing incorrect information.
3. Navigational: Selecting wrong frequency for the required radio navigation station; selecting the wrong radial or heading; misreading charts.
4. Procedural: Failure to make required callouts, making inaccurate callouts; not conducting or completing required checklists or briefs; not following prescribed checklist procedures; failure to consult charts or obtain critical information.
5. Resource management: Failure to assign task responsibilities or distribute tasks among crewmembers; failure to prioritize task accomplishment; overloading crewmembers; failure to transfer/assume control of the aircraft.
6. Situational awareness: Controlling aircraft to wrong parameters.
7. Systems operation: Mishandling of engines or hydraulic, brake, and fuel systems; misreading and mis-setting instruments; failure to use ice protection; disabling warning systems.
8. Tactical decision: Improper decisionmaking; failure to change course of action in response to signal to do so; failure to heed warnings or alerts that suggest a change in course of action.

Secondary Errors.—In contrast to a primary error, a secondary error (the ninth descriptive error type) is dependent on another crewmember previously or simultaneously making a primary error.

9. Monitoring/challenging: Failure to monitor and/or challenge faulty action or inaction (primary error) by another crewmember.⁷

Procedural, monitoring/challenging, and tactical decision errors were the most prevalent types, accounting for 73 (24 percent), 70 (23 percent), and 51 (17 percent) of the 302 errors, respectively.

⁷ Every primary error was not linked to a secondary error (failure to monitor or challenge the primary error). Some of the primary errors were challenged; thus, no secondary error was made. Other primary errors were not challenged, but there was insufficient evidence to document a secondary error. Also, in some cases, a monitoring/challenging failure was associated with multiple primary errors that were similar and occurred at nearly the same moment. For analytical purposes, these monitoring/challenging failures were linked to only one of the primary errors.

The most common procedural errors identified were failures to make required callouts, failures to initiate required checklists, and the improper conduct of checklists. The failures to make required callouts typically were observed in accidents that occurred during approach and landing, whereas failures to initiate required checklists or the improper conduct of checklists were most frequent in accidents that occurred during takeoff. The most common tactical decision error made was the failure to execute a go-around, or missed approach, during an unstabilized approach.

Of the 232 primary errors identified, 123 (53 percent) were errors of omission, and 109 (47 percent) were errors of commission. Procedural and resource management errors were largely errors of omission, whereas most of the aircraft handling, communication, and systems operation errors were errors of commission. All of the navigational errors were errors of commission.

Error Types and Carryover of Causal Errors to Subsequent Phase of Operation

Only one accident occurred during the taxi phase of operation. However, errors made during the taxi phase of operation were more consequential than would be suggested by considering only the phase of flight in which the accident actually occurred. For example, 8 of the 10 accidents that occurred during the takeoff phase were caused, in part, by errors made during the preceding taxi phase.

The errors made during the taxi phase of 6 of the 10 takeoff accidents were procedural: uninitiated or inadequately performed checklists. The Safety Board has previously addressed the need for improved checklists. As a result of its investigation of the August 1987 crash of a Northwest Airlines DC-9-82 at Detroit Metropolitan Wayne Airport in Romulus, Michigan, in which the flaps were not extended for takeoff, the Board issued the following safety recommendation to the FAA.⁸

Convene a human performance research group of personnel from the National Aeronautics and Space Administration, industry, and pilot groups to determine if there is any type or method of presenting a checklist which produces better performance on the part of user personnel. (A-88-68)

In response to this 1988 safety recommendation, the FAA contracted with the Volpe National Transportation Systems Center (VNTSC), a facility of the Research

⁸ National Transportation Safety Board. 1988. Northwest Airlines, Inc., McDonnell Douglas DC-9-82, N312RC, Detroit Metropolitan Wayne County Airport, Romulus, Michigan, August 16, 1987. Aircraft Accident Report NTSB/AAR-88/05. Washington, DC.

and Special Programs Administration within the DOT, to study checklist design and usage. The VNTSC reported its results to the FAA in April 1991.⁹ Effective June 30, 1991, the FAA revised its Air Transportation Operations Inspector's Handbook to provide additional guidance to principal operations inspectors (POIs) for evaluating the acceptability of air carrier checklists.

In a May 28, 1992, letter to the FAA, the Safety Board stated, "Although [it] agrees with the intent of the revisions, the Board believes that the POIs, without human factors expertise and specific checklist design guidelines, cannot be expected to adequately address this complex problem." In the letter, the Safety Board classified Safety Recommendation A-88-68 "Closed—Unacceptable Action."

