APPENDIX N

FLIGHT CREW VIEW
JULY, AUGUST
1994

RECURRENT GROUND TRAINING

JULY, AUGUST, 1994

STUDY TIME: 4 HOURS

APPROXIMATE PILOT EXAM TIME: 1 HOUR

AIRCRAFT: B-767, B-757, B-727, MD-80, DC-9, F-100, F-28, B-737

EXAMINATION DATE: SEPTEMBER 30, 1994

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FLIGHT CREW VIEW IS PUBLISHED BI-MONTHLY FOR USAir's PILOTS AND DISPATCHERS. IT IS PART OF USAir's FLIGHT CREW RECURRENT TRAINING PROGRAM.

EDITOR: Capt. Frank Petee

MAILING ADDRESS: FLIGHT CREW VIEW
USAir, Inc.
Flight Publications
Pittsburgh International Airport
Pittsburgh, PA 15231
or
Flight Publications, PIT K-135

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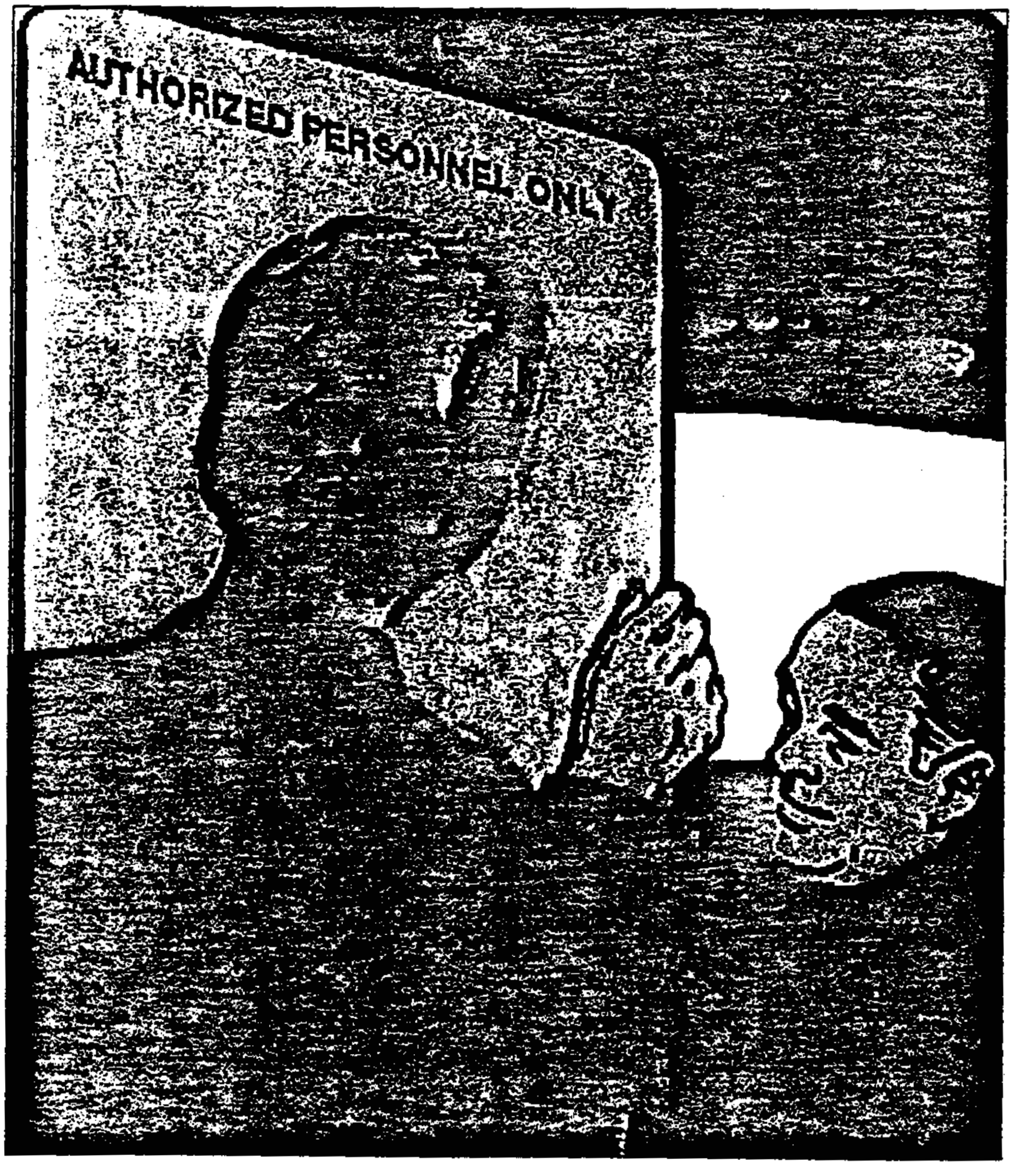
Accident and Incident Reports Show Importance of 'Sterile Cockpit' Compliance



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at Charlotte, the NTSB stated that the crew's nonpertinent conversations "were distractive and reflected a casual mood and lax cockpit atmosphere, which continued throughout the remainder of the approach and which contributed to the accident." In the Dallas-Fort Worth accident, the NTSB said that "had the captain exercised his responsibility and asked the flight attendant to leave the cockpit or, as a minimum, stopped the nonpertinent conversations, the 25-minute taxi time could have been used more constructively and the flap position discrepancy might have been discovered."

Numerous accidents and serious incidents have occurred when the flight crews diverted their attention from the tasks at hand and engaged in activities unrelated to flying.

The cockpit of an aircraft during taxi-out or approach is neither the time nor the place for nonflight-related conversation. Numerous accidents and serious incidents have occurred when flight crews diverted their attention from the tasks at hand and engaged in activities unrelated to flying.

In 1981, the U.S. Federal Aviation Administration (FAA) enacted Federal Aviation Regulations (FARs) Part 121.542 for air carriers and Part 135.100 for air taxi operators. "Flight Crewmember Duties," also known in the industry as the "sterile cockpit rule," are the subject of these two parts of the FARs. These regulations prohibit crewmembers from performing nonessential duties or activities while the aircraft is in a "critical phase of flight."

The FARs define "critical phase of flight" as all ground operations involving taxiing, takeoff and landing and all other flight operations conducted below 10,000 feet (3,050 meters) mean sea level (MSL), except cruise flight.

The *Federal Register* explains the FAA's rationale for the rule making: "Critical phases of flight ... are the phases of a flight in which the flight crew is busiest, such as during takeoff and landing and instrument approaches. When many complex tasks are performed in a short time interval, distracting events could cause errors and significant reductions in the quality of work performed. The performance of a non-safety related duty or activity when flight crew workload is heavy could be the critical event which precludes a flight crewmember from performing an essential task such as extending the landing gear prior to touchdown."[3]

There are situations where 10,000 feet MSL might be an insufficient boundary for defining the critical phase of flight. At high-altitude airports, 10,000 feet above ground level (AGL) may be a more appropriate boundary. For flights with cruise altitudes below 10,000 feet MSL, crews can use a specific distance from the airport or the beginning of descent as a signal to begin sterile cockpit procedures.

The FARs never intended to prohibit functions that are necessary for flight safety. Items that must never be stifled include: accomplishment of checklists, crew callouts, procedural discussions, voicing safety concerns and crew interactions such as acknowledgments and commands. Conversely, because they are not related to the safe operation of aircraft the regulations specifically prohibit the following during critical phases of flight: "non-safety related [radio calls] as ordering galley supplies and confirming passenger connections, announcements made to passengers promoting the air carrier or pointing out sights of interest and filling out company payroll and related records, ... eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight ... ."

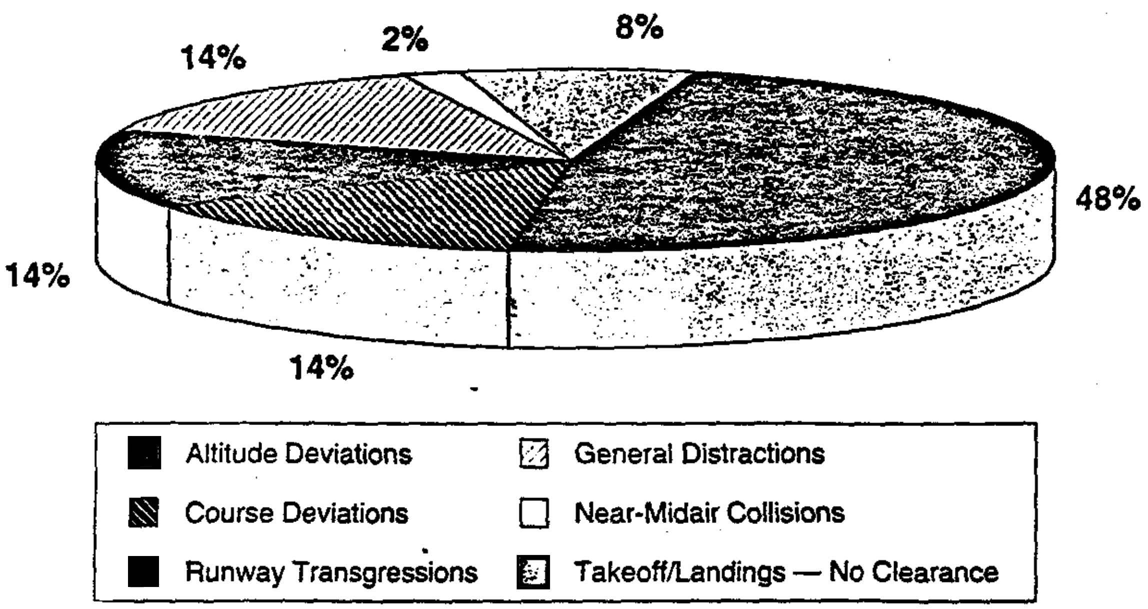
Responsibility To Maintain Sterile Cockpit Shared by Crewmembers

The regulations are carefully worded to apportion the responsibility of keeping the cockpit "sterile": "Regarding crewmember involvement with nonessential activities: No flight crewmember may engage in, nor may any pilot in command permit ... nor may any flight crewmember perform ... ." Responsibility for maintaining the sterile cockpit is on each crew member. If any duties except those duties required are conducted during the critical phase of flight, the pilot in command must not permit them to continue.

The FAA also places the regulatory responsibility in the hands of companies: "No *certificate holder* shall require ... any flight crewmember [to] perform any duties during a critical phase of flight except those duties required for the safe operation of the aircraft." [Italics added for emphasis.]

The following report was submitted to the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS).[4] The report illustrates how poorly designed company procedures can contribute to unsafe conditions.

"Distracted by flight attendant with passenger count. [We] took off, and to this moment, I do not remember being cleared for takeoff. This had the potential for a 'Canary



Source: U.S. National Aeronautics and Space Administration, Aviation Safety Reporting System

Figure 1

distraction of the passenger announcement [caused us to overshoot] altitude [by] 500 feet [152 meters]." An additional nine similar reports were among the 63 in the ASRS review.

- *Sightseeing*

"Nowhere does Webster's [Dictionary] define 'sightseeing' as an activity that is essential to the safe operation of aircraft," said the ASRS researchers who found three such reports in its review. "When sightseeing is conducted by flight crewmembers below 10,000 feet, not only is it potentially dangerous, but it is illegal."

The cockpit voice recorder (CVR) transcript of Flight 212 illustrated the danger of sightseeing (page 5).

"It is apparent that during this discussion a considerable degree of the flightcrew's attention was directed outside the cockpit," the NTSB said. "This particular distraction assumes significance because during this period the aircraft descended through ... the altitude which should have been maintained until it crossed ... the final approach fix (FAF)."

Flight Attendant Notification Policies Vary

Because the cockpit should remain sterile below 10,000 feet MSL, cabin crews need a method of determining whether the aircraft is above or below 10,000 feet. A 1988 U.S. Department of Transportation (DOT) report highlighted cabin crew difficulties determining precisely when sterile cockpit procedures were in effect.[7] DOT researchers surveyed pilots and flight attendants, and of the 35 flight attendants from 16 airlines who responded, 80 percent said that their companies had a signal or policy to indicate when sterile cockpit procedures were in effect. Nevertheless, some confusion was suggested by the respondents; some flight attendants stated that their airlines had such procedures, while others from the same airlines said no such procedures were in place.

Flight attendants reported several different procedures by flight crews for notifying the cabin crews when sterile cockpit procedures were required. "Some airlines have advocated the 10-minute rule, i.e., the sterile cockpit rule should

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procedures are in effect is an indicator light above the cockpit door or on the annunciator panel." Unlike a discrete tone or a PA announcement, this method was less likely to be missed or confused with another signal, according to the report. For optimum performance, a light should be installed near the cockpit door and adjacent to the interphone on each flight attendant communications panel. The indicator light's major disadvantage is that it requires installation.

Misinterpretations of Sterile Cockpit Are Possible

Although the sterile cockpit was implemented to increase safety by minimizing distractions during critical flight phases, there is evidence to suggest that safety can be impaired by misunderstandings. An airline captain, for example, was observed reprimanding his first officer for accomplishing the after-takeoff checklist below 10,000 feet. The first officer's actions, however, were entirely appropriate because the checklist function was required for flight safety and was clearly stated as such in the company's operating procedures.

Misunderstandings can also prevent important safety-related information from reaching the flight deck.

"Flight attendants, many already intimidated by the authority and mystique of the flight deck, are expected to determine which situations are essential to the safe conduct of the flight," according to Rebecca Chute and Earl Wiener in a recently published crew communications study.[8] "Rather than take the chance of being wrong and thereby breaking the law or, at the very least, embarrassing themselves and perhaps subjecting themselves to a reprimand from the captain, they [may fail to] communicate valuable, safety-related information to the pilots."

In 1984, a United Air Lines Boeing 727 encountered a severe wind shear on takeoff from Stapleton International Airport, Denver, Colorado, U.S. The wind shear caused the takeoff roll to be excessively long, resulting in the 727's underside being dragged through the localizer antenna at the departure end of the runway. The antenna punctured the fuselage and remained lodged there. The cockpit crew was unaware that the aircraft had struck the antenna, but could not determine why the aircraft would not pressurize. The flight attendants, on the other hand, had heard and felt a loud thump and vibration shortly after takeoff, but did not notify the cockpit crew because of the senior flight attendant's desire to adhere to the sterile cockpit procedures. Capt. Ricky Davidson, chairman of the U.S. Air Line Pilots Association's (ALPA) Accident Survival Committee, said, "It is crucial [that flight attendants] understand that it is better to risk interruption and break the sterile cockpit rule than to fail to communicate."[9]

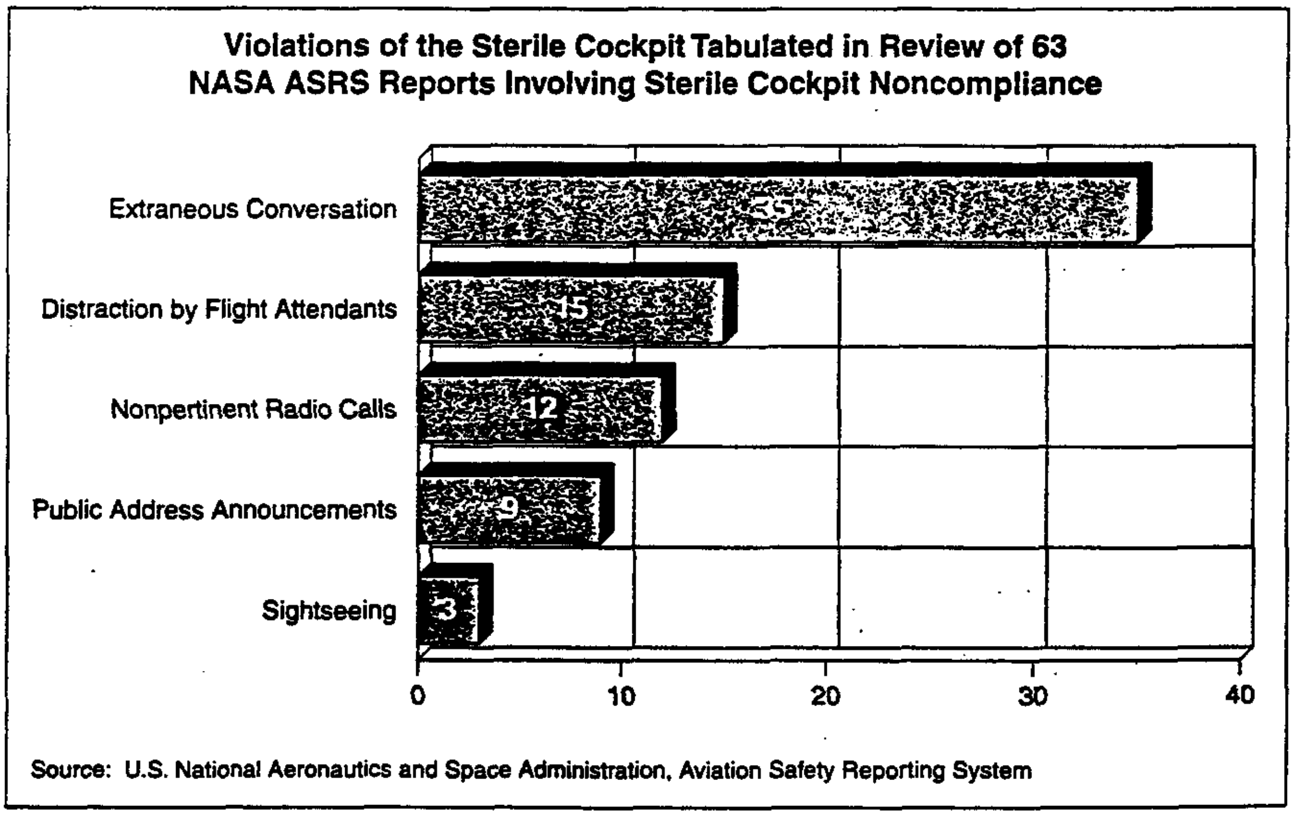

Figure 2

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3. U.S. Federal Register. Volume 46, No. 12. *Elimination of Duties and Activities of Flight Crewmembers Not Required for the Safe Operation of Aircraft.* Final Rule. Pp. 5500–5503. January 19, 1981.

