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# NTSB Report of Wake Turbulence

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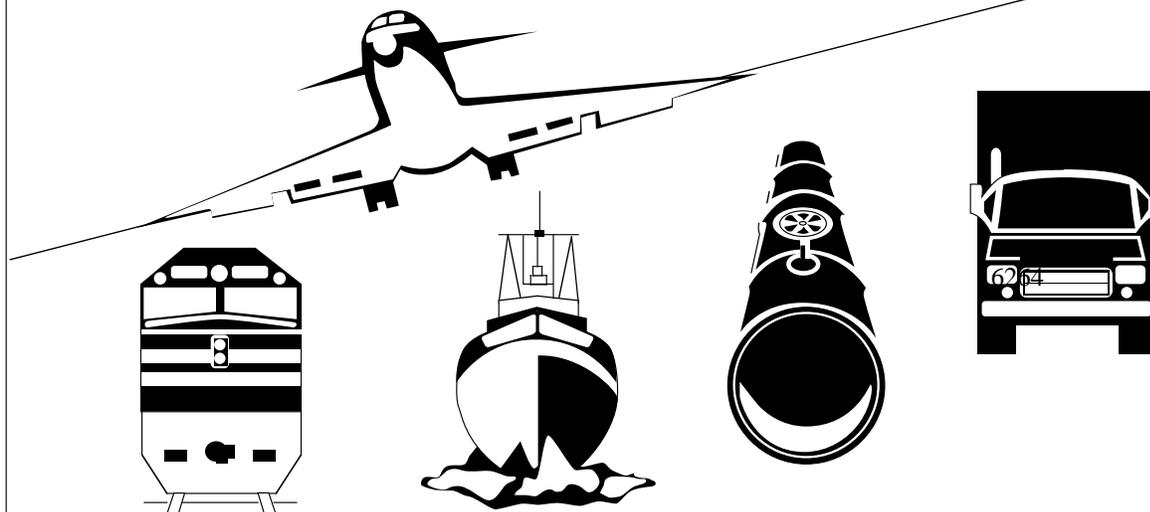
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NTSB/SIR-94/01

# NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

## SPECIAL INVESTIGATION REPORT

SAFETY ISSUES RELATED TO  
WAKE VORTEX ENCOUNTERS  
DURING VISUAL APPROACH  
TO LANDING



**National Transportation Safety Board. 1994. Safety issues related to wake vortex encounters during visual approach to landing. Special Investigation Report NTSB/SIR-94/01. Washington, DC.**

The Safety Board conducted a special investigation to examine in detail the circumstances surrounding five recent accidents and incidents in which an airplane on approach to landing encountered the wake vortex of a preceding Boeing 757. Thirteen occupants died in two of the accidents. The encounters, which occurred during visual conditions, were severe enough to create an unrecoverable loss of control for a Cessna Citation, a Cessna 182, and an Israel Aircraft Industries Westwind. Additionally, there were significant but recoverable losses of control for a McDonnell Douglas MD-88 and Boeing 737 (both required immediate and aggressive flight control deflections by their flightcrews). The safety issues discussed in this special investigation report are: the adequacy of the current aircraft weight classification scheme to establish separation criteria to avoid wake vortex encounters, the adequacy of air traffic control procedures related to visual approaches and visual flight rules operations behind heavier airplanes, 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. Recommendations concerning these issues were made to the Federal Aviation Administration.

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WAKE VORTEX ENCOUNTERS  
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TO LANDING**

**Special Investigation Report**

Special Investigation Report NTSB/SIR-94/01  
Notation 6264

National Transportation  
Safety Board



Washington, D.C.  
February 1994

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## Executive Summary

Since December 1992, there have been five accidents and incidents in which an airplane on approach to landing encountered the wake vortex of a preceding Boeing 757 (B-757). Thirteen occupants died in two of the accidents. The encounters, which occurred during visual conditions, were severe enough to create an unrecoverable loss of control for a Cessna Citation, a Cessna 182, and an Israel Aircraft Industries Westwind. Additionally, there were significant but recoverable losses of control for a McDonnell Douglas MD-88 and a B-737 (both required immediate and aggressive flight control deflections by their flightcrews).

Safety Board data show that between 1983 and 1993, there were at least 51 accidents and incidents in the United States, including the 5 mentioned above, that resulted from probable encounters with wake vortices. In these 51 encounters, 27 occupants were killed, 8 were seriously injured, and 40 airplanes were substantially damaged or destroyed.

The Safety Board conducted a special investigation to examine in detail the circumstances surrounding the five recent accidents and incidents to determine what improvements may be needed in existing procedures to reduce the likelihood of wake vortex encounters.