The Safety Board recognizes that, as a result of research already completed on checklists, many of the shortcomings in traditional checklist design and usage have been identified. The 1991 report on checklists concluded that "there are some [air] carriers who are operating with poorly designed checklists and manuals, and who have flightcrews who are not well trained in the use of these aids and who admit to not using them when they were expected to." The report made 11 recommendations to the FAA to further conduct research in several areas, including checklist presentation methods, checklist format, typography, readability, and user behavior. It recommended the development of prototypes using human factors principles, standard terminology, and the application of new technology.

NASA has sponsored several studies of checklist design and usage.¹⁰ One of the NASA studies recognized that "the human factors of a paper checklist as a display...is only the outer shell of the problem." The study identified "the core of the problem...as the design concepts and the social issues surrounding the use of the checklist that have led some pilots to misuse it or not use it at all."¹¹ The study concluded with 16 general guidelines for the design and use of checklists.

⁹ Turner, John W.; Huntley, M. Stephen, Jr. 1991. *The use and design of flightcrew checklists and manuals*. Report No. DOT/FAA/AM-91/7. Washington, DC: U.S. Department of Transportation, Federal Aviation Administration.

¹⁰ The research includes the following: (a) Degani, A.; Weiner, E.L. 1990. *Human factors of flight-deck checklists: the normal checklist*. NASA Contractor Report 177549. Moffett Field, CA: NASA Ames Research Center. (b) Degani, A.; Weiner, E.L. 1991. *Philosophy, policies, and procedures: the three P's of flight-deck operations*. In: Jensen, R.S., ed. *Proceedings, 6th international symposium on aviation psychology; 1991 April 29-May 2; Columbus, OH*. Columbus, OH: The Ohio State University: 184-191. Vol. 1. (c) Linde, C.; Goguen, J. 1991. *Checklist interruption and resumption: a linguistic study*. NASA Contractor Report 177460. Moffett Field, CA: NASA Ames Research Center.

¹¹ Degani and Weiner (1990, p 4).

However, because of the recurrence of causal errors involving checklists made during the taxi phase of operation, the Safety Board believes that the FAA should improve the error-tolerance of air carrier checklist procedures for taxi operations, by enhancing flightcrew monitoring/challenging of checklist execution, providing cues for initiating checklists, and considering technological or procedural methods to minimize the omission of any items on a checklist. Further, once these procedures have been developed, the Safety Board urges the FAA to provide specific guidance to air carriers for implementing them.

Crew Assignment and Pattern of Errors

In more than 80 percent of the accidents, the captain was the flying pilot and the first officer was the non-flying pilot.¹² Even when the subset of accidents believed to be least biased toward crew assignment 1 was examined, 13 of the remaining 15 accidents (87 percent) involved crew assignment 1. In contrast, crew assignment 1 prevails during about 50 percent of all non-accident flights, based on the common practice among air carrier pilots of swapping flying duties on alternate flight legs. Although the Safety Board was unable to determine any particular significance to, or draw any conclusions from, this finding alone, many of the accidents involving crew assignment 1 demonstrated a consistent pattern of errors by captains and first officers.

Crew Assignment and Captain Decisionmaking.—The error type observed most frequently for captain/flying pilots in the 37 accidents was a tactical decision error (with more than half constituting a failure to initiate required action). When serving as the flying pilot, captains must devote at least some of their attention and other cognitive resources to aircraft control. Research on captain decisionmaking suggests that captains take significantly more time to make decisions while flying the airplane than when they are the non-flying pilot. As part of a full-mission simulation experiment, NASA tested captains for the amount of time required to decide to shut down a malfunctioning engine.¹³ Captain/flying pilots took more time to make the decision than captain/non-flying pilots.

Also, a captain/flying pilot who decides to make a change must perceive a need to change, then must alter his or her own current plan and behavior. The decision to change a course of action may be inhibited by overconfidence in ability or the

¹² For convenience in the study, this combination of flightcrew positions and duties (captain was the flying pilot and first officer was the non-flying pilot) was referred to as crew assignment 1. Crew assignment 2 referred to the combination of the first officer as the flying pilot and the captain as the non-flying pilot.

¹³ Ruffell Smith (1979).

earlier decision to engage in the ongoing course of action.¹⁴ These dynamics probably were relevant in eight accidents involving a failure to execute a go-around during unstabilized approaches.