4. U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) is a confidential incident reporting system. Each month ASRS receives approximately 2,500 reports, the majority of which come from air carrier pilots. These reports are often rich with information, as many reporters describe in detail their perspective of the circumstances surrounding an incident.

5. Sumwalt, Robert L. "The Sterile Cockpit." *ASRS Directline* Issue 4 (June 1993): 16–20.

6. NTSB. *Pacific Southwest Airlines B-727, N533PS and Gibbs Flight Center Cessna 172, N7711G. San Diego, CA. September 15, 1978.* Aircraft Accident Report, NTSB/AAR-79/5. April 1979.

7. Cardosi, Kim M., Huntley, M. Steven. *Cockpit and Cabin Crew Coordination,* Report No. DOT/FAA/FS-88/1. A special report prepared at the request of the U.S. Department of Transportation. 1988.

8. Chute, Rebecca D., Wiener, Earl L. "Cockpit/Cabin Communication: A Tale of Two Cultures." In *Proceedings from the Eleventh Annual International Aircraft Cabin Safety Symposium and Technical Conference.* Long Beach, California, United States: Southern California Safety Institute, 1994.

9. Davidson, Ricky R. "Cockpit/Cabin Communications." In *Proceedings from the Tenth Annual International Aircraft Cabin Safety Symposium.* Costa Mesa, California, United States: Southern California Safety Institute, 1993.

10. American Airlines. *1993 Flight Attendant Home Study.* Dallas-Fort Worth International Airport, Texas, U.S.: American Airlines, 1993.

11. Japan Air Lines' Editors of *Flight Safety Magazine.* "Communication from the Cabin Crew to the Cockpit Crew." *Cabin Crew Safety* Volume 25 (January/February 1990): 1–4.

12. Price, Alan W. "The Art of the Brief." *Up Front* (Delta Air Lines) Third Quarter 1993: 1–3.

About the Author

Robert L. Sumwalt III is president of Aviatrends, a company that specializes in aviation safety research and consulting. In this capacity, he serves the U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) as a research consultant. Sumwalt is also a captain for a major U.S. air carrier, where he has served as an airline check airman and instructor pilot. He is a regular contributor to Professional Pilot *magazine.*

Of at least equal importance to us, the author is a frequent contributor to Flight Crew View, mostly through his articles under Flight Safety Foundation headings. Even more important, Captain Sumwalt flies a Boeing 737 300/400 for USAir.

report. Moreover, it appears that there is a level of animosity between the two crews that may be based on a lack of awareness and understanding of the duties of the other crew members during flight.

In the captain's view, the flight attendant did not comply with his request for a meal to be served immediately and exhibited a lack of concern for his well-being and, therefore, that of the flight. In addition, he believed that the flight attendant violated the "sterile cockpit" regulation [U.S. Federal Aviation Regulation (FAR) 121.542)] by entering the cockpit below 10,000 feet to remove the meal trays. The captain's view is also intensified by the perception that the flight attendant is only answerable to the marketing department, making the chain of command on board the aircraft ineffectual.

Several changes in aviation compel a re-examination of the safety implications of cockpit/cabin communication: crew resource management (CRM), previously confined to the cockpit[17]; the emergence of the two-pilot crew, even on wide-body jets and trans-oceanic routes; and the recognition by the U.S. National Transportation Safety Board (NTSB) of the critical role of cockpit/cabin communications in accidents and incidents.[5]

Several changes in aviation compel a re-examination of the safety implications of cockpit/cabin communication ...

Deficient crew communication has been cited in a number of accidents and incidents as a contributing factor. In 1989 an Air Ontario Fokker F-28 crashed on takeoff at Dryden, Ontario, resulting in 24 fatalities. An investigation found that flight attendants withheld critical information (wet snow on the wing) for a number of complex reasons. Among those reasons cited were professional respect, an assumption that the pilots were aware of all pertinent information and a reluctance to second-guess the pilots.[9]

This reluctance was also evident in the January 1989 British Midlands Boeing 737-400 accident when the captain reported (over the public address system) a problem with the right engine, but the passengers and cabin crew could see fire on the left engine. The error went uncorrected and the captain proceeded to shut down the only good engine.

An examination of accident and incident reports, including federal agency reports and reports in aviation history books, and visits by the authors to joint training classes of cockpit crews and cabin crews, suggest that five basic factors have influenced the differences between the two cultures and perpetuate the division and the problem. The factors are:

- Historical background — origins of the jobs and their influence on personal attributes and attitudes today;
- Physical separation — lack of awareness of other's duties, responsibilities and problems, each influenced by lack of physical proximity;
- Psychological isolation — personality differences, misunderstanding of motivations, pilot skepticism and flight attendant ambivalence about chain of command;
- Regulatory factors — sterile cockpit confusion and licensing issues; and,
- Organizational factors — administrative segregation, training differences and schedules.

Some of the differences can be traced to the origins of the professions themselves. The first flight attendants were known as "skygirls." They were required to be under 25 years of age, weigh less than 115 pounds, be under 5 feet 4 inches (162.6 centimeters) tall, single and female. The height and weight restrictions originally were based on aircraft weight and balance limitations. (Today, this is not a consideration, but their weight is still monitored for marketing reasons.) In addition to serving box lunches to passengers, duties included swatting flies before takeoff and cleaning passengers' shoes during the flight. Subservience and compliance were important attributes in the skygirls.

A 1930 manual admonished them to "maintain the respectful reserve of the well-trained servant when on duty." Interactions between the pilots and skygirls were guided by another rule to "treat captains and pilots with strict formality while in uniform. A rigid military salute will be rendered as they go aboard and deplane."[3] Passengers liked the attentive service that the skygirls offered, and airlines grew to view the skygirls as a marketing asset. In the decades since the inception of inflight service, the image of the flight attendant has been glamorized and popularized in the media and by the air carriers themselves.

The role of the commercial aviator evolved from daredevil barnstorming and the bravado of the coast-to-coast air mail flights of the 1920s.[14]

While the populations of both cultures are now large and diverse, members of the two groups still exhibit some characteristics that have been imbued by tradition and valued by their peers and management. An independent spirit, for example, is still prized among pilots, and a gracious demeanor is well regarded in flight attendants.

The commercial airliner has long been divided into two geographical environments: the cockpit and the cabin. Each environment has distinct boundaries, space constraints and technological differences. These physical differences have ramifications when a member of one crew enters the other crew's domain.

The physical barrier of the cockpit door exacerbates communication difficulties. The lack of contact results in

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The stewardesses were also forbidden to conduct conversations with pilots on duty or to enter the field office except when necessary. Remnants of this historical philosophy still characterize some crew member interactions.

David Adams, Australian accident investigator, observed: "If you look at almost any company, you will usually find that the cabin attendants and the flight crews are very very clearly separated. They work for different branches of the company in most cases. The culture is one of almost complete separation. Yet the fact of the matter is, in a safety situation, these two sections of the company have to work together. And the consequences of not efficiently working together quite often means a bunch of people get killed."[9]

Compounding the departmental obstacles, crews often work together for only one or two flights of a sequence. They can work with as many as four or five different crews in one day.

Additional research supported the concept that familiarity played an important role in the quality of flight operations.[4] It was found that post-duty flight crews performed at a higher operational level than pre-duty crews. In fact, there were no cases where pre-duty crews were rated better than post-duty crews. This finding was attributed to the fact that post-duty crews had increased familiarity, more accurate expectations and comfort with each other's style of communication. It should follow that the entire flight crew would function at a higher level if given an opportunity to develop a rapport and a smooth operating system.

> ***Formal briefings and introductions can alleviate some of the detrimental impact of short crew pairings.***

Although cabin crews typically board a flight 45 minutes before departure, pilots often join the flight minutes before or during boarding. Briefings and introductions are therefore often precluded by this lack of availability. Formal briefings and introductions can alleviate some of the detrimental impact of short crew pairings. A briefing can establish expectations, set the tone for crew interactions, address particular problems or requirements for a flight and serve as a refresher for emergency and security procedures. At the very least, an introduction can set the tone and open communication for ongoing requests and clarifications. The omission of briefings and introductions can carry serious implications in emergency situations when crew members must work as a team but may not have met each other prior to the flight.

Training exaggerates the problem by creating gaps in the instruction that crews receive. Flight attendants from one airline, for example, were trained for nine years that in an emergency they could expect to receive four critical pieces of information from the cockpit crew: type of emergency, signal to brace, signal to evacuate and time available to prepare. To a person, the airline's pilots had never heard of this procedure and even had difficulty guessing what the four pieces of information were.

It has become increasingly vital that cabin crews be knowledgeable concerning aircraft systems and architecture. Valuable time can be wasted in the inaccurate transfer of information, especially when pilots cannot leave the flight deck to validate the accuracy of the information. In the 1989 United Airlines Sioux City accident, a flight attendant told the cockpit crew there was damage to the "back wing."[10] The second officer proceeded to the cabin and looked at the wing, but the damage was to the horizontal stabilizer rather than the wing. [The DC-10 was flown by manipulating the power controls of the two engines that remained functioning after a third engine's fan rotor failed and caused the loss of all the aircraft's hydraulic controls. The aircraft crashed at the airport 45 minutes after the engine failure. Of the 285 passengers and 11 crew members aboard, 174 passengers and 10 crew survived.] The implications of an inadequate command of aircraft terminology and mechanical knowledge are potentially serious. Fortunately, in the Sioux City situation there was sufficient time available and enough personnel in the cockpit to check the flight attendant's information. In a more time-critical situation, valuable time could be wasted rediagnosing the problem or taking the wrong solution path.

Despite the fact that there is much anecdotal evidence of coordination difficulties between the cockpit and the cabin crews, no empirical data existed on the depth and breadth of these issues. Therefore, a survey was conducted of crew members at two U.S. airlines to investigate communication issues between the two cultures based on the five identified factors. Only the data on organizational factors will be reported here.

The subjects in this study were 177 current line pilots and 125 flight attendants who voluntarily returned surveys (302 total).

The general survey comprised 30 objective questions designed to probe the five identified factors with multiple choice, yes/no and five-point scale responses. For example, the following item phrased for flight attendants investigated sterile cockpit confusion: "How often are you unclear under which specific circumstances it is appropriate to interrupt the sterile cockpit?" The following question was designed to measure flight attendant reluctance to communicate with the flight deck: "If turbulence occurs and the flight deck does not turn on the seat belt sign, how often do you call them and ask for it to be turned on?" Equivalent questions were asked of the pilots in appropriate language. Both of these questions offered a five point range of response options from "never" to "frequently."

Of the 800 surveys distributed, 302 were completed and returned for a response rate of 38 percent.

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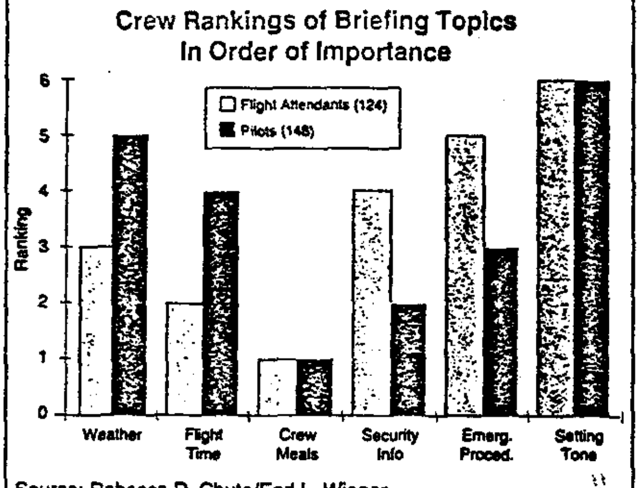


Source: Rebecca D. Chute/Earl L. Wiener

Figure 2

briefed at all. This would result in the majority of the cabin crew not receiving a briefing from the flight deck as well as the impression that those briefings were infrequent. Another factor could be that the lead flight attendant was not passing the information to the rest of the cabin crew, leaving the impression that there had been no cockpit briefing.

Having established that crew briefings are desirable, what kind of information should be conveyed? Crews were very clear about which elements of a briefing were important to them. They were asked to rank each element in terms of importance or to indicate that a topic was not important by leaving it blank (Figure 2). Both flight attendants and pilots ranked setting the tone for crew communication as the most important element of a briefing. Flight attendants ranked emergency procedures as a close second; however, pilots ranked weather as the second most important topic. Both regarded information about crew meals as least important. Flight attendants rated discussion of security information higher than the pilots.

Two items probed the frequency of flight attendant-initiated introductions and pilot-initiated introductions. Once again there was considerable disagreement between pilots and flight attendants regarding their perception of the frequency of introductions (Figure 3 and Figure 4, page seven).

Flight attendants repeatedly requested pilot briefings and introductions. The study asked respondents to complete the sentence "I like it when pilots ... ."

Responses included: "Hold briefings — or at least introduce themselves and establish communication"; "Introduce themselves and give a short briefing regarding communication, etc. It shows respect"; and, "Introduce themselves, give us a briefing on what they like to do in emergencies. Let us know about any problems that may arise including weather and delays."

Pilots also requested anecdotally that flight attendants go out of their way to introduce themselves, although to a lesser extent. This is consistent with findings that U.S. pilots scored low relative to flight attendants on a dimension where importance was placed on the coordination of cockpit and cabin crew.[5] Consequently, it appears that each crew often waits for the other to introduce themselves.

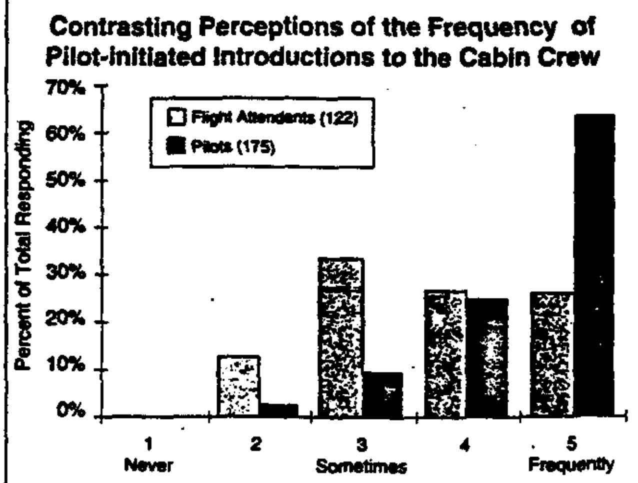
These findings provided the first empirical evidence that problems existed in cockpit/cabin coordination and communication. The crews perceived that they operated as two distinct crews with many barriers between them. These findings indicated that each group believed that it was doing a good job of trying to communicate with the other, but the other group's efforts were inadequate. They appeared to recognize that a gulf existed between them, and wanted to reduce the distance by administrative unification and longer crew pairings. In addition, cockpit crews may have been underestimating the gravity with which flight attendants viewed briefing topics such as security and emergency procedures.

Issues about crew communication and coordination have been successfully addressed by CRM. CRM has been defined as "using all available resources — information, equipment and people to achieve safe and efficient flight operations."[6]

CRM has been widely recognized and used by airlines throughout the world because of its value to the improvement of communication and coordination of flight crew members. Thus, a model exists that could extend CRM beyond the flight deck to the cabin crew. Data suggest that CRM training could bring these two disparate cultures into greater cohesion.