Crew Assignment and First Officer Monitoring/Challenging.—Tactical decision errors were the primary error type most frequently associated with monitoring/challenging failures. Fifty-one tactical decision errors were identified in 25 of the 37 accidents; 28 of these errors were not challenged. Of these 28 unchallenged errors (which were identified in 17 of the accidents), 20 (71 percent) were errors of omission. The 20 tactical decision/errors of omission were identified in 13 accidents.

The tactical decision/errors of omission may be particularly difficult to catch, especially for first officers. In monitoring and challenging a captain's tactical decision error, a first officer may have difficulty both in deciding that the captain has made a faulty decision, and in choosing the correct time to question the decision. A first officer may be concerned that a challenge to a decision may be perceived as a direct challenge to the captain's authority. For example, challenging a captain's failure to execute a go-around may be much more difficult for a first officer to do, in a timely fashion, than challenging a straightforward procedural error whose correction is unarguable, such as failure to turn on a transponder prior to takeoff.

The absence of action (error of omission) may not call attention to itself as an error as readily as an error of commission. Also, in many situations there may be a period of seconds or minutes when action could be taken. Thus, there may be no distinct signal or cue that *now* is the time to speak up about another crewmember's failure to act, and a challenge may be deferred in hope that the error will be corrected soon.

¹⁴ Nagel, David C. 1988. Human error in aviation operations. In: Weiner, Earl L.; Nagel, David C., eds. Human factors in aviation. San Diego, CA: Academic Press, Inc.: 263-303. Chapter 9.

Strategies for Improving the Dynamics of Captain Decisionmaking and First Officer Monitoring/Challenging

The pattern of error types observed in many of the accidents involving crew assignment 1 indicates that improvements are needed in the monitoring/challenging function of crewmembers, especially as related to challenges by first officers of the errors made by captains. The Safety Board recognizes that monitoring/challenging procedures generally are included in air carrier standard operating procedures and training programs. In addition, many air carriers address this subject in crew resource management (CRM) programs¹⁵ they voluntarily provide to their flightcrews. However, the specific monitoring/challenging problem areas identified in this study—particularly decisionmaking errors, errors of omission, and errors made during the taxi phase of operation—warrant special attention. Further, the Safety Board believes that air carriers could enhance flightcrew performance in these areas with strategies designed for use in conjunction with crew resource management training and initial operating experience. Also, flight deck automation has the potential to improve the monitoring/challenging function.

Crew Resource Management Programs.—A comprehensive CRM program is one tool an air carrier can use to improve both decisionmaking and monitoring/challenging by crewmembers. The CRM programs currently implemented by some air carriers attempt, in addition to other objectives, to enhance crewmembers' skills in monitoring and challenging.

The Safety Board has previously addressed crew resource management as a result of its investigations of several air carrier and regional airline accidents. In a safety recommendation issued on January 9, 1990, the Board asked the FAA to:

Require 14 CFR Part 121 operators to develop and use CRM programs in their training methodology by a specified date. (A-89-124)

In its response of April 12, 1990, the FAA indicated that it was considering proposed rulemaking to require CRM training. About a year later, on June 17, 1991, the FAA informed the Safety Board that it had issued special regulations to establish alternative methods for air carrier training (the Advanced Qualification Program, or AQP). Air carriers have the option of adopting AQP's alternate training and checking methods, which require CRM and line operational simulations. The FAA also

¹⁵ In its study, the Safety Board uses the term crew resource management rather than cockpit resource management. Crew resource management has been widely adopted by the FAA and industry to describe a philosophy of CRM that includes the management of resources outside the cockpit (such as flight attendants and dispatchers) as well as the resources inside the cockpit. In keeping with this philosophy, many CRM programs allow for joint participation between flightcrew and non-flightcrew personnel.

reiterated in its 1991 response that proposed rulemaking to require CRM training was still under consideration. On December 11, 1991, the Safety Board classified Safety Recommendation A-89-124 as "Open—Acceptable Response," based on the AQP information from the FAA and pending further action to require CRM training.

Crew resource management was also addressed as a result of the Safety Board's investigation of a June 8, 1992, GP Express regional airline accident at Anniston, Alabama.¹⁶ Following the investigation, the Board recommended that the FAA:

Develop guidance and evaluation criteria for principal operations inspectors to use to ensure that airline cockpit resource management training programs adequately address crew interaction, decision-making process, information gathering, flightcrew communication, and leadership skills. (A-93-37)

In its June 16, 1993, response to Safety Recommendation A-93-37, the FAA indicated that "guidelines for developing, implementing, reinforcing, and assessing crew resource management programs" are provided in Advisory Circular (AC) 120-51A, which the FAA issued on February 10, 1993.

Through the advisory circular, the FAA provides non-regulatory guidance to air carriers regarding the content of CRM programs. According to AC 120-51A, CRM programs should include three components to develop and maintain crew resource management skills. First, *initial indoctrination and awareness* training introduces the concepts of CRM through classroom lectures, group exercises, and videotape presentations. Second, *recurrent practice and feedback* sessions reinforce CRM by placing full crews in realistic flight scenarios (using simulators or flight training devices) and giving them feedback about their performance from videotaped segments of their sessions. Third, *continuing reinforcement* of CRM must be provided throughout training and line operations by check airmen, instructors, and managers who are attuned to and supportive of CRM.

In a reply to the FAA on November 19, 1993, the Safety Board indicated its support of the guidance provided in AC 120-51A and agreed that the AC was appropriate guidance for FAA principal operations inspectors to use in evaluating air carrier CRM programs. Accordingly, the Board classified Safety Recommendation A-93-37 "Closed—Acceptable Action."

¹⁶ National Transportation Safety Board. 1993. *Controlled collision with terrain, GP Express Airlines, Inc., flight 861, a Beechcraft C99, N118GP, Anniston, Alabama, June 8, 1992. Aircraft Accident Report NTSB/AAR-93/03.* Washington, DC.

The Safety Board notes that the FAA makes the following statement in the AC, based on research conducted by NASA and the FAA: "...when there is no effective reinforcement of CRM concepts by way of recurrent training, improvements in attitudes observed after initial indoctrination tend to disappear, and individuals' attitudes tend to revert to former levels." The three components of CRM, as described in AC 120-51A, form a comprehensive CRM program, and the Safety Board concurs with the FAA that flightcrews should receive all three components to improve their crew resource management performance. Further, because of the patterns of errors observed in this safety study, the Board concludes that comprehensive CRM training should be mandatory. Therefore, the Safety Board urges the FAA to require U.S. air carriers operating under 14 CFR Part 121 to provide, for flightcrews not covered by the Advanced Qualification Program, a comprehensive crew resource management training program as described in Advisory Circular 120-51A. The Board also classifies Safety Recommendation A-89-124 "Closed—Acceptable Response/Superseded" by the new recommendation issued as a result of this study.

The Safety Board is concerned about the high incidence, in the accident flights, of first officer failures to challenge decision errors made by the captain/flying pilots. The high incidence highlights a need for air carrier training programs to devote additional attention to the monitoring/challenging function of crewmembers. Literature about CRM addresses monitoring/challenging as principles of inquiry, advocacy, and assertion. The FAA describes this aspect of CRM, in Advisory Circular 120-51A, as "training in the potential benefits of crewmembers advocating the course of action that they feel is best, even though it may involve conflict with others." The Safety Board recognizes that many of the current CRM programs use classroom lectures and role-playing exercises to address inquiry, advocacy, and assertion.

The Board believes that a positive attitude toward monitoring/challenging and effective use of monitoring/challenging procedures can be developed and enhanced with appropriate training. In addition to training crewmembers in such matters under classroom conditions, air carriers could maximize the effectiveness of the training by providing crewmembers opportunities to practice monitoring and challenging under the realistic conditions of line operational simulations (LOS).

According to FAA Advisory Circular 120-35B, "Line Operational Simulations," LOS includes line-oriented flight training (LOFT), special purpose operational training (SPOT), and line operational evaluation (LOE). LOFT and SPOT could provide opportunities for pilots to practice monitoring and challenging other crewmembers' errors.

The AC defines LOFT as, "...training in a simulator with a complete crew using representative flight segments which contain normal, abnormal, and emergency

procedures that may be expected in line operations.” LOFT is no-jeopardy,¹⁷ full-mission, simulator training in which crews are provided with an opportunity to practice technical and CRM skills during routine and abnormal flight conditions. With regard to the practice of CRM skills during LOFT, the AC states:

LOFT scenarios should contain CRM skills, whereby crewmembers utilize and reinforce various CRM concepts. CRM skills should be integrated into each operator’s maneuver/procedure learning objectives. In addition, focused CRM training could be provided independently during separate Special Purpose Operational Training.