Another resource that yields valuable data is NASA's ASRS program. ASRS is a confidential, anonymous reporting mechanism for all types of safety-related aviation incidents.

To date, the reports have primarily come from pilots and controllers, although it is intended to be used by mechanics, flight attendants and even passengers. However, flight



Source: Rebecca D. Chute/Earl L. Wiener

Figure 3

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11. Novello, J.R. and Youssef. Z.I. "Psycho-social Studies in General Aviation: I. Personality Profile of Male Pilots." *Aerospace Medicine* Volume 45 (1974): 185-188.

12. Novello, J.R. and Youssef, Z.I. "Psycho-social Studies in General Aviation: II. Personality Profile of Female Pilots." *Aerospace Medicine* Volume 45 (1974): 630-633.

13. Ruffell Smith, H.P. "Some Human Factors of Aircraft Accidents During Collision with High Ground." *Journal of Institute of Navigation* Volume 21 (1968): 1-10.

14. Taylor, F. *High Horizons.* New York, New York, United States: McGraw-Hill, 1951.

15. Vandermark, M.J. "Should Flight Attendants Be Included in CRM Training?" *International Journal of Aviation Psychology* Volume 1 (1991): 87-94.

16. Wiener, E.L. "Controlled Flight Into Terrain Accidents: System-induced Errors." *Human Factors* Volume 19 (1977): 171-181.

17. Wiener, E.; Kanki, B.; Helmreich, R. (eds.) *Cockpit Resource Management.* San Diego, California, United States: Academic Press, 1993.

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Chute received a master's degree from San Jose State University in psychology with a human factors emphasis. She has a bachelor's degree in industrial and organizational psychology from San Francisco (California) State University. She is a former flight attendant for Trans International Airlines, where she served on the union health and safety committee. Chute is a member of the Cabin Safety Issues Identification Team, an inter-agency group devoted to cabin safety.

Earl L. Wiener is a professor of management science at the University of Miami (Florida). He received his bachelor's degree in psychology from Duke University, and his doctorate in psychology and industrial engineering from Ohio State University. He served as a pilot in the U.S. Air Force and the U.S. Army. He has been active in aeronautics and cockpit automation research at NASA-Ames since 1979.

 ISSN 1057-5553

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requirements to be seated with belt fastened except for takeoff and landing.

Although passengers outnumbered flight attendants 20 to one on turbulence-accident flights, flight attendants sustained serious injuries nearly as often as passengers (Tables 5–7, page 4). The majority of these injuries occurred while flight attendants were conducting normal duties or were attempting to secure the cabin and passengers after the seat belt sign had been illuminated.

Fifty-five percent of all reported serious injuries occurred during the cruise phase of flight, and nearly 40 percent occurred during descent (including approach). Most serious injuries (60 percent) occurred after the seat belt.sign had been illuminated in adequate time for passengers to comply. In all except one of these cases, passengers who were injured had failed to comply with the seat belt sign and verbal instructions by the crew.

The most common types of serious injuries for both flight attendants and passengers were fractures of the leg/ankle/foot and back/spinal injuries (Table 8, page 5). In some accidents, loose objects in the cabin, such as serving carts, caused serious injuries. Further study is recommended to determine the extent to which loose objects and interior cabin design contribute to serious injuries.

Turbulence-related injuries are preventable. Of the 5,501 passengers, 281 flight attendants and 132 flight crew members on board turbulence-injury flights, only one serious injury was documented in which the injured person was restrained by a seat belt. Passengers who disregard the seat belt sign and verbal crew instructions expose themselves and flight attendants to unnecessary risk.

Flight attendants are at the greatest risk of turbulence-related injuries because they often continue working after the seat belt sign is illuminated unless advised by the flight crew to discontinue cabin service. Even flight attendants so advised are frequently delayed in being seated because they are securing equipment and checking passenger seat belts.

The relative infrequency of turbulence-related injuries on Part 135 commuter flights merits further study. Although some reasons for this appear obvious — shorter flight segments, less room to move about and lower cabin ceilings — some knowledge gained from studying this type of operation might be applied to reduction of turbulence-related injuries in Part 121 operations.

While emerging technology enhancing the pilot's ability to predict and/or avoid turbulence may result in fewer turbulence-related accidents, steps can be taken now to reduce injuries at little or no financial cost to carriers.

These steps include increased flight attendant enforcement of seat belt sign compliance, increased flight crew and flight attendant awareness of turbulence risk to flight attendants, improved cockpit/cabin communications and promotion of increased passenger awareness of the need to use seat belts at all times except when movement about the cabin is necessary and permissible. A joint government/industry effort should be initiated to determine the most effective way of communicating this important message to airline passengers. ♦FCV

TABLE 1 — Total Turbulence-related Injuries 1982–1991

U.S. Federal Aviation Regulations Part 135	Total	Phase of Flight: Climb	Cruise	Descent
Flights	1	0	1	0
Serious Injuries	1	0	1	0
• flight attendant	[1]	[0]	[1]	[0]
• passenger	[0]	[0]	[0]	[0]
Minor Injuries *	0	0	0	0
U.S. Federal Aviation Regulations Part 121	**Total**	**Climb**	**Cruise**	**Descent**
Flights	54	5	29	20
Fatal Injuries	1	0	1	0
Serious Injuries	78	4	43	31
• flight attendant	[37]	[2]	[22]	[13]
• passenger	[41]	[2]	[21]	[18]
Minor Injuries	320	1	198	121
• flight attendant	[70]	[0]	[38]	[32]
• passenger	[250]	[1]	[160]	[89]

* Minor injuries on flights in which no serious injury occurred are not included in this analysis.

Source: U.S. Federal Aviation Administration, U.S. National Transportation Safety Board

TABLE 5 — Turbulence-related Injuries — Seat Belt Sign Not Illuminated 1982–1991
(Unanticipated Turbulence)

U.S. Federal Aviation Regulations		Phase of Flight		
Part 121	**Total**	**Climb**	**Cruise**	**Descent**
Flights	13	1	9	3
Serious injuries	17	1	13	3
• flight attendant	[12]	[1]	[8]	[3]
• passenger	[5]	[0]	[5]	[0]
Minor injuries	56	0	55	1
• flight attendant	[23]	[0]	[23]	[0]
• passenger	[33]	[0]	[32]	[1]

TABLE 6 — Turbulence-related Injuries — Seat Belt Sign Illuminated With Insufficient Time to Restrain Occupants* 1982–1991

U.S. Federal Aviation Regulations		Phase of Flight		
Part 121	**Total**	**Climb**	**Cruise**	**Descent**
Flights	7	0	5	2
Serious injuries	14	0	12	2
• flight attendant	[6]	[0]	[5]	[1]
• passenger	[8]	[0]	[7]	[1]
Minor injuries	24	0	24	0
• flight attendant	[7]	[0]	[7]	[0]
• passenger	[17]	[0]	[17]	[0]

* Except in one case, turbulence occurred within seconds after the seat belt sign had been illuminated. One passenger was in the lavatory when the sign was illuminated approximately four minutes prior to encountering turbulence.

TABLE 7 — Turbulence-related Injuries — Seat Belt Sign Illuminated In Adequate Time to Restrain Occupants 1982–1991

U.S. Federal Aviation Regulations Part 135				
One flight, one serious flight attendant injury; flight attendant was hit by a loose object in the galley.				
U.S. Federal Aviation Regulations		**Phase of Flight**		
Part 121	**Total**	**Climb**	**Cruise**	**Descent**
Flights	34	4	15	15
Fatal injuries	1	0	1	0
Serious injuries	47	4	18	25
• flight attendant	[19]	[1]	[9]	[9]
• passenger	[28]	[3]	[9]	[16]
Minor injuries	240	1	119	120
• flight attendant	[40]	[0]	[8]	[32]
• passenger	[200]	[1]	[111]	[88]

- A DC-9 flight resulted in one fatality, two serious injuries and 23 minor injuries to passengers. The seat belt sign had been on since departure and passengers had been verbally briefed to remain seated, but flight attendants indicated the seat belt instruction had not been enforced. According to flight attendants, all injured passengers were either standing in the aisle, in lavatories or seated without belts on.
- In accidents in which the seat belt sign was on with sufficient time, all but one injured passenger failed to comply with the seat belt sign and verbal instruction by the crew. The injured passenger who was restrained stated that he was pulled back down into his seat by his seat belt after impacting the ceiling.

Source: U.S. Federal Aviation Administration, U.S. National Transportation Safety Board

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Advances in Medicine and Data Technology Will Bring Dramatic Changes to Civil Aeromedical Certification Process

Healthier lifestyles, new medical treatments and computer technology are making it easier for pilots to achieve and maintain medical flight certification.

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The first minimum medical standards for pilots were established in Germany in 1910.[1] These standards, and standards developed in other countries in the following years, were developed by military authorities to prevent people who might not be fit for military flight operations from becoming, or remaining, military pilots.

The era of human flight began during a time when tuberculosis was rampant. Streptococcal throat infections caused rheumatic heart disease as well as kidney disease; typhoid fever was widespread, and poliomyelitis caused permanent disabilities in survivors. After recovery from childhood diseases such as measles, chicken pox, mumps and diphtheria, millions of individuals experienced permanent adverse effects. The life expectancy during this period in the United States was about 50 years of age.

During World War I, some physicians assigned to examine pilots were given flight training, and the term "flight surgeon" was coined by the U.S. military.[1] A flight surgeon manual was published by the U.S. Government Printing Office, and the standards and tests it contained emphasized selecting people who could perform flight duties in addition to military missions.[2] A school for military flight surgeons was established in New York in May 1919 and subsequently moved to Brooks Field, Texas, in December 1922.[1] As military flight surgeons returned to civilian life after World War I, some of them became civilian aviation medical examiners when a U.S. federal regulatory program was established in 1926.[3]

The new civilian standards were relatively simple (less than two pages in a very small booklet) and had provisions for waivers.[4] U.S. civilian medical standards remained relatively unchanged until 1958, when the U.S. Federal Aviation Agency (FAA) [later the Federal Aviation Administration] was established and additional more-specific standards were prepared. The standards were proposed in 1959 for each of the three classes of medical certificates.[5] The requirement for a resting electrocardiogram (ECG) at age 35, age 40 and each year thereafter was developed by the FAA for Class I medical certificates (for airline transport pilots) at that time.

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Table 2
Average Expectation of Life in Years in the United States

Expected Years of Additional Life[1]

AGE/SEX*		WHITE	BLACK	ALL RACES[2]
Age 20:	Male	54.0	46.7	53.3
	Female	60.3	55.3	59.8
Age 40:	Male	35.6	30.1	35.1
	Female	41.0	36.8	40.6
Age 50:	Male	26.7	22.5	26.4
	Female	31.6	28.2	31.3
Age 65:	Male	15.2	13.2	15.1
	Female	19.1	17.2	18.9

* Age in 1990

(1) As an individual becomes older, the individual's likelihood for additional years of life will increase.

(2) Includes respondents who did not identify themselves as Black or White. Can include those of Asian, Native American, Eskimo or Pacific Island origin.

Source: U.S. Department of Commerce. Bureau of the Census

high-performance career. Thus, the benefits of enhanced population health and advances in science, medicine and aeronautics must be appreciated by air crew members and applied in their private and working lives. The same holds true for modern flight surgeons who, after developing trust, should work with air crew members to prevent disease and obtain special issuances where indicated.

Progress Made in Establishing Common Medical Standards

Ideally, all countries should have the same civil medical standards within flight operations categories. The International Civil Aviation Organization (ICAO) based in Montreal, Canada, works to establish common medical standards. Significant progress has been made in recent decades in the establishment and administration of agreed-upon civil medical standards among ICAO member countries.

The United States, Canada, Great Britain and Australia have been leaders in the individualization of medical certification for those pilots who do not meet certain published medical standards. This can be attributed in part to the large number of general aviation pilots in these countries, which has provided a substantial data base on special issuances (or similar procedures) that allow pilots who have disqualifying medical histories or conditions to fly. Many other countries are now modifying their medical certification procedures accordingly.

In the 21st century, the flight medical examination may be achieved by interactive television and computer. The pilot, while at home, may use biomedical data acquisition modules that would interact in real time with the aviation medical examiner. The examiner would have a video conference from the office with the pilot at home, taking the pilot's medical history and noting the acquired biomedical data, including sensory, neurologic, cardiovascular and interactive psychomotor coordination tests relevant to flying.[8] These tests exist in prototype today.[9] If a medical problem that requires further evaluation exists, a referral to the FAA or an appropriate specialist could be made.

For those pilots who immediately meet the medical standards, the medical certificate could be issued and transmitted to the pilot's computer printer. If the pilot does not meet the standards, a deferral or denial letter would be sent. The data on such actions would be sent to the FAA central medical facility where a permanent record would be maintained.

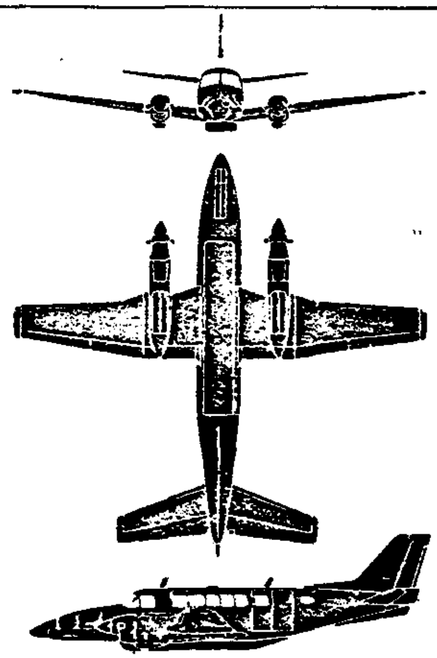
A potential dividend of such a certification system would be the capability to download preventive medicine lifestyle data to pilots, tailored to the individual pilot's medical needs. This would help pilots to remain healthy and to achieve a long flying career.

The above approach would markedly diminish the time and costs of periodic physical examinations. In the United States, for example, 900 examiners are currently entering the history and physical data on the pilots they examine into their personal computers and are transmitting these data by telephone to CAMI. All routine ECGs collected on Class I pilots in the United States are also transmitted by telephone to CAMI for computer assessment. These activities are the beginning of the future for civil air crew video certification. ♦

The April 30, 1990, accident occurred at 2138 local time. It was a scheduled domestic flight operated by Frontier Air Ltd. and originated in Timmins, Ontario, at 2043 local time. Moosonee is located in northeastern Ontario near James Bay.

The aircraft struck trees while on a heading of 230 degrees. About 432 feet (132 meters) from the point of initial impact, the charred remains of the fuselage were found, along with inboard sections of both wings, cockpit and both engines and propellers, according to the TSB report.

Moosonee Airport is located on the north shore of the Moose River, just east of the town. The surrounding terrain is flat, and vegetation consists of trees about 25 feet (8 meters) high. The area was flooded from melted ice and snow packs at the time of the accident.



Beechcraft C99 Airliner

The B99, the predecessor of the C99, first flew in 1966 and deliveries began in 1968. A large main cargo door allowed the aircraft to be used for either all-cargo or cargo/passenger operations. The C99, with increased power and systems refinements, was first delivered in 1981. It has a service ceiling of 28,080 feet (8,560 meters) and a range of 910 nautical miles (1,686 kilometers).

The C99 was certified for operation with one pilot, but U.S. Federal Aviation Regulations require two pilots in commuter air carrier operations. There are about 23 C99s in operation in the United States and about 52 operating in other countries.

The accident aircraft was configured to accommodate 15 passengers. It was equipped with two Pratt & Whitney PT6A-36 engines rated at 715 standard horse power. It has a cruising speed of 245 knots (454 kilometers per hour, 282 miles per hour) at 16,000 feet (4,880 meters).

Source: Jane's All the World's Aircraft

"Darkness, cloud cover and flooding created a ... featureless visual environment," the TSB said.

The report added: "Because the terrain is flat and because the Moosonee town lights are oriented more laterally than longitudinally on this approach, a pilot's ability to perceive angle is limited. There are no approach lights on runway 24, nor is there a visual approach slope indicator system (VASIS)."

The TSB said that by using a helicopter at night at the same altitudes, it was determined that the runway lights could be seen down to the tree level at the accident site.

Weather at the time of the accident was reported as estimated ceiling 400 feet (122 meters) above ground level (AGL) broken, 1,000 feet (305 meters) AGL overcast, visibility four miles (6 kilometers) in intermittent light rain and winds from 270 degrees at four miles per hour. The captain of the accident flight reported layers of cloud throughout his en route descent from 7,000 feet (2,135 meters) to an initial approach altitude of 1,500 feet (457 meters). The captain reported no turbulence, precipitation or icing during the descent.