Monitoring/challenging could be practiced in LOFT scenarios designed to increase the likelihood of operational errors by the flying pilot resulting from high workload, distractions, or complacency. The Safety Board supports emphasis in LOFT briefings and debriefings on the monitoring and challenging of errors that occur during the course of the session. However, given that the flying pilot might perform reasonably or even flawlessly under such conditions, this approach does not guarantee that pilots will have experienced an opportunity to practice monitoring and challenging of errors under realistic conditions.

One way to ensure that the non-flying pilot has an opportunity to practice monitoring/challenging is through the intentional introduction of a procedural or decision error by the flying pilot in the LOFT scenario. This technique would make certain that the non-flying pilot is confronted with the opportunity to detect and challenge the error made by the flying pilot. There may be some concern, however, that instructing the flying pilot to generate an error deliberately during LOFT violates the underlying premise that LOFT be conducted under realistic conditions. The intentional generation of errors by participants represents a departure from standard air carrier training practice, and it would have to be executed with due regard to the possibilities for transferring negative habits to line flight operations. However, it is the Board’s opinion that the benefits of practicing monitoring/challenging under realistic conditions outweigh the potential negative aspects of artificial interruption of LOFT scenarios and deliberate introduction of errors by LOFT participants.

As an alternative to, or in conjunction with LOFT, training in monitoring/challenging also could be provided to pilots through SPOT, which AC 120-35B defines as training, conducted in a simulator or advanced training device, designed specifically to target unique areas of concern, including CRM skills. Like LOFT, SPOT is operationally-oriented flight training, utilizing scenarios that are real-world and real-time. SPOT is also no-jeopardy training and places emphasis on

¹⁷ AC 120-35B states, “LOFT is ‘no-jeopardy’ training; i.e., the instructor does not issue a passing or failing grade to a participating crewmember.”

instructor feedback and critique. Unlike LOFT, SPOT may be conducted on a wide range of flight simulators or training devices. Further, SPOT allows for direct instruction and the interruption of the scenario by the instructor.

Many air carriers provide LOFT or LOS training to various crewmembers at various times; for example, as initial (new hire) training, when being upgraded to a new crew position, when making a transition to a new aircraft type, or during recurrent training. Air carriers with more extensive CRM programs provide LOS training that is oriented around the briefing, practice, and debriefing of CRM concepts, usually on an annual basis during recurrent training. All air carrier pilots are not currently provided such training.

The Board's study found that of the 32 accidents for which information was available, 53 percent of the first officers involved in the accidents had not yet completed their first year of service in the first officer position. Thus, any CRM-oriented LOS training that was to be provided them during forthcoming recurrent training would not have occurred prior to the accident flight. The behavior of first officers, including inquiry and assertion, has been viewed as heavily influenced by the personality, attitudes, and resource management style of captains.¹⁸ The Safety Board supports the attention given by CRM programs to captains' resource management. However, CRM-oriented LOS training, if provided, could have positive effects on the ability of subordinate crewmembers—first officers and flight engineers (when applicable)—to interact successfully with captains. Further, such training may be especially helpful in dealing with problems associated with crew unfamiliarity.¹⁹

The FAA does not maintain a data base of information about which air carriers provide CRM-oriented LOS training, what crew positions receive the training, when the training is provided, or what specific educational objectives, if any, are incorporated in LOS training scenarios. Consequently, it is impossible to know the percentage of all first officers currently receiving LOS training in skills such as monitoring and challenging when they are newly hired or upgraded to the first officer position.

The Safety Board obtained information about the training practices of a limited number of air carriers from a 1993 survey sent by the Air Line Pilots Association

¹⁸ See, for example, the following publication: Foster, Gramer C.; Garvey, Michael C. 1979. Left seat command or leadership? Flight leadership training and research at North Central Airlines. In: Cooper, George E.; White, Maurice E.; Lauber, John K., eds. Resource management on the flight deck: Proceedings, NASA/industry workshop; 1979 June 26-28; San Francisco, CA. NASA Conference Publication 2120. Moffett Field, CA: NASA Ames Research Center: 133-151.

¹⁹ In its study, the Safety Board found that, of the 15 accidents for which data were available, 73 percent occurred during the first duty day together for the captain and first officer. Of the 16 accidents for which data were available, 44 percent occurred during the crew's first flight together.