The TSB report said the captain reported that a lower layer of cloud was based at about 900 feet (274 meters) AGL and that "when he broke out of the cloud on final approach at about nine nautical miles [17 kilometers] on the distance measuring equipment (DME), he could see clearly the airport lights."

Passengers also reported that the aircraft was clear of the clouds at that time and that the airport was in sight before the accident.

The captain, 25, had logged a total of 2,423 flight hours, of which 298 hours were in the Beechcraft C99. The first officer, 35, had logged a total of 1,038 flight hours, of which 102 were in the C99. The captain held an airline transport pilot certificate. The first officer held a commercial certificate.

The TSB said the captain's last night of flight training was logged on Aug. 24, 1987, in a twin-engine Piper Seminole.

But the TSB noted that the captain had flown a twin-engine Piper Navajo PA-31 and the C99 at night without receiving any on-type night training, which is required by Canadian air navigation regulations. The TSB said the captain's last night flight logged before the accident was April 10, 1990.

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The TSB concluded: "The fact that there is a design eye position that guarantees certain fields of visibility, but which cannot be achieved for a pilot the size of the [accident] captain because of cockpit layout and control interference is a problem in this type of aircraft.

"The captain on this flight was unable to adjust his seat to achieve the DERP and, therefore, was unable to see anything below the nose of the aircraft without either leaning forward and/or stretching or by lowering the nose, thereby introducing a descent.

"Measuring the captain in the C99 seat position he used during the accident flight and later repositioning him to achieve the DERP resulted in two specific findings. First, in order for him to see the runway lights, from breakout below the cloud to impact, as he indicated, the aircraft would have had to be in, and continued to be in, a descent. Second, he could not achieve the DERP because the seat could not be elevated high enough."

Cockpit crew coordination was also lacking, the TSB report said.

The report said the captain was not aware of the first officer's activities in the final portion of the flight and that the first officer may have been directing his attention outside the cockpit. The TSB said that company procedures for a night visual approach required that the pilot not flying call out the airspeed and altitude every 100 feet (30 meters) below 500 feet (152 meters) AGL.

"According to the captain, this was not done," the TSB report said. "Moreover, it is clear that the captain was not referring to his altitude throughout the visual approach. If either of these two requirements had been done, it is likely that the descent would have been arrested prior to impact."

The TSB said a lack of a company crew-pairing policy also contributed to the accident. It said the captain and first officer had been in their respective crew positions for less than one month.

Based on its investigation, the TSB recommended that the Department of Transport provide guidance to air carriers in setting up crew-pairing plans, encourage the continuing implementation of crew resource management and human factors training and take steps to ensure that "pilots receive appropriate guidance for positioning their eyes at or close to the DERP."

The TSB also called on the Department of Transport to "validate its current procedures for checking that carriers provide the required multi-engine night training."

"Transport Canada's process for ensuring compliance with night training requirements is inadequate," the TSB report concluded. ♦ FCV

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replied that he could investigate the possibility of a north landing. The captain told the controller to "wait 'til we get a little closer and look at it. The radar at this range is not really as accurate as it is when we get in 40, 50 miles [64.4, 80.5 kilometers] away," the report said.

For about the next 10 minutes the captain and first officer discussed what they observed on their airborne weather radar. "The captain indicated they were 80 miles [128.8 kilometers] out, that he saw 'yellow scud' on the scope, and they were 'not looking at anything that even approaches red,'" the NTSB report said. Minutes later, the captain and first officer agreed that they were seeing red returns. The report said that one of the crew commented, "Red should be a really bad cell."

Two minutes later, the flight deck crew saw a brilliant flash of light and the cockpit area microphone picked up a rumble that sounded like thunder. "Everything appears to be functioning," the flight engineer said. The report said that several passengers and flight attendants reported a possible lightning strike.

Two minutes later, the flight deck crew saw a brilliant flash of light and the cockpit area microphone picked up a rumble that sounded like thunder. "Everything appears to be functioning," the flight engineer said.

The NTSB said that the captain told air traffic control (ATC), "We just had a big blast of lightning," and said that he didn't believe the airplane had been struck by it. "He [the captain] again requested a landing to the north. The controller expressed his doubts that a north landing would be approved, but assured him that he would forward the request," the report said.

AAL 102 was handed off from the ARTCCC to DFW approach control. "On initial radio contact with approach control, the captain verified the status of his request [for a north landing], but was told that DFW's southbound departures would preclude landing to the north," the report said. Shortly thereafter, the captain asked for a 50-degree heading change to deviate around weather, which the controller approved.

At 0645:31, the captain stated on the cockpit microphone, "I don't know what the [expletive] happened with this radar." This prompted the first officer to ask, "Is it not working or is it working?" the report said.

The report said that the flight engineer briefed the captain and first officer on the current ATIS [automatic terminal information service]: "Echo, 1,400 [feet (427 meters)] overcast, 2½ miles [four kilometers] visibility, winds 220 at 6, [altimeter] 29.48 inches [998 millibars], lightning cloud-to-cloud, cloud-to-ground, thunderstorms moving northeast and pressure falling rapidly."

At 0647:58, AAL 102 was descending to 3,000 feet (915 meters), and received a broadcast from ATC that DFW weather was 1,400 feet overcast, visibility 2½ miles, with thunderstorms, rain showers and fog. The wind was 140 at 11, altimeter 29.49 inches, and all aircraft were told to expect a south landing.

The controller told AAL 102 to expect the instrument landing system (ILS) Runway 17L and stated the localizer frequency. The captain acknowledged by repeating the localizer frequency and asked, "How's it look coming down final on your radar?" The report said that the controller replied, "I show an area of weather at 15 miles [24 kilometers] either side of DFW Airport, proceeding straight north 15 miles on each side for about 30 miles [48.3 kilometers]."

The captain then asked, "Okay, can you give us a good heading then to come in on?" The controller responded that he could give a good heading to the localizer, but there was weather all the way down the final approach course. The captain then asked if the weather was moving. The controller replied that the weather did not appear to be moving, and he gave a heading to intercept the localizer, the report said.

"At 0650:33, the captain radioed, 'I don't think we're going to be able to do that, that's a pretty big red area on our scope about 90 degrees, and that's about what we're looking at. We're gonna have to, just go out I guess and wait around to see what's going on here,'" the report said. The controller told AAL 102 that eight miles [12.9 kilometers] south of their position, a McDonnell Douglas DC-8 was intercepting the localizer at 3,000 feet and had reported a smooth ride.

The captain responded, "Okay, we'll head down that way then and, worse comes to worse, we'll go out from there," the report said. The controller gave AAL 102 a heading of 200 degrees to intercept the Runway 17L localizer.

"The airplane was in approach configuration with the flaps set to 15 degrees," the report said. "At 0652, the captain questioned the first officer as to the veracity of the localizer frequency, despite the fact that the captain had read it back to approach control at 0649:34. Subsequently, at 0652, the captain questioned the first officer as to whether they were landing on Runway 17L or 17R. The first officer reminded the captain that they were landing on Runway 17L. At 0652:40, they were cleared for the approach.

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"At one point during the evacuation from [exit] 3-R, passengers bunched up on the right wing because of the steepness of the slide from the wing to the ground. A flight attendant saw a holdup at the top of the slide and came out on the wing. Noting the steepness of the slide, the high number of older passengers attempting to evacuate, and the passenger pileup at the bottom of the slide, the flight attendant told the passengers on the wing that they would have to return to the cabin and use another exit. At the same time, some passengers said that a flight attendant inside the cabin, behind the group of people trying to exit onto the right wing, told them that they would have to move quickly from the airplane because of a fire out the left side cabin windows."

The report said that some elderly passengers were unwilling to jump onto the slides until they were urged to do so or were pushed onto the slides. "Some female passengers wanted to take personal items with them, especially purses. Flight attendants warned against taking these items and physically removed them from several passengers as they jammed forward attempting to enter the slides. The urgency of the situation was described by several passengers and flight attendants as becoming apparent when the glow from the left side fire was observed clearly in the dark cabin through the aft left cabin windows. Many of them said later that the flight attendants and nearly all the passengers evacuated expeditiously and as calmly as possible from the dark cabin," the report said.

The report said some elderly passengers were unwilling to jump onto the slides until they were urged to do so or were pushed onto the slides.

Crash, fire and rescue services arrived at the accident site within minutes. "The DFW fire and rescue department's crash alarm sounded about 0701, within about one minute from the time the airplane came to rest. About one minute later, the first trucks were arriving at the airplane. They extinguished a fire at the left wing in about 50 seconds, while the passengers were still exiting the airplane. DFW emergency medical services (EMS) responded with three DFW ambulances and eight mutual aid ambulances."

The NTSB said that of a total of 202 persons aboard the airplane (189 passengers, three flight crew, 10 cabin crew), "two injuries were described as serious, involving fractured bones or spinal injuries to passengers that occurred during the evacuation of the airplane. There were 38 reported minor injuries (35 passengers, two cabin crew, and one flight crew)."

The report added: "Two passengers received minor injuries that could be attributed to ceiling panels as the airplane slowed to a stop in the soft soil. However, most of the minor injuries and all of the serious injuries were reported to have occurred during the emergency evacuation, especially as passengers attempted to slide down steep-angled slides from the right side of the cabin, landing in sticky mud that made it difficult or impossible for some of them to move away from the bottom of the slides.

"The flight attendant stationed at 3-R said that the problem was exacerbated by the high number of elderly persons attempting to evacuate at that exit. The steep angle of the slides at 3-R and 4-R resulted from the final resting attitude of the airplane. In addition to deep mud at the bottom of the slides, winds, driving rain, and slippery slides heightened the difficulties. Due to the resting attitude of the airplane, slides at 3-R and 4-R were described by some witnesses as not touching the ground, a situation that contributed significantly to the steepness of the slides."

In addition, several passenger and crew statements said that the cabin was only partially illuminated during the evacuation. "The airplane's emergency cabin lighting system consisted of two subsystems: one to illuminate overhead and door exit lights, and one to illuminate the floor path and side wall exit sign lights. Both emergency lighting systems were removed from the accident airplane and shipped to their respective manufacturers where each subsystem was subjected to additional testing under Safety Board supervision," the report said.

One of the eight control modules for the floor path and side wall exit sign lights was found to be nonfunctional.

The cabin overhead and door emergency lighting system was disassembled and re-examined. "All logic units tested satisfactorily; however, examination of the system battery packs, which contained 24 individual power cells, revealed that the tap wire or primary lead was incorrectly soldered onto all four battery packs. In addition, individual battery cells were out of the original factory-assembled sequence. This factor affected the amount of charge each battery cell would accept during charging and thereby diminished the overall level of power for the battery packs," the report said.

The NTSB report said that "American Airlines' maintenance records showed that the battery packs had been serviced by the airline's maintenance department. It was established that neither the manufacturer of the battery packs nor the system's manufacturer had provided written guidance to the airline's maintenance department on

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side. Both sides of the No. 2 flap track fairing were burned through. Only minor fire damage forward of the front spar was observed. All fuel tanks were found intact," the report said.

Investigators reviewed the weather briefing obtained by the flight crew before departing HNL and during the flight. The report said that "American Airlines meteorology and flight dispatch sections correctly advised AAL 102 of expected thunderstorms, moderate-to-heavy rain showers, low-level wind shear, and variable surface winds, gusting 20 to 40 knots, upon arrival at DFW."

During the investigation, data were obtained regarding thunderstorm activity during the approach and landing of AAL 102. "During the final approach of AAL 102, cloud bases north of DFW were, from the evidence, likely 1,000 to 2,000 feet [305 to 610 meters] broken to overcast. Doppler radar at 0650:23 showed an area of radar echoes up to and including VIP [video integrator processor] level-4 intensity, northwest through north of the airport. Cockpit communications and sounds similar to windshield wipers, recorded on the CVR, indicated that AAL 102 was in and out of thunderstorms and rain showers during most of its approach. The flight crew reported runway lights in sight, at 0658:14, and the airplane touched down at 0659:29.

"The first period of moderate-to-heavy rain showers at DFW ended at the weather observatory located in the Delta Air Lines hangar, about 0645. These showers moved off to the east of the airport. The precipitation recording chart at the facility showed that only about 0.02 inch [0.05 centimeter] of rain fell during the next 15-minute period, ending at 0700. Interviews and statements by the duty observer and oncoming weather observers confirmed that rain shower intensity increased about 0658.

"At 0645, the leading edge of the second band of significant precipitation was approximately seven miles west of [Runway] 17L. Doppler radar at 0650:23 showed that the line was slightly west of the airport complex. The LLWAS [low-level wind shear alerting system] west sensor went into sector alert at 0653:25, as the line traversed the area."

The report said radar returns from Doppler radar at 0656:10 showed that the leading edge of mostly "VIP level-2 echoes was near the terminal area, and that VIP level-3 and VIP level-4 echoes were just west of [Runway] 18R.

"The runway visual range (RVR) sensor for [Runway] 17L was located between [Runways] 17R and 17L, approximately 1,000 feet south of the thresholds. According to the NWS [National Weather Service] recording, the RVR began a marked decrease around 0659 and stabilized between 0700 and 0701. This decrease in runway visibility is consistent with a heavy rain shower passing over the RVR location. In addition, the captain of American Airlines Flight 1710, which was awaiting clearance for departure on [Runway] 17R, later stated: 'The aircraft [AAL 102] appeared to be in a normal attitude and altitude for landing as he crossed the runway threshold. The rain had just picked up to a more moderate to almost heavy level as I watched him for a very short time.'

"The evidence shows that a line of moderate-to-heavy rain showers and thunderstorms was crossing Runway 17L as AAL 102 was landing. The flight crew of AAL 102 should have had sufficient information to realize that this was occurring at the time of landing," the report said.

"The evidence shows that a line of moderate-to-heavy rain showers and thunderstorms was crossing Runway 17L as AAL 102 was landing."

Data from several sources were used to estimate the winds during the final three minutes of flight of the accident airplane. "The calculated wind directions varied between approximately 225 and 310 degrees during the final 2½ minutes before touchdown (except for the final seven seconds of data, which are assumed to be inaccurate since the airplane was in a side-slip). The calculated wind speeds varied from 30 to 50 knots early in the approach to 15 to 30 knots as the airplane neared the touchdown point," the report said.

The NTSB report added: "The calculated wind direction varied randomly between a quartering headwind and a quartering tailwind between 0657 and 0659. At 0659, AAL 102 was approximately 270 feet [82 meters] AGL [above ground level], and the wind was from about 270 degrees at 25 knots. Wind speed then decreased to about 15 knots, and changed to a direct crosswind at approximately 0659:08 when the airplane was at 150 feet [45 meters] AGL. Calculated wind directions remained constant, but the speeds increased to 25 to 30 knots over the next few seconds. These data would indicate that AAL 102 was subjected to a direct right crosswind of 25 to 30 knots, when the first officer stated, 'I'm gonna go around,' at 0659:17, about one second after the automated voice called out '50' [feet AGL].

"Wind conditions could not be continued in the program after touchdown, because the crosswind component cannot be calculated by this method when the airplane is on the ground. After touchdown, the closest LLWAS anemometer to the airplane (centerfield) was used to provide winds calculated during the airplane's ground roll.

The flight engineer, 60, held a U.S. flight engineer certificate. He was first employed by American Airlines in 1955. He had logged a total of 20,000 flight hours, all of which were as a flight engineer, and 4,800 hours of which were in the DC-10.

The flight crew were interviewed individually during the investigation, and the report summarized their description of events during the approach and landing. "When the first officer had the runway in sight, he disconnected the autopilot, but not the auto throttles," the report said. "He swung the nose of the airplane slightly to the left, and the airplane drifted left. He swung the nose of the airplane back to the right and said that he was 'not comfortable.' He felt that they were 'high' and that the airplane would need too much nose down to accomplish the landing. He announced that he was going to make a missed approach.

"The captain said he believed the aircraft was drifting to the left, and he felt he could make a safe landing. He did not want to make a missed approach and have to deal with the thunderstorm activity again. He said that they were at 200 feet [61 meters] AGL and that he took control of the airplane from the first officer. He made an alignment correction, but said it was not necessary to make an attitude/glideslope adjustment. He was confident that the landing would be within 'the desired 3,000-foot [915-meter] touchdown zone.' He said that there was no need to go around, no wind shear, no airspeed, height, or alignment problem.

"The captain said he believed the aircraft was drifting to the left, and he felt he could make a safe landing. He did not want to make a missed approach and have to deal with the thunderstorm activity again."

"He [the captain] aligned and landed the airplane on centerline. The touchdown was very smooth. After he lowered the nose, he activated the reverse thrust. The spoilers had extended and the normal reverse deployed, but he felt only a slight deceleration. At that time, he said that the airplane 'weathervaned' about five degrees to the right. He acted 'instinctively' to return to the centerline of the runway. He released the control column and used nosewheel steering handwheel control. He commented that the airplane does not normally need forward pressure on the control column. He felt some 'sliding,' but he did not use asymmetric reverse power. He applied the brakes, although he commented that braking was normally not done until the airplane was moving slower than 100 knots. After the airplane did not respond to his actions, he said that 'there was nothing we could do but hang on.'

"The first officer said that after the captain took control of the airplane, the airplane seemed to 'float,' and that he was not sure where the touchdown was made. The CVR data showed that the first officer made call-outs expected of the non-flying pilot. After the landing, he did not hold forward pressure on the control yoke after the nosewheel touchdown. He said it was not normal procedure to do so unless he was previously briefed. When asked his opinion regarding the captain continuing the approach to landing after the first officer judged the need to initiate a missed approach, the first officer replied, 'I've got to trust him.'"

The NTSB also reviewed the pilots' use of control column pressure and nosewheel steering during landing. The report noted: "DAC [Douglas Aircraft Co.] had published specific information regarding the use of forward pressure on the control column during the landing roll, as well as on the use of the nosewheel steering handwheel, in an AOL [all operator letter], two flight crew newsletters, and in its DC-10 Flightcrew Operating Manual. However, the Safety Board could find no reference to these procedures in American Airlines DC-10 Operating Procedures or training program. The 'technique' section of the American Airlines DC-10 Operating Manual makes a short reference to the importance of forward pressure on the yoke after touchdown. However, the manual does not provide either a procedure or technique for the non-flying pilot to apply forward pressure on the yoke after touchdown."

The NTSB report said that when asked, "the captain said that he thought forward pressure was not necessarily a DC-10 procedure, but generally a good thing to do. The first officer said that he did not push forward on the yoke, after the captain released it, and would not unless it was specifically requested by the captain."

The report added: "The information published by DAC regarding the necessity for forward pressure on the yoke, after landing, explained that it was necessary to reduce lift and improve steering characteristics of the nose gear. In addition, DAC's DC-10 Flightcrew Operating Manual states that, 'The pilot not flying must apply sufficient forward pressure on the control column to maintain the nose-wheel firmly on the ground for maximum directional control.'"

In addition, the NTSB reviewed the captain's use of reverse thrust during the landing: "For about seven seconds, about one second after touchdown, until about the time the airplane departed the runway, the FDR shows that the captain kept all three engines near maximum reverse thrust. DAC, and some other operators of the DC-10, factors involved and the context in which the decisions were made to determine whether they were appropriate.

"Despite the thundershowers north and south of DFW, as AAL 102 proceeded to the ILS approach to [Runway] 17L, there were no weather conditions that made the decision of the captain to initiate or continue the approach unacceptable. Although the airplane was in a 10-degree right crab on short final to [Runway] 17L, this condition was not inherently unsafe. The DC-8, which had landed on [Runway] 18R about four minutes before AAL 102, had reported a 'smooth ride' that had been passed by an approach controller to AAL 102. Also, on approach to [Runway] 17L behind AAL 102, an SA-340 captain, who flew a missed approach beginning about 600 feet [183 meters] AGL, reported that he experienced light to moderate turbulence during the approach and no wind shear activity."

The NTSB report concluded that the captain of AAL 102 was "well within his authority to take the airplane from the first officer after the first officer had announced, without prior warning, that he was going around. The fact that the captain was able to land the airplane on centerline provides evidence that he was in control of the airplane through the touchdown. No clear evidence exists that there was any fault in the captain's decision-making throughout the initiation or continuation of the approach to [Runway] 17L, or in his decision to take control of the airplane from the first officer and land on the intended runway. The departure from the runway resulted from the captain's failure to maintain directional control of the airplane after touchdown rather than from events or decisions made prior to touchdown.

The NTSB report concluded that the captain of AAL 102 was "well within his authority to take the airplane from the first officer after the first officer had announced, without prior warning, that he was going around."

"Finally, in light of the captain's improper aircraft control during the landing roll, the relatively long duration of his overnight flight, and the fact that the captain's sleep periods were disrupted in the 48 hours prior to the accident, the Safety Board considered the possibility that fatigue adversely affected his performance. These factors and the captain's age of 59 years led the Safety Board to believe that the captain might have been fatigued to some extent. Even though the circumstances surrounding the flight crew's activities from April 12 through 14 could have led to a deterioration of his judgment and piloting skills, there is no information available regarding the captain's ability to perform under either long-term or short-term fatigue. Therefore, a finding that his performance on the accident flight was the result of fatigue could not be supported, nor could it be dismissed."

As a result of its investigation, the NTSB expressed concern about American Airlines' record-keeping of flight crew training and performance: "The Safety Board attempted to obtain information about the quality of the past training and checking performance of the flight crew of AAL 102 from American Airlines, but was unable to do so because of the lack of detailed information in the records. The FAA-approved record-keeping system only provided information on when pilots completed required actions such as flight checks. Their performance on those checks, or even the number of unsuccessful checks, was not included. As a result, the Safety Board was unable to determine if the quality of the performance of the flight crew on AAL 102 was an aberration or was consistent with a performance decrement.

"At the time of the accident, American [Airlines] employed over 9,000 pilots based at several domiciles throughout the United States. Given the extent of supervision possible by one chief pilot over several hundred pilots, the Safety Board believes that American's record-keeping systems for its pilots did not provide sufficient information to allow the airline, or the FAA, to determine if trends existed to suggest changes in flight crew performance over time, or to evaluate the effectiveness of the overall training program. Such information could be easily obtained and recorded by the airline and would enable the airline to assist a flight crew member who might be experiencing performance difficulties. Such a program would enhance safety by allowing the airline to undertake a performance enhancement before a problem developed outside of the training environment."

The NTSB recommended that the FAA "review record-keeping systems of airlines operating under FAR [Federal Aviation Regulations] Parts 121 and 135 to determine the quality of information contained therein and, if necessary, require the airlines to maintain information on the quality of pilot performance in training and checking programs."

In addition, investigators examined the condition of the landing runway used by AAL 102: "The investigation found a buildup of rubber at the approach end of [Runway] 17L that showed a coefficient of friction below the FAA minimum standard. According to airport records, for the

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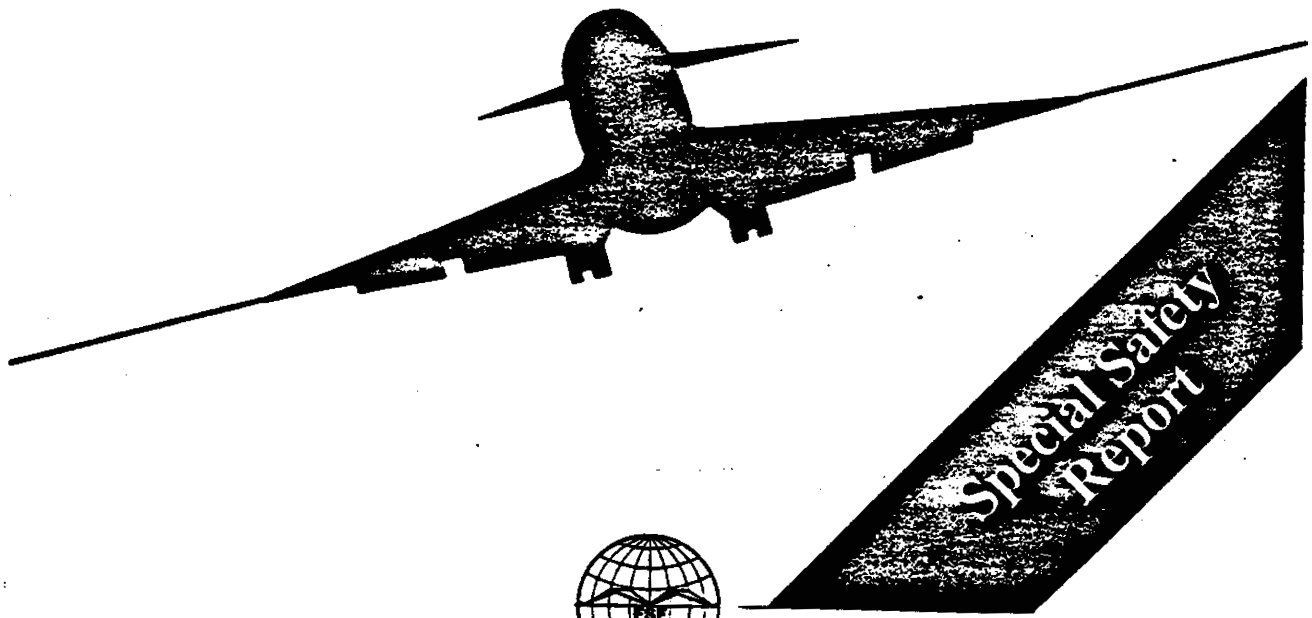
DIGEST

Safety Issues Related to Wake Vortex Encounters During Visual Approach To Landing



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Editorial Note: Appendixes B through H are not included in the *Flight Safety Digest.*

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- pilot knowledge related to the avoidance of wake vortices; and
- the lack of available data to analyze the history of wake vortex encounters in the United States.

As a result of this special investigation, 19 recommendations were issued to the Federal Aviation Administration, U.S. Department of Transportation.

Table 1—Five airplane encounters with the wake vortex of the preceding airplane on visual approach to landing since December 1992

Date	Location	Leading aircraft	Trailing aircraft	Comments
12/18/1992	Billings, MT	B-757	Cessna Citation 550	Cessna rapidly rolled left and contacted ground in a near vertical dive when about 2.8 nm behind and about 300 feet below the flight path of leading aircraft.
3/1/1993	Orlando, FL	B-757	MD-88	At about 110 ft AGL,[a] MD-88 suddenly rolled right about 15°; crew regained control and approach continued.
4/24/1993	Denver, CO	B-757	B-737	About 1,000 ft AGL, B-737 rolled left violently, pitch decreased 5°, and the airplane lost 200 feet altitude; a go-around was initiated, and the airplane landed without further incident.
11/10/1993	Salt Lake City, UT	B-757	Cessna 182	On final approach, airplane rolled 90° to the right; as pilot attempted to level airplane, it crashed short of runway.
12/15/1993	Santa Ana, CA	B-757	Westwind	About 2.1 nm behind and 400 feet below the flight path of leading airplane, Westwind rolled suddenly and contacted the ground with a 45° nose down pitch attitude.

[a] Above ground level.

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B-757. The clearance was issued to the pilot about 4.5 minutes prior to the accident while following the B-757 at a distance of 4.2 nm. After the visual approach clearance was acknowledged, the speed of the Citation increased while the speed of the B-757 decreased in preparation for landing. The controller informed the pilot of the Citation that the B-757 was slowing and advised the pilot that a right turn could be executed to increase separation. Although the pilot never asked the controller about his distance from the B-757, a statement recorded on the cockpit voice recorder (CVR) indicates that the pilot recognized the separation had decreased because he stated, "Almost ran over a seven fifty-seven," about 40 seconds prior to the upset.

The Citation's rapid and extreme departure from controlled flight occurred when the airplane was about 2.78 nm (about 74 seconds) behind the B-757. Calculations indicate that an additional 0.22 nm (about 6 seconds) would have provided the required 3 nm of longitudinal IFR separation had the pilot not requested the visual approach clearance. However, available data show that under the existing atmospheric conditions, a vortex would not likely have diminished an appreciable amount in the next 6 seconds. Consequently, this accident indicates that lighter weight airplanes in the large category, such as the Cessna Citation, require a separation distance greater than 3 nm when following heavier airplanes in the large category, such as a B-757.

Although radar data indicate that, at any instant, the Citation was at least 600 feet higher than the leading B-757 during the last 4 miles of the approach, the flight path of the Citation was actually at least 300 feet below that of the B-757.

The only cue available to the Citation pilot to determine his flight path relative to the flight path of the B-757 would have been the Citation pilot's visual alignment of the B-757 and objects on the ground. For example, assuming that the B-757 was on a relatively constant flight path, the Citation flight path would have been similar to that of the B-757 if the Citation pilot had observed that the B-757 was aligned with the runway touchdown zone. If the B-757 were aligned with the far end of the runway, the flight path of the Citation would have been lower than the flight path of the B-757. If the B-757 were aligned with the approach lights, the flight path of the Citation would have been above the flight path of the B-757.

The failure of the Citation pilot to prevent the decrease in separation distance strongly suggests that the pilot failed to realize that he was placing the airplane in a dangerous position relative to the wake of the B-757. Although the Airman's Information Manual (AIM) suggests that the pilot of the following airplane should remain above the flight path of the preceding airplane, the Safety Board is not aware of existing training material that wind was from the north at about 10 knots gusting to 16 knots. The flight path angle of both airplanes was about 3°.

Runway 26L is parallel to, and displaced 900 feet south of runway 26R. The threshold of runway 26L is offset about 1,300 feet to the east of the threshold of runway 26R, resulting in a flight path to 26R that is about 70 feet higher than the flight path to 26L. Under the existing wind conditions, a wake vortex from the B-757 would descend and move to the south, toward a standard flight path to runway 26L.

Air traffic controllers are required to provide standard separation to IFR airplanes that are approaching 26L and 26R because the runways are separated by less than 2,500 feet. If the flightcrew of the B-737 had not accepted a visual approach, the controller would have been required to provide 3-nm separation. During the early portions of the approach, ATC provided vectors to the B-737, which resulted in S-turns for spacing (see appendix D). Subsequently, the B-737 and B-757 were on converging courses within 12 nm of the runway. Upon completion of the S-turns, the actual separation between the airplanes was about 4.6 nm. However, the separation was predominately lateral, not in-trail or longitudinal. The lateral component of the separation was about 4.55 nm, and the longitudinal component was only about 0.65 nm along the intended approach path. The B-757 was 1.6 nm to the right of its final approach path, and the B-737 was 2.8 nm to the left of its final approach path. The final approach paths were separated by 0.15 nm. Radar data show that the B-757 was on a 15° intercept from the right side to align for the approach to runway 26R. The B-737 was on an 8° intercept from the left side to align with the approach to runway 26L. Both airplanes converged to their respective runway alignments, which resulted in a 900-foot lateral (left-right) separation. The longitudinal component of the separation increased from about 0.65 nm to an in-trail separation of about 1.35 nm. The controller should have recognized that the relative spacing, in conjunction with the converging courses, would result in less than a 3-nm separation when the B-737 was in-trail behind the B-757. To maintain a 3-nm separation after the acceptance of a visual approach clearance, the pilot of the B-737 would have had to continue to execute S-turns.

Santa Ana, California.—On December 15, 1993, an Israel Aircraft Industries Westwind, operating under 14 CFR 135 at night, crashed while on a visual approach to runway 19R at the John Wayne Airport, Santa Ana, California.[9] The two crewmembers and three passengers were killed. Witnesses reported that the airplane rolled, and CVR data indicate that the onset of the event was sudden. The airplane pitch attitude was about 45° nose down at ground contact. Recorded radar data show that at the point of upset, the Westwind was about 1,200 feet mean sea level (MSL) and 3.5 nm from the end of runway 19R. The Westwind was about 2.1 nm (60 seconds) behind a B-757 and on a flight path that was about 400 feet below the flight path of the B-757. The flight path angle of the Westwind was 3°, and the flight path angle of the B-757 was 5.6° (see appendix G, altitude profile). CVR data indicate that the Westwind pilots were aware they were close to a Boeing airplane and that the airplane appeared high. They anticipated encountering a little wake and intended to fly one dot high on the glide slope (about 3.1° instead of 3.0°). There is no evidence that the crew were advised specifically that they were following a B-757.

While receiving radar vectors to the airport, the crews of both airplanes were flying generally toward the east and would have to make right turns to land to the south. Radar data and ATC voice transcripts show that the Westwind was 3.8 nm northeast of the B-757 when cleared for a visual approach (see appendix G, ground track). The Westwind started its right turn from a ground track of 120° while the B-757 ground track remained at about 90°. The resultant closure angles started at 30° and became greater as the Westwind continued its turn. About 23 seconds later, the B-757 was cleared for the visual approach. The average ground speeds of the Westwind and B-757 were about 200 and 150 knots, respectively. The Westwind was established on course 37 seconds prior to the B-757. Although the combination of the closure angle and the faster speed of the Westwind reduced the separation distance from about 3.8 nm to about 2.1 nm in 46 seconds, the primary factor in the decreased separation was the converging ground tracks. The only way the pilot of the Westwind could have maintained adequate separation was to execute significant maneuvers.