(ALPA) to its safety representatives at member airlines. Of the 13 responses received by ALPA from its safety representatives at the time the safety study report was completed, 8 were known to pertain to Part 121 carriers. According to the survey responses, three (38 percent) of the eight air carriers do not provide LOFT as part of their first officer upgrade training.²⁰ Four of the eight air carriers hire pilots directly into the first officer position. Two of those four do not provide first officers with LOFT as part of their new-hire training program.

The results from the survey suggest that no industry standard exists for CRM-oriented LOFT or LOS training. Based on the pattern of errors associated with crew assignment, the high incidence of first officers who were serving their first year in that crew position, and the high incidence of crew unfamiliarity among the accident flights, the Safety Board believes that the FAA should require air carriers to provide, for flightcrews not covered by the Advanced Qualification Program, LOS training during each initial or upgrade qualification into the flight engineer, first officer, and captain position that allows flightcrews to practice, under realistic conditions, non-flying pilot functions, including monitoring and challenging errors made by other crewmembers.

Data analyzed in this study also highlight the need for LOS training that addresses other specific educational objectives. As discussed in earlier sections, the accidents involved a high incidence of decision errors that were errors of omission and causal errors made during the taxi phase of operation. Consequently, the Safety Board believes the FAA should also require that air carrier LOS training be designed to attune flightcrews to the hazards of tactical decision errors that are errors of omission, especially when those errors are not challenged, and to include practice in monitoring and challenging errors during taxi operations, specifically with respect to minimizing procedural errors involving inadequately performed checklists.

Initial Operating Experience (IOE):—As a result of its investigation of the November 15, 1987, crash of a Continental Airlines DC-9-14 at Stapleton International Airport in Denver, Colorado,²¹ the Safety Board issued several safety recommendations. One of the recommendations asked the FAA to take the following action:

²⁰ One of the three air carriers that does not provide LOFT to upgrading first officers, according to its ALPA safety representative, provides LOFT for new-hire flight engineers, which is followed by annual, recurrent LOFT.

²¹ National Transportation Safety Board. 1988. Continental Airlines, Inc., flight 1713, McDonnell Douglas DC-9-14, N626TX, Stapleton International Airport, Denver, Colorado, November 15, 1987. Aircraft Accident Report NTSB/AAR-88/09. Washington, DC.

Amend 14 CFR 121.434 to require that a second-in-command pilot complete initial operating experience for that position while actually performing the duties of a second-in-command under the supervision of a check pilot. (A-88-138)

On March 23, 1993, the FAA issued a Notice of Proposed Rulemaking (NPRM) that addresses pilot operating experience and requirements.²² The NPRM includes a requirement for first officers of all Part 121 air carriers to obtain initial operating experience while actually performing the duties of the second-in-command. The Safety Board indicated support for the proposed requirement in comments on the NPRM submitted to the FAA on June 23, 1993. Under current regulations, a first officer is provided IOE credit for observing a second-in-command performing the duties of first officer during a flight. In its comments to the FAA, the Board stated that IOE obtained by passive observation in the cockpit is not as effective as IOE obtained by performing the duties under the supervision of a check pilot. Accordingly, the Board further stated, "passive observation should not be allowed as credit toward meeting the required supervised operating experience hours." On November 19, 1993, the Safety Board classified Safety Recommendation A-88-138 "Open—Acceptable Response," pending final rulemaking on requirements for first officer IOE.

The Safety Board suggests that the proposed requirement for first officers to receive their IOE while performing, rather than observing, the duties of the position is, in addition to CRM training with LOS exercises, an excellent opportunity for air carriers to instill monitoring and challenging habits in their new first officers. During IOE, all crewmembers—not just the new first officer—may be more inclined to form good habits and be responsive to comments from the check airman. Consequently, the Safety Board believes that the FAA should require air carriers to structure their IOE programs to include (a) training for check airmen who provide IOE in enhancing the monitoring and challenging functions of captains and first officers; (b) sufficient experience for new first officers in performing the non-flying pilot role to establish a positive attitude toward monitoring and challenging errors made by the flying pilot; and (c) experience (during IOE and annual line checks) for captains in giving and receiving challenges of errors.

Fatigue and Flightcrew Performance

Prior wakefulness, characterized in this study as time since awakening prior to the accident, is one of several factors researchers have associated with increased

²² Federal Register, Vol. 58, No. 54, dated March 23, 1993, page 15730.

vulnerability to fatigue.²³ In the accidents examined in the Board's study, half the captains for whom data were available had been awake for more than 12 hours prior to their accidents. Half the first officers had been awake more than 11 hours.

Where possible, other fatigue-related factors were explored for their possible influence on flightcrew performance. These other factors include time of day, time zone crossings, and changing work schedules.

Of the factors regarded as contributing to an increased vulnerability to the effects of fatigue, significant differences in performance, in terms of the number and types of errors made by pilots, were observed only for the measure of prior wakefulness; that is, time since awakening. Crews comprising captains and first officers whose time since awakening was above the median for their crew position made more errors overall, and significantly more procedural and tactical decision errors.

On May 12, 1989, as a result of its review of and concern about the rising number of accidents in all modes of transportation attributable to human fatigue, the Safety Board issued the following recommendations to the U.S. Department of Transportation:

Expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety. (I-89-1)

Develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest. (I-89-2)

Review and upgrade regulations governing hours of service for all transportation modes to assure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues. (I-89-3)

Currently, the three safety recommendations are classified "Open—Acceptable Response." In a briefing on the status of these recommendations held in September 1993, a representative of the FAA informed the Safety Board of fatigue research currently being sponsored by the FAA.

²³ Rosekind, Mark R.; Ganda, Philippa H.; Connell, Linda J. [In press]. Crew factors in flight operations: X. Strategies for alertness management in flight operations. NASA Technical Memorandum. Moffett Field, CA: NASA Ames Research Center.

The Safety Board recognizes that an extensive body of useful knowledge exists about the factors that contribute to a pilot's vulnerability to fatigue and associated performance decrements. Programs such as the Fatigue Countermeasures Program at NASA Ames Research Center have used this information to develop integrated educational and training modules on fatigue in flight operations and strategies for alertness management. This training provides participants with a general understanding of the physiological mechanisms underlying fatigue, the performance decrements that accompany fatigue, and applied strategies for maintaining alertness. The Safety Board believes that the FAA should require air carriers to include, as part of pilot training, a program similar to the NASA-Ames Fatigue Countermeasures Program, to educate pilots about the detrimental effects of fatigue, and strategies for avoiding fatigue and countering its effects.

Therefore, as a result of this study, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Apply the results of research conducted to date on the design and use of checklists to improve the error-tolerance of air carrier checklist procedures for taxi operations, by enhancing flightcrew monitoring/challenging of checklist execution, providing cues for initiating checklists, and considering technological or procedural methods to minimize the omission of any items on a checklist. Provide specific guidance to air carriers for implementing these procedures. (Class II, Priority Action) (A-94-1)

Require U.S. air carriers operating under 14 CFR Part 121 to provide, for flightcrews not covered by the Advanced Qualification Program, a comprehensive crew resource management program as described in Advisory Circular 120-51A. (Class II, Priority Action) (A-94-2) (Supersedes A-89-124)

Require U.S. air carriers operating under 14 CFR Part 121 to provide, for flightcrews not covered by the Advanced Qualification Program, line operational simulation training during each initial or upgrade qualification into the flight engineer, first officer, and captain position that: (1) allows flightcrews to practice, under realistic conditions, non-flying pilot functions, including monitoring and challenging errors made by other crewmembers; (2) attunes flightcrews to the hazards of tactical decision errors that are errors of omission, especially when those errors are not challenged; and (3) includes practice in monitoring and challenging errors during taxi operations, specifically with respect to minimizing procedural errors involving inadequately performed checklists. (Class II, Priority Action) (A-94-3)

Require that U.S. air carriers operating under 14 CFR Part 121 structure their initial operating experience programs to include: (a) training for check airmen in enhancing the monitoring and challenging functions of captains and first officers; (b) sufficient experience for new first officers in performing the non-flying pilot role to establish a positive attitude toward monitoring and challenging errors made by the flying pilot; and (c) experience (during initial operating experience and annual line checks) for captains in giving and receiving challenges of errors. (Class II, Priority Action) (A-94-4)

Require U.S. air carriers operating under 14 CFR Part 121 to include, as part of pilot training, a program to educate pilots about the detrimental effects of fatigue, and strategies for avoiding fatigue and countering its effects. (Class II, Priority Action) (A-94-5)

Chairman VOGT, Vice Chairman COUGHLIN, and Members LAUBER, HAMMERSCHMIDT, and HALL concurred in these recommendations.


By: Carl W. Vogt
Chairman