Based on radar data, at the time the visual approach clearance was issued, the separation distance was rapidly approaching the 3 nm required for IFR separation. To prevent compromise of the separation requirement, the controller would have had to take positive action to change the Westwind's track, or to issue the visual approach clearance and receive confirmation that the pilot accepted the visual approach within 29 seconds.

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[9] NTSB accident LAX 94-F-A073.

ground-based systems to monitor wake vortex movements and believes that the FAA should continue funding research in these areas.

Data on Wake Vortex Encounters

Data are not available to analyze the wake vortex incident history in the United States because the FAA does not require pilots to report wake vortex encounters. The only existing U.S. data on wake vortex encounters of which the Safety Board is aware are the Board's own accident and incident reports and reports filed through the Aviation Safety Reporting System (ASRS). Despite the limitations of the ASRS data,[11] the report narratives provide insight into specific safety issues, such as wake vortex encounters. Appendix H contains incident reports derived from the ASRS data base. Although the airplane models are not identified in the ASRS data base, on the basis of ASRS reporting categories, it can be inferred that most pilot reports defining a large (LRG) airplane (150,000 to 300,000 pounds) were referring to a B-757.

Unlike the FAA, the Civil Aviation Authority of Great Britain (CAA), in 1972, established a voluntary reporting system to gather data on wake vortex encounters. In 1982, using data from the reporting system, the CAA changed from a three-group airplane weight category to a four-group weight category. (See table 2 for a comparison of the weight categories used by the CAA, the FAA, and the International Civil Aviation Organization (ICAO).) According to a paper presented at the FAA-sponsored international conference of aircraft wake vortices held in Washington, D.C., in October 1991, "The four group scheme (weight categories) introduced in 1982 was divided as a result of incident data gathered in earlier years, and was designed to provide extra protection for some types of aircraft found to suffer particularly severe disturbance behind heavy group aircraft."[12]

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[11] Because all ASRS reports are voluntarily submitted, they cannot be considered a measured random sample of the full population of like events. Moreover, not all pilots, controllers, air carriers, or other participants in the aviation system are equally aware of the ASRS or equally willing to report. Consequently, the data reflect reporting biases.

[12] Proceedings of the Aircraft Wake Vortices Conference, October 29, 1991, DOT/FAA/SD-92/1.1, p. 6.2.

371,000 Kg) is a likely explanation for its higher incident rates. However, the cause of the higher B-757 incident rates is uncertain.[13]

The B-737 was cited as being most involved as the following airplane. Of note, the CAA requires a 3-nm separation when a B-737 is following a B-757, and the B-757 is the largest airplane in its category.

The CAA Wake Vortex Reporting Programme (WVRP) was transferred to the Air Traffic Control Evaluation Unit (ATCEU) in 1989.[14] The ATCEU collects data from various parties on each wake vortex encounter and enters the data into the wake vortex data base. The notification usually comes from the affected airplane crew or ATC. Formal procedures for the reporting of wake vortex incidents by ATC are in operation only at London City and Heathrow airports. Additional data are collected from the pilot of the airplane causing the vortices, the Meteorological Office, London Air Traffic Control Center (for recorded radar data provided to ATCEU by data link), and from the airlines (flight data recorder data). One airline has agreed to extract FDR data for all reported wake vortex incidents. The data are analyzed to determine if the cause of the reported incident is, in fact, an encounter with a wake vortex. A total of 86 incidents were reported in 1990, and 87 incidents were reported in 1991.[15]

The Safety Board believes that the FAA should also require reporting of wake vortex encounters and establish a system to collect and analyze pertinent information, such as recorded radar data (including wind and temperature data recorded on many of the newer airplanes), atmospheric data, and operational information, including selected flight data recorder data. The Safety Board acknowledges the difficulty in developing clearly usable definitions and suggests that the CAA program could be an excellent source in developing this reporting system. Because pilots may be reluctant to report wake vortex encounters as a result of concerns of enforcement actions, the FAA will need to address the issue of enforcement when developing the reporting procedures.

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[13] Proceedings of the Aircraft Wake Vortices Conference, October 29, 1991, DOT/FAA/SD-92/1.1, p.8.2.

[14] National Air Traffic Services. Civil Aviation Authority, ATCEU Memorandum No. 177.

[15] ATCEU Memorandum No. 184.

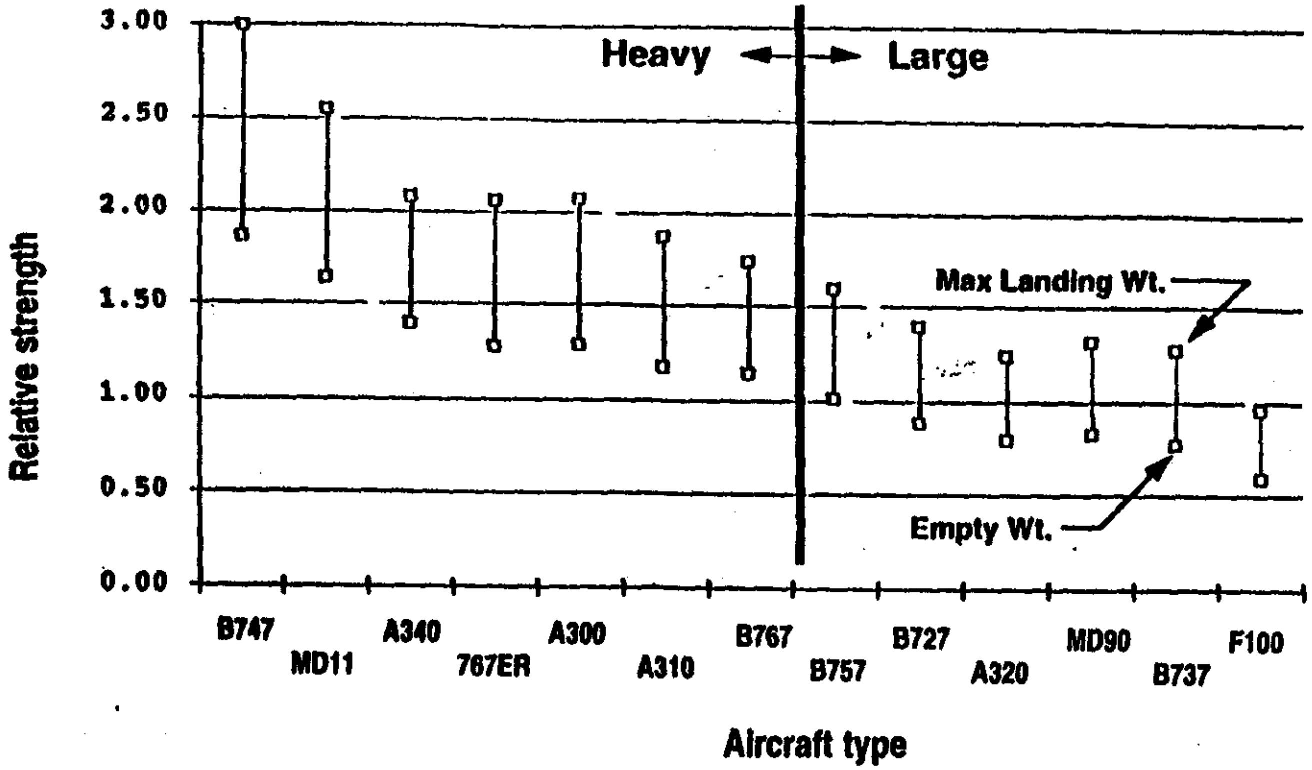

Figure 1—Calculated initial vortex strength of aircraft types. (Courtesy of the National Aeronautics and Space Administration.)

the Board also believes, as discussed in more detail later in this report, that the accident at Billings, Montana, provides sufficient evidence to warrant increasing the separation distance behind the B-757.

The Safety Board is concerned that the design of future airplanes could result in wake vortices that are unusually strong or persistent for the weight of the airplane. Flight testing would provide data about the vortex decay, transport, residual strength, effects of atmospheric conditions, and unusual or unique characteristics of the airplane's vortex. Accordingly, the Board believes that the FAA should require manufacturers of turbojet, transport category airplanes to determine, by flight test or other suitable means, the characteristics of the airplanes' wake vortices during certification.

Until the FAA has developed the knowledge and systems that will permit a significant reduction in the probability of wake vortex encounters, there will be a need to visually determine adequate separation distances. Further, the five vortex encounters described earlier and the CAA data demonstrate the need to increase the IFR separation distances for small and large airplanes on approach and in-trail behind the B-757 and other airplanes of similar weight if they are introduced into service. The accident at Billings and the incident at Orlando show that an encounter with a B-757 vortex at 3 nm can be dangerous to most large airplanes. In addition, greater ATC separation standards may have reduced or prevented the excessive closures noted in the other three encounters.

The FAA requires less radar separation for wake vortex considerations for IFR airplanes under positive air traffic control than that recommended by the ICAO and required by the CAA (see table 3). A Citation or Westwind following an airplane such as a B-757 would require a 5-nm separation based on ICAO recommendations and a 6-nm separation based on CAA standards, rather than the 3-nm separation required by the FAA.

One method to achieve increased separation behind a B-757 would be to reclassify the B-757 as a heavy airplane.[19] Large airplanes would benefit from a 5-nm separation and small airplanes would benefit from a 6-nm separation when executing an instrument approach in-trail behind a B-757. However, the reclassification would reduce the required radar separation of a B-757 in-trail behind a B-747 (maximum gross weight of 820,000 pounds) from 5 nm to 4 nm, increasing the risk of a wake vortex upset for the B-757. The FAA and Boeing have expressed concern about increasing the risk of a wake vortex encounter if a B-757 followed a heavy airplane more closely.

[19] Canada has reclassified the B-757 as a heavy airplane when it is the leading airplane.

Safety Board staff used the maximum landing weights to represent the roll inertia of B-757s and Citations. The vortex strengths of B-747s and B-757s were also calculated using maximum landing weights. The combination of the B-747 vortex strength and the B-757 landing weight was compared to the combination of the B-757 vortex strength and the Citation landing weight. The comparisons show that, at equal separation distances, the risk of loss of control when a Citation encounters the wake vortex of an airplane similar in weight to a B-757 is 8 times greater than the risk associated with a B-757 encountering the wake vortex of a B-747 (see appendix I for calculations). In practice, however, the B-757/B-747 pair would be separated by 4 nm if both were classified as heavy airplanes, thus lessening the risk for that pair (because 3 nm was used in the risk calculations). Therefore, the relative risk of the two pairs is greater than a factor of 8. In addition, the determination of the relative risk does not reflect the CAA data, which suggest that the wake vortex of a B-757 may last longer than would be expected for its weight. Clearly, therefore, if the risk associated with reclassifying the B-757 as a heavy category airplane is unacceptable, the current risk to a Citation at 3 nm behind a B-757 is also unacceptable.

The Safety Board shares the concern of the FAA and Boeing about reclassifying airplanes such as the B-757 as heavy airplanes. The Safety Board believes it would be preferrable to maintain the current separation distance of 5 nm when such airplanes are following a heavy airplane and to increase the separation distances for other airplanes when they are following a B-757 or other airplanes of similar weight. The accident in Billings, Montana, for example, clearly demonstrates that lighter weight airplanes in the large airplane category require a separation distance greater than 3 nm when following a B-757. Further, the CAA wake vortex incident data raise concern about airplanes of the size of B-737s following only 3 nm behind airplanes of the size of the B-757. Accordingly, the Board believes that the FAA should immediately establish the following interim wake vortex separation requirements for IFR airplanes following a Boeing 757 and other airplanes of similar weight: 4 nm for airplanes such as the B-737, MD-80, and DC-9; 5 nm for airplanes such as the Westwind or Citation; and 6 nm for small airplanes. The current separation requirement of 5 nm when a B-757 or other airplane of a similar weight is following a heavy category airplane should be maintained.

Air Traffic Control Procedures Related to Visual Approaches and VFR Operations Behind Heavier Airplanes

The Safety Board believes that one common element to the five wake vortex encounters described earlier is that a combination of ATC procedures and pilot actions resulted in separation distances that were too small for the airplane trailing behind a B-757 while on a visual approach to landing. Currently, controllers are required to ensure that airplanes have the proper radar separation prior to the issuance of a visual approach clearance. However, the incident at Denver and the accident at Santa Ana illustrate that controllers sometimes issue visual approach clearances when the separation distance and closure rate preclude the pilot from maintaining a safe separation distance without excessive maneuvering. During peak traffic periods, controllers rely on the use of visual approaches to increase traffic capacity and to reduce delays. Pilots may try to accommodate the controller by accepting a visual approach even though they may be unable to maintain adequate separation from the preceding traffic without excessive maneuvering, excessive reconfiguration of the airplanes, or drastic reduction of their airspeed. When this situation occurs, a compression effect can be created, increasing the exposure of each successive arrival to a wake turbulence encounter.

The Safety Board believes that the FAA should amend 7110.65H, Air Traffic Control,[21] to prohibit controllers from issuing a visual approach clearance to an IFR airplane operating behind a heavier airplane (in the large or heavy airplane category) until the controller has determined that the in-trail airplane should not have to execute S-turns, make abrupt configuration changes, or make excessive speed changes while maintaining a separation distance that would be required for IFR approaches. If the airplane is in-trail or on a converging course at the time the visual clearance is issued, closure rate should be consistent with the required separation distance. That is, if the separation distance is slightly greater than the required separation distance, the closure rate should be minimal. However, if the separation distance is large, a greater closure rate may be tolerated. The controller should set up the in-trail situation in a manner in which both airplanes can continue the approach in a reasonable manner.

[21] This document is the air traffic control handbook that prescribes air traffic control procedures and phraseology for use by personnel providing air traffic control services.

pilots involved in these accidents and incidents known the manufacturer and model of the other aircraft, they might have been able to maintain adequate separation distances. Therefore, the Safety Board believes that the FAA should amend handbook 7110.65H, Air Traffic Control, to require that controllers issue both the manufacturer and model of airplane when issuing information about air carrier traffic.

The Safety Board recognizes that the proposed changes will be an additional burden for air traffic controllers. However, until more reliable systems are in place to predict and detect wake votices, these measures should further reduce the likelihood of wake vortex encounters.

Pilot Knowledge Related to the Avoidance of Wake Vortices

The accident and incident data suggest that a combination of pilots' lack of understanding of the hazards of wake vortices and the difficulty of knowing the movements of wake vortices are major contributors to wake vortex encounters. A pilot's visual estimate of range is not sufficiently accurate to ensure safe separation. It is especially difficult to estimate separation distances at night. In addition, Safety Board accident and incident data show that student pilots and pilots operating under 14 CFR 91 rules continue to encounter wake vortices at an unacceptable rate. The Safety Board notes that many pilots involved in accidents and incidents had instrument ratings, had been given wake vortex precautions, and yet continued on, either ignoring the caution, or mistakenly believing that they were above the vortex. To help pilots avoid wake vortex encounters, the Board urges the FAA to develop comprehensive training programs related to wake turbulence avoidance and to publish the information in the Airman's Information Manual[24] and other training materials. This information should include techniques for determining relative flight paths and separation distances. The accident at Billings, Montana, for example, clearly demonstrated the need for techniques to help pilots maintain a flight path that is higher than that of the leading airplane. In that accident, the flight path of the Citation was at least 300 feet below that of the B-757. Further, the information should define the vertical

[24] The Airman's Information Manual provides information on wake vortices and instructs pilots to maintain a flight path that is higher than that of the leading airplane. The manual, however, does not provide guidance on how to avoid wake vortices or to maintain the proper flight path.

Use of Traffic Collision and Avoidance Systems

As discussed above, the investigations show that pilots typically do not possess the skills to accurately determine the flight paths of airplanes they are following nor can they accurately estimate the distance to those airplanes. The Safety Board believes that training can improve those skills but cannot eliminate the problem. One possible remedy would be to develop technology to help the pilots determine their position relative to a preceding airplane. Currently, ground-based radar is the only operational tool designed for that purpose. With radar, air traffic controllers can determine separation but cannot easily determine relative flight paths. However, radar separation requires the constant attention of the controller and the controller's communication with the following airplane.

Another possibility would be to use Traffic Collision and Avoidance Systems (TCAS) to provide range information to a pilot following another airplane. Although TCAS was designed only for warning of pending collisions, certain models provide position data of other airplanes. The Safety Board understands that some pilots are currently using the range information provided by TCAS to corroborate range information provided by ATC. In addition, the FAA and some airlines are currently evaluating the feasibility of using TCAS to provide separation information over the Atlantic Ocean when radar coverage is not available. According to the FAA, TCAS manufacturers have determined that the systems are sufficiently accurate for use over the Atlantic when the range is within 10 to 15 miles.

However, various concerns have been raised about the use of TCAS for separation during a visual operation in the terminal environment. Among these concerns are: that TCAS was not designed to provide separation information; the pilot's attention may be diverted into the cockpit; the pilot will have more tasks to perform; the display of some TCAS systems are not adequate for use as a separation aid; and the systems have had problems with reliability and false alarms. Also, the smaller general aviation and corporate airplanes that would benefit the most from accurate range information are less likely to have TCAS installed.

Findings

1. The Safety Board's investigations of five recent accidents in which an airplane on approach to landing encountered the wake vortex of a preceding Boeing 757 indicated that the following factors were more important than any specific characteristic of the B-757 wake vortex: (1) inadequacies in the current airplane weight classification scheme to establish separation criteria, (2) inadequacies in air traffic control procedures related to visual approaches and visual flight rules operations behind heavier airplanes, and (3) insufficient pilot knowledge and training related to the avoidance of wake vortices.

2. Because of the large weight differences between the high and low end of the large airplane category, lighter weight airplanes are at high risk of upset from the vortices generated by the heavier weight airplanes.

3. Current air traffic control procedures and pilot reactions can result in airplanes following too closely behind larger airplanes while on a visual approach to landing.

4. Pilots of arriving visual flight rules airplanes and instrument flight rules airplanes cleared for visual approach often do not have sufficient information to maintain adequate separation distances or to determine relative flight paths.

5. Pilots are not provided adequate training related to the movement and avoidance of wake vortices or for determining relative flight paths and separation distances.

6. Data are not available to analyze the wake vortex incident history in the United States because the Federal Aviation Administration does not require pilots to report wake vortex encounters.

7. The wake vortex characteristics of transport category airplanes are not required to be determined at the time of airplane certification; airplane separation requirements to avoid wake vortex encounters are based solely on weight.

8. New technology being developed may find application in future airborne and ground-based systems to monitor wake vortex movements.

Amend FAA Handbook 7110.65H, Air Traffic Control, to prohibit the issuance of a visual approach clearance to an instrument flight rules airplane operating behind a larger airplane (in the large or heavy airplane category) until the airplane is in-trail and the closure rate is such that the pilot can maintain the minimum instrument flight rules separation without excessive maneuvering. (Class II, Priority Action) (A-94-46)

Amend FAA Handbook 7110.65H, Air Traffic Control, to require that instrument flight rules airplanes cleared for a visual approach behind a heavier turbojet airplane be advised of the airplane manufacturer and model, be provided a wake turbulence cautionary advisory, and be provided other information relevant to the avoidance of wake turbulence, such as separation distance and the existence of an overtaking situation. (Class II, Priority Action) (A-94-47)

Amend FAA Handbook 7110.65H, Air Traffic Control, to require that arriving visual flight rules airplanes that have been sequenced for approach behind a heavier turbojet airplane be advised of the airplane manufacturer and model, be provided a wake turbulence cautionary advisory, and be provided other information relevant to the avoidance of wake turbulence, such as separation distance and the existence of an overtaking situation. (Class II, Priority Action) (A-94-48)

Amend FAA Handbook 7110.65H, Air Traffic Control, to require that controllers issue both the manufacturer and model of airplane when issuing information about air carrier traffic. (Class II, Priority Action) (A-94-49)

Develop annual refresher training for air traffic controllers regarding wake turbulence separation and advisory criteria. The training should emphasize the need for controllers to avoid using phrases or terminology that would encourage pilots of visual flight rules or instrument flight rules (IFR) airplanes to reduce separation to less than that required during IFR operation, thereby increasing the chance for a wake turbulence encounter when operating behind a turbojet airplane. (Class II, Priority Action) (A-94-50)

Determine if the Traffic Collision and Avoidance System (TCAS) is appropriate for providing pilots with the separation distance to the preceding airplane during visual approaches to landing. If appropriate, develop procedures to allow the use of TCAS for that purpose. (Class II, Priority Action) (A-94-59)

Encourage operators of smaller general aviation and corporate airplanes to install and use the Traffic Collision and Avoidance System (TCAS), if procedures to allow the use of TCAS to confirm separation distances during visual approaches are developed. (Class II, Priority Action) (A-94-60)

By the National Transportation Safety Board

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Adopted: February 15, 1994

Table 4—Accidents and incidents investigated by the National Transportation Safety Board from 1983 to 1993 that resulted from probable encounters with wake vortices (continued)

Date	Location	Leading aircraft	Trailing aircraft	Phase of operation	File No.
03/04/87	Miami, FL	B-737	Piper PA-34-200	Landing	0253
07/14/87	Raleigh, NC	B-727	Cessna 172M	Descent	1041
09/08/87	Monterey, CA	BAE-146	Beech 95	Descent	2519
12/09/87	Anchorage, AK	B-727	Cessna 402B	Approach	2213
01/09/88	Colorado Springs, CO	C-141	Rotorway Executive	Taxi	0043
01/26/88	El Toro, CA	C-130	Cessna 152	Landing	1722
11/01/88	Nashville, TN	B-727	Cessna 210D	Descent	1122
11/09/88	Gainesville, FL	Navy P-3	Cessna 152	Takeoff	1744
11/19/88	Van Nuys, CA	King Air	Piper PA-28R-201T	Landing	2067
12/31/88	Grand Rapids, MI	B-727	Cessna 152II	Landing	2404
05/23/89	Phoenix, AZ	B-737	Piper PA-32RT-300T	Descent	0667
06/14/89	Columbus, OH	B-737	Grumman American AA-5	Approach	1343
06/18/89	Port Huron, MI	Junker JU-52	Cessna 150	Approach	0846
09/06/89	Santa Ana, CA	B-737	Cessna 180	Landing	1615
09/14/89	Santa Paula, CA	UNK	Cessna 152	Approach	0802
09/26/89	Portland, OR	Large airplane[a]	Piper PA-32-260	Landing	1987
10/05/89	Palm Springs, CA	B-727	Piper PA-28RT-201T	Approach	1536
04/01/90	Westfield, MA	UNK	Walter Hudson Mustang 2	Takeoff	2344
05/31/90	Anchorage, AK	B-757	Cessna 195	Landing	0284
06/20/90	Rialto, CA	Bell Helicopter 412	Cessna 152II	Takeoff	1054

Aviation Safety.
The twice-monthly journal of accident prevention
Vol. XIV, Number 15 August 1, 1994

Slow Down and Back Off!

Pilots had best keep their distance when following behind a landing Boeing 757.

By Martin Caidin

We, as pilots with any measurable level of experience, are aware of the wake turbulence generated by aircraft in flight. It doesn't matter if the machine is rag-winged and small, with a putt-putt for an engine; it disturbs the air and creates bumps and grinds for following aircraft.

Under certain conditions, the interference is minor and brings no cause for alarm. The little "speed bumps in the sky" do nothing to prevent the following machine from being flown under proper control, albeit with extra muscling and heightened caution.

Pilots know these things. We also know that the *big* airplanes flying in today's airspace are monstrous winged augers that transform the sky into violent rapids of induced turbulence with horizontal tornados that can *and have* broken up trailing airplanes or gripped their control surfaces with loads so great that they are sent into a violent rolling motion and smacked down as if by a giant, invisible hand.

Wake turbulence. Vortices. Horizontal tornados. Wake signature. Wake

TREND ANALYSIS

vortices. Wing tip vortices. A real danger comes in all these names and others. They can all be dumped into the indigestible cauldron which tells us that under certain conditions quite prevalent today, flying behind other aircraft can be extremely dangerous.

Okay, so what's new? The AIM is chock-full of information, examples and warnings. Instruction books and videos leave little to the imagination. And any instructor worth his or her salt makes certain their students are informed and, hopefully, well-versed in what to avoid, how to stay out of trouble and what to do in the event they get into trouble and must safely extricate themselves from the whirlwind. (Hopefully, that is. Sometimes, the pilot just doesn't have a chance.)

After so many years, thousands of tests, hundreds of airplanes and unknown millions of dollars to locate and identify the problem of turbulence following an aircraft, what's the ruckus all about *now*?

Cocked Hat

Color the answer *Boeing 757*.

The problem is that despite all the mountains of material on the subject, the twinjet beauty from Boeing is sending much of what pilots are warned about into a cocked hat. The airplane

INSIDE

dangerous to get too close to a B-757 as it returns to Mother Earth.

The issue here is that the existing rules of separation distance may not be (and mostly likely are not) sufficient to avoid disaster. Here's the warning code and edict:

"When Air Traffic is providing wake turbulence separations, controllers are required to apply no less than specified minimum separation for aircraft operating behind a *heavy* jet and, in certain instances, behind large *non*heavy aircraft. When a small or large aircraft is operating directly behind a heavy jet at the same altitude or less than 1,000 feet below it, five or six miles separation is provided."

That "*non*heavy aircraft" is the B-757. It is *not* a "heavy" aircraft by FAA standards; it is a "large" aircraft. The 757 produces wake turbulence that does *not* fit the standard formulas for safe separation. It is producing wake turbulence characteristic of a "heavy" aircraft.

Nevertheless, NOAA (the National Oceanic and Atmospheric Administration) judges the FAA's warnings and advisories as needless hysteria. NOAA insists B-757 wake turbulence isn't a bit stronger than other aircraft in its weight class (about 250,000 pounds for an average flight operation). NOAA says the pilots involved in the crashes simply weren't paying attention to their distance behind the 757s.

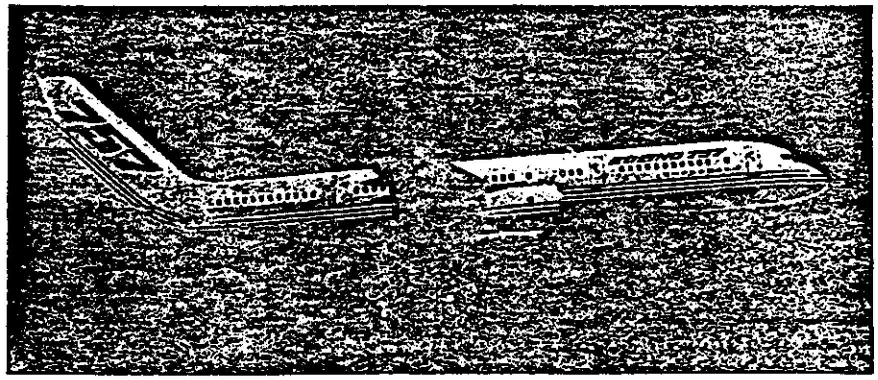
NTSB isn't quite that emphatic, but it sure is shuffling from one foot to the other. It has stated that "there are no special problems with the Boeing 757's wake vortex." But, NTSB admits that the existing (IFR) three-mile separation rule is "inadequate" if you're flying VFR.

Let's try that again. According to FAA and NTSB, and certainly NOAA, there's no need to change existing separation distance for *IFR* traffic following a landing 757. That distance is three miles. But, since the accidents were all VFR, there is a need, according to the FAA, to make some changes in VFR separation distances.

Absolute Minimum

The 757 is a splendid machine, but it seems to be throwing back wake turbulence way out of proportion to its size, wingspan and weight. The vortices it creates are catching following pilots by surprise.

The key, according to the FAA, is



Wake turbulence produced by the Boeing 757 seems to be out of proportion to the airplane's size, wingspan and weight.

that VFR traffic needs to be kept back when following a descending 757. They recommend a minimum separation distance of four nautical miles for so-called medium-weight jets such as the DC-9 and MD-80 series, and the Boeing 737. The call now is that any jetliner in this class should increase its following distance behind a 757 from three to four miles, as the absolute minimum, when on a visual approach.

If you're in a bizjet (Sabreliner, Falcon, DH-125, Lear, Citation, Westwind, etc.), safety calls for a separation of *five* miles behind a 757. You're flying a piston job? Then, make that an absolute minimum of *six* miles and stay well above the descent path of the 757. Like, at least 1,000 feet above that path.

(The rules even say a *large* jet, such as a 757, following a heavy jet, such as a 767, A300, DC-10, L-1011, 747, etc., needs at least five nautical miles to be safe. If you're flying a machine grossing under 300,000 pounds, keep your loved ones happy by staying back six miles—or, preferably, *eight* miles.)

The airline crowd (and everyone else flying these aircraft types) tell the FAA that the 757 is spewing wake turbulence so powerful that it should be put into the *heavy* class. The FAA, according to an NTSB spokesman, doesn't want to do that. It might only increase the danger because then the rules would allow a 757 to close in to only four miles behind another heavy during its let-down.

So, why not simply require the 757 to remain at least five or six miles behind a descending heavy? Well, that would be breaking the classification rules, it seems, and require pilots and controllers to remember another little detail.

Now, if that doesn't have your head shaking, get this: The government—and this seems to include FAA, NOAA and NTSB—has made urgent recommendations to "advise" *all* IFR and VFR traffic behind either a large or heavy aircraft of the specific make and model of the aircraft, and to be careful of wake turbulence ... and to have controllers watch their radar carefully to be sure the following traffic doesn't speed up and reduce its separation from the lead aircraft.

The rule-makers, who insist that 757 wake turbulence is not a problem, are also recommending new studies, tests, update training for controllers, AIM modifications, etc., etc., all for an aircraft that "doesn't present any problems."

New Warnings

Out of all this shuffling of paper and issuing of edicts comes some things likely not to be in the forefront of pilot thinking. Such as the ramifications of when you're flying IFR and request a VFR clearance.

At the moment ATC issues that clearance, you, the pilot, assume all responsibility for continued safe flying.

Meanwhile, the FAA reminds everybody within earshot that it's obvious some pilots tailgate the bigger airplanes they're following. This, FAA insists, was the cause of the accident that sent the Citation vertically into a city street when dumped by the vortex of a 757.

Advisories and warnings about wake turbulence have been with us for decades, but new warnings are being sounded—among them, the need to modify old procedures.

In earlier days of flight, anything with decent climb performance could

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ON THE RECORD

Trouble in the Wake

A rash of recent accidents illustrates the hazards of tangling with vortices from a B-757.

By Patrick R. Veillette
and Rand Decker, Ph.D.

The hazard created by wake vortices, particularly behind the Boeing 757, has been highlighted by several recent accidents and incidents. Although there is activity in the FAA at this time to study the wake turbulence characteristics of the 757, there is no disagreement within the scientific community that it will be some time before any definitive results are available.

In the July issue of *Aviation Safety*, we described some of the factors which influence wake vortex development, strength and movement. From a scientific standpoint, much more is to be learned about the very fundamental processes that occur within a vortex. Even state-of-the-art computer modeling is not able to predict vortex motion with sufficient accuracy. Several recent NOAA reports have emphasized that trailing vortex systems differ greatly among aircraft.

Wake vortex encounters tend to be under-reported, and the NTSB has recommended that the FAA establish a mandatory reporting requirement so that we may gain a better understanding of the hazard.

Several general aviation and air carrier pilots have informed us of their wake vortex encounters. In some instances, the wings of their aircraft came within inches or feet of striking the ground. One B-767 crewman described just such an encounter. Many of the pilots believed they were safely above the preceding aircraft's wake.

Several pilots learned that the wake vortices from a slightly larger aircraft, such as a light twin, could upset their single-engine aircraft. Some pilots described encounters with wake from helicopters hovering in ground effect.

All of the pilots considered themselves *extremely* lucky to have survived their encounters. But, as we shall see, some pilots have not been so lucky. Please keep in mind that the accidents and incidents we'll review are only the "tip of the iceberg"; we can only guess how many near-accidents have resulted from wake encounters.

Cessna Citation, 12/18/92

The Citation 550 was on a IFR flight plan to Billings, Mont. with two pilots and six passengers aboard. The weather at Billings was reported as 10,000 scattered, 25,000 scattered, visibility 40 miles and wind from 350 degrees at five knots. (Note the wind direction and velocity.)

The Citation began its descent at 1626 MST, sequenced behind a United Parcel Service Boeing 757. At 1636, the Citation was advised that the 757 was at 12 o'clock and six miles ahead. The UPS jet was then cleared out of 11,000 feet to 5,700 feet and instructed to maintain 250 knots. The Citation was descending through 16,000 feet.

At 1638, the 757 reported the airport in sight and was cleared for a visual approach to Runway 27R (which had an almost direct crosswind). The Citation was maintaining a very high speed (which continued throughout its descent), so the approach controller asked the 757 to maintain its maximum forward speed.

The controller then advised the Citation that the 757 was at 12 o'clock and four miles, descending through 8,000 feet. (Note that the Citation had closed the separation distance from six to four miles in a very short time.) The Citation's first officer replied that they were looking for the traffic.

At this point, the distance between the two aircraft had stabilized at 4.2 nautical miles. The 757 crew requested permission to slow down, but the controller asked them to keep their speed up as much as they could.

Ten seconds later, the Citation reported the 757 in sight and was cleared to follow that aircraft for a visual approach to the same runway. The Citation's speed then *increased* from 215 to 250 knots. As the 757 slowed, the speed differential grew from 30 to 70 knots. The controller warned the Citation that the 757 was slowing and cleared the 757 to resume normal speed.

After contacting the tower, the Citation again was warned that the 757 was slowing down and advised that if they needed to turn for spacing, they could turn to the right. At this point, the aircraft were less than 2.5 miles apart.

The 757 flew a relatively constant 4.7-degree glide path, staying above the electronic glide slope by several hundred feet, until 1.2 miles from the threshold. However, the Citation had a greater descent rate and stabilized 200 to 300 feet *below* the 757's glide path, principally tracking the glide slope until the wake encounter. (Note: When a visual approach clearance is accepted, the crew acknowledges that they are accepting responsibility for wake clearance from the preceding aircraft.)

At the point of upset, the Citation was about 2.78 nm (about 74 seconds) behind the 757 and about 300 feet below its glide path. The ground controller saw the Citation roll from a

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737 crew accepted clearance for a visual approach, the controller was no longer required to provide three miles' separation.

Cessna 182R, 11/9/93

The Civil Air Patrol airplane was on a night, VFR approach to Salt Lake City International Airport and was cleared to land on Runway 32.

The tower warned the Cessna pilot about a Boeing 727 on short final to Runway 35, with additional traffic on a three-mile final. (Winds were reported out of the south at five knots.) The pilot reported that he was uncertain of the location of the traffic and was asked by the controller to execute a left, 360-degree turn.

The Cessna was three-quarters of the way through the turn when the pilot again was cleared to land on Runway 32 and advised of "Boeing" traffic on short final to Runway 35 (the controller did not identify the Boeing as a 757). The threshold of Runway 32 is adjacent to the threshold of 35.

The pilot reported that he was flying the approach "a little higher so we would miss ... any turbulence" and had just crossed behind Runway 35 in a shallow turn to final when the 182 encountered a "slight bump" and then pitched up and rolled into a 90-degree right bank.

Radar data shows that the 182 was at less than 100 feet AGL when it crossed the flight path of the 757. The pilot said he immediately applied full left rudder and aileron, and full nose-down elevator. He was able to level the wings before the airplane struck the pavement short of Runway 32's threshold.

The pilot and his two passengers survived with minor injuries. (This once again bears witness to the importance of maintaining aircraft control. Pilots who maintain control even to the point of impact have a much better chance of surviving that those who lose or relinquish control.)

Winds at the time were from 180 degrees at five knots; so, in effect, the 757 landing on Runway 35 had a tailwind. This may be significant; the tailwind would likely have caused the wake vortices to drift further into the Cessna's flight path. The tailwind also might have moved the wake higher into the Cessna's glide path or, at the very least, partially canceled out some of the downward drift of the vortices.

The Boeing 757 passed the crossing position about 38 seconds prior to the Cessna 182. Trends in the recorded radar data suggest that the Cessna was slightly above the flight path of the 757 at the crossing point.

The accident points out the importance of accurately predicting the behavior of vortices in ground effect. The vortex may have "bounced"—a phenomenon which has been observed on many occasions by researchers in the U.S. and Germany.

Additionally, the flow field of a vortex is usually about equal to the wingspan of the generating airplane. Therefore, the Cessna 182 could have been affected by the vortex at any altitude between ground level and 200 feet. The NTSB notes that although the Cessna's flight path was above that of the 757, the pilot did not adequately compensate for the height of the vortex.

(The AIM recommends flying above the wake, but it does not state how far to fly above it. Also, the AIM does not warn pilots of the bouncing behavior of vortices in ground effect, though this information has been published in articles and had been presented at conferences by the FAA for several years preceding this accident.)

IAI Westwind, 12/15/93

At 1734 hours local time, an Israel Aircraft Industries Westwind was cleared for a visual approach to Runway 19R at John Wayne Airport in Santa Ana, Calif. The wind was calm.

The Westwind's flight path converged with that of a Boeing 757 which also was receiving radar vectors to the airport. When the distance between the 757 and the following Westwind was rapidly closing to the required minimum of three miles, the controller issued a visual approach clearance to the Westwind crew.

The NTSB said the only way the Westwind crew could have maintained adequate separation from the 757 at this point was by executing "significant maneuvers."

The 757 flew a 5.6-degree glide path (for reasons unstated in the NTSB's report), whereas the Westwind flew a standard three-degree glide path initially. However, anticipating that they would encounter a "little" wake turbulence, they began to fly the approach one dot high on the glide slope.

CVR information indicates that the Westwind pilots were aware that they were close to the Boeing and that the preceding airplane appeared high.

When control was lost, the Westwind was 2.1 miles (60 seconds) behind the 757 and 400 feet below its glide path. All five occupants were killed when the aircraft hit the ground.

NTSB's Recommendations

In its report on these accidents and incidents, the NTSB made a number of excellent recommendations for interim and long-term solutions to the hazard. Among the recommendations which specifically address pilots and flight operations were the following:

1. Establish the following separation requirements for IFR airplanes following a Boeing 757 and comparable aircraft: *five* nm for airplanes such as the Westwind and Citation, and *six* nm for small airplanes.

2. Establish ATC procedures that would result in approaches being conducted, when available, on a standard flight path angle of three degrees. Inform operators of B-757s (and other comparable aircraft) of the importance of maintaining this standard flight path angle on approach.

3. Amend ATC procedures to prohibit the issuance of a visual approach clearance until the closure rate is such that the pilot can maintain separation without excessive maneuvering.

4. Amend ATC procedures to advise pilots sequenced behind a jet airplane (or a heavier jet) of the preceding aircraft's make and model, and provide "information relevant to the avoidance of wake turbulence," such as separation distance and whether an overtaking situation exists.

5. Expand current guidance in the AIM to help pilots determine that their flight path remains above the flight path of the leading airplane and that their separation remains consistent with that required for IFR operations.

6. Expand the information in the AIM to define the vertical movement of wake vortices in ground effect, such as core height, upper and lower limits of the vortex flow field, and the potential to bounce twice as high as the steady state. ◆ FCV

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6. REF. Fatal Commuter Crash Blamed on Numerous Causes.
   Was the Captain's inexperience flying into a "black hole" cited ?

   A. He had not received "black hole" training.

   B. In addition to the inexperience, the captain's seat position was named as a factor (including lack of required night training).

   C. The Captain had flown into that airport numerous times but had no familiarity with "black hole" illusion. He was not cited for that.

7. REF. DC-10 Destroyed After Veering Off Landing Runway.

   A. The First Officer was flying the approach, decided to go around.

   B. The Captain took over control and landed. NTSB concluded he was within his authority to do so. However, the plane was destroyed.

   C. The Captain took over control and landed. NTSB considered whether the 59 year old Captain might have been fatigued, affecting his landing performance.

   The value to us of digesting this report does not lie in correctly answering a test question, and so each one is correct. The report is long, detailed, and thought-provoking. Much of it could be read a second time.

We think the lengthy, detailed NTSB Report, sent to us by Flight Safety, is even more thought-provoking. It would interest us for all its thoughtful detail, even if we weren't especially interested because of the Boeing 757 involvement.

Then, the two timely articles - somewhat easier reading, courtesy of Aviation Safety magazine, sort of put the frosting on the 757 size cake.

Timely also is the 'Black Hole' article from the BOEING Airliner. After suffering with the commuter Captain on his lack of knowledge about flying the 'hole', TWA Captain Schiff does a good job of explaining all about it. Test question! What is the 'black hole'?

ANSWERS: 1. B, 2. B, 3. C, 4. C, 5. B, 6. C, 7. ALL correct

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Despite claims to the contrary, night operations are still more hazardous for us than daylight flying. This is because the horizon is often not visible, optical illusions are more prevalent, and fatigue is often more of a factor. Also, obstructions and clouds may be difficult or impossible to see. to see. Regarding this last point, consider that hundreds-if not thousands-of pilots and passengers have collided with terrain that was never seen, even though visibility was unlimited.

NIGHT VISIBILITY

Such mishaps occur because night visibility is determined by the greatest distance at which prominent lighted objects can be seen and identified. Seeing a distant light, however, does not mean that the pilot can see rising terrain directly in front of the aircraft on a moonless, overcast night.

Executing visual arrivals and departures over certain areas and under certain conditions is much like instrument flying and requires the same attention to minimum safe altitudes. Obviously, the crew is responsible for ensuring that the aircraft is always at a high enough altitude to keep from flying headlong into unseen obstructions.Avoiding obstructions, however, can be easier said than done, particularly during a long, straight-in approach to an airport at night. A subtle danger associated with some night visual approaches can lead airline crews to fly at dangerously (and sometimes fatally) low approach altitudes.

When descending toward an airport during the day, a pilot uses depth perception to estimate distance to and altitude above an airport. The pilot can fairly easily descend along an approximately 3 degree visual approach path to a distant runway.

On a moonless or overcast night, however, the pilot has little or no depth perception because the necessary visual clues (color variations, shadows and topographical references) are absent. This lack of depth perception makes estimating altitude and distance more difficult.

For example, a pilot flying six miles from and 2000 feet above a runway that is 12,000 feet long and 300 feet wide sees the same picture through the windshield as when the aircraft is only three miles from and 1000 feet above above a runway that is only 6000 feet long and 150 feet wide. Remember that this is true either day or night; making consistent approaches assures consistent landings.

APPROACHES OVER WATER

The problem is exacerbated when straight-in approaches are made over water or dark, featureless terrain on an overcast or moonless night. The only visual stimuli are distant sources of light in the vicinity of the destination airport. Such situations are often referred to as 'black-hole approaches. The'black hole' refers not to the airport, but to the featureless darkness over which the approach is being conducted. Overwater approaches are notable examples.

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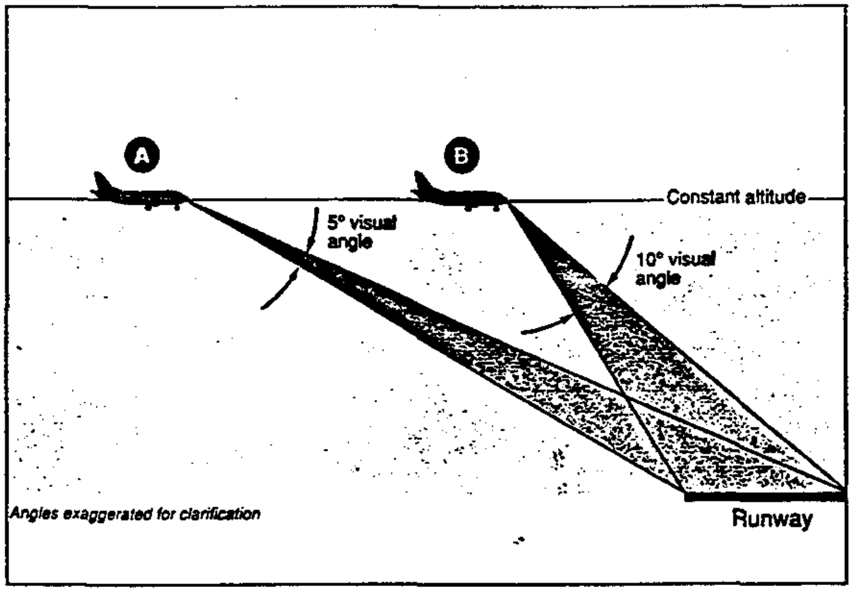

Figure 2. Distance and altitude from an airport effect the pilot's perspective. If a constant altitude is maintained, the airport will subtend a greater visual angle, and therefore appear larger, as the airplane approaches the airport.

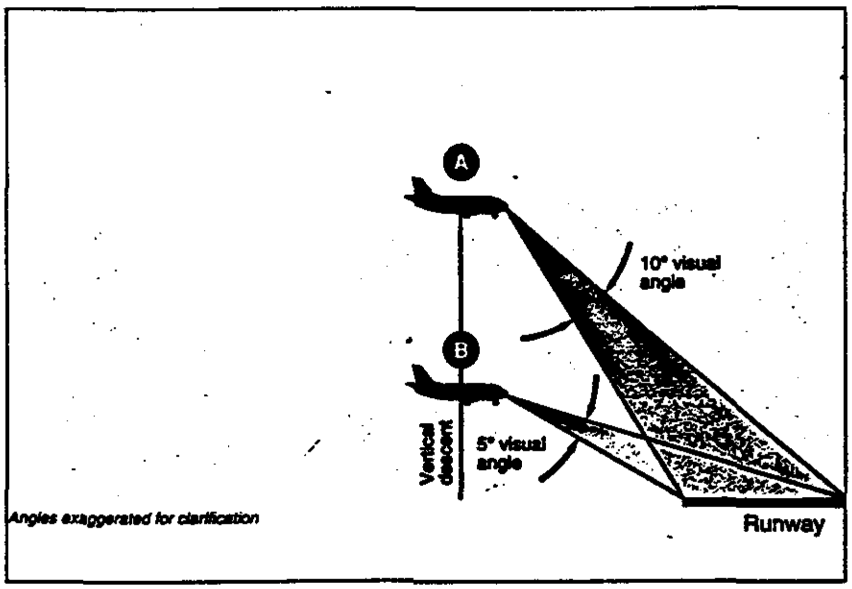

Figure 3. Assuming that an airplane could descend vertically at a constant distance from an airport, the visual angle would decrease, making the airport appear to move farther away.

becomes smaller. Finally at position B, the visual angle is only 5°. In other words, the visual angle decreases as altitude decreases.

Because the visual angle becomes larger as a pilot nears the airport and becomes smaller as the aircraft loses altitude, a pilot can descend toward an airport in such a way that the resultant visual angle remains constant.

Not only can a pilot approach an airport in this manner, but this is exactly what pilots tend to do-without realizing it-while executing black-hole approaches. The problem is shown in Figure 4. The flightpath during which the visual angle remains constant consists of the arc of a circle centered high above the light pattern toward which the pilot is descending.

Note that flying such an arc places the aircraft well below the 3° descent profile normally used when a pilot has better depth perception. Also, the circumference of this arc is sufficiently large that the pilot has no way of detecting that he is flying along an arc instead of a straight line.

LOW APPROACH SHORT OF RUNWAY

The pilot actually makes a low approach to a point about two to three miles from the runway. Upon arriving at this point, the error starts to become apparent and the pilot takes corrective action (unless the aircraft's striking an intervening object interrupts the process).

Some may wonder how a pilot can possibly crash during a straight-in approach without first losing sight of the airport. A pilot about to collide with the terrain or an obstruction does begin to lose sight of the airport, but this can occur after it is too late to effect a timely recovery.

LIGHTS AT SMALL CITIES

The Boeing researchers also discovered that if the airport is at the edge of a small city, the additional lighting cues do not provide improved reference information to the pilot as long as the approach is made over dark terrain or water. Curiously, their experiments suggested hole. Pilots seldom are victimized by illusions when the final approach is less than two-to-three miles long.

A pilot can use certain precautions to increase altitude and distance awareness during long, straight-in approaches at night when an ILS or VASI is unavailable for descent guidance. (Although a VASI may be visible for 30 miles at night, safe obstruction clearance is guaranteed only within four miles of the runway threshold.)

DME (if available and appropriate) can help establish a safe descent profile using the principle that a 3° descent profile can be maintained by being 300 feet above the ground (AGL) for each nautical mile from the runway. (For example, an aircraft that is three miles from the runway should be at 900 feet AGL.) A 4° descent is established by maintaining 400 feet per nautical mile, and so forth.

Always maintain a watchful eye on airspeed, altitude and sink rate. An excessive sink rate (for the airspeed being flown) indicates either a strong tailwind or an abnormally steep descent profile. Remain alert!

Although stating this might seem silly, be certain that you are descending toward an airport. Pilots have been deceived by highway lights that-from a distance-give the illusion of being runway lights.

Maintain a safe altitude until the airport and its associated lighting are distinctly visible and identifiable.

Like most people, pilots usually believe what they see. In *black-hole* approaches, however, pilots should have compelling reasons to not do so.

Airliner References -

- Night Visual Approaches - Mar-Apr 1969
- The Last Two Minutes - Jan-Mar 1991
- Stopping on the Runway Visual Approaches - Apr-Jun 1991

The facts and opinions contained in this article are presented by the author and are not necessarily concurred in nor endorsed by The Boeing Company. Questions regarding the contents of the article may be directed to the author.

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