The Safety Board's investigation initially focused on why the B-757 appeared to be involved in a disproportionate number of wake vortex encounters. Several reports indicated that the B-757 generated wake vortices that were more severe than would be expected for an airplane of its weight. However, as a result of a thorough study and analysis of the issue, the Safety Board found little technical evidence to support the notion that the wake vortex of a B-757 is significantly stronger than indicated by its weight.

The Safety Board's investigation, therefore, raised concerns about the following safety issues:

- the adequacy of the current aircraft weight classification scheme to establish separation criteria to avoid wake vortex encounters;
- the adequacy of air traffic control procedures related to visual approaches and visual flight rules operations behind heavier airplanes;

- 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.

# Introduction

Since December 1992, there have been five accidents and incidents in which an airplane on approach to landing encountered the wake vortex of a preceding Boeing 757 (B-757) (see table 1). Thirteen occupants died in two of the accidents. The encounters, which occurred during visual conditions, were severe enough to create an unrecoverable loss of control for a Cessna Citation, a Cessna 182, and an Israel Aircraft Industries Westwind. Additionally, there were significant, but recoverable losses of control for a McDonnell Douglas MD-88 and a B-737 (both required immediate and aggressive flight control deflections by their flightcrews).

Safety Board data show that between 1983 and 1993, there were at least 51 accidents and incidents in the United States, including the 5 mentioned above, that resulted from probable encounters with wake vortices (see appendix A). In these 51 encounters, 27 occupants were killed, 8 were seriously injured, and 40 airplanes were substantially damaged or destroyed.

In the last 20 years, the Safety Board has issued several safety recommendations to the Federal Aviation Administration (FAA) to address wake vortex issues. In 1972, following the crash of a Delta Air Line DC-9-14 at Fort Worth, Texas,<sup>1</sup> the Safety Board asked the FAA to “reevaluate wake turbulence separation criteria for aircraft operating behind heavy jet aircraft,” and to “develop new ATC separation standards which consider the relative span loadings of the vortex-generating aircraft and the following aircraft under meteorological conditions conducive to the trailing vortices.” The FAA responded that such actions were not necessary. (Appendix B contains details of the Board’s past safety recommendations that address wake vortex issues.)

The Safety Board conducted a special investigation to examine in detail the circumstances surrounding the five recent accidents and incidents in which an airplane on approach to landing encountered the wake vortex of a preceding B-757. The purpose of the Safety Board’s special investigation was to determine what improvements may be needed in existing procedures to reduce the likelihood of wake vortex encounters.

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<sup>1</sup> National Transportation Safety Board. 1973. Delta Air Lines, Inc., McDonnell Douglas DC9-14, N3305L, Greater Southwest International Airport, Fort Worth, Texas, May 30, 1972. Aircraft Accident Report NTSB-AAR-73-3. Washington, DC.

**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 2.8nm 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, <sup>a</sup> 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.

<sup>a</sup> Above ground level.

## Recent Encounters With Wake Vortices

*Billings, Montana.*—On December 18, 1992, a Cessna Citation 550, N6887Y, operating under Part 91, Title 14 of the Code of Federal Regulations (14 CFR 91), crashed while on a visual approach<sup>2</sup> to runway 27R at the Billings Logan International Airport, Billings, Montana.<sup>3</sup> The two crewmembers and six passengers were killed. Witnesses reported that the airplane suddenly and rapidly rolled left and then contacted the ground while in a near-vertical dive. Recorded ATC radar data show that at the point of upset, the Citation was about 2.78 nautical miles (nm) (about 74 seconds) behind a B-757 and on a flight path that was about 300 feet below the flight path of the B-757 (see appendix C). The flight path angle of the Citation was 3°, and the flight path angle of the B-757 was 4.7°.

The B-757, at a takeoff weight of 255,000 pounds, and the Citation, at a takeoff weight of 13,000, are both classified as large airplanes.<sup>4</sup> Standard IFR separation (greater than 3 nm) was provided to the pilot of the Citation until the pilot requested and was cleared for a visual approach behind the B-757. The clearance was issued to the pilot

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<sup>2</sup> Air traffic controllers are required to provide lateral and vertical separation guidance between airplanes when the airplanes are operating under instrument flight rules (IFR) and receiving air traffic control (ATC) services. The separation criteria are intended to physically separate airplanes and to minimize the risk of wake vortex encounters. However, under prescribed conditions, the controller may issue a visual approach clearance to the pilot of the following airplane. Once the pilot accepts the visual approach clearance, the pilot is responsible for maintaining adequate wake turbulence separation and visual contact with the lead airplane and airport.

<sup>3</sup> NTSB accident SEA 93-G-A041.

<sup>4</sup> The FAA classifies airplanes as small, large, and heavy based on their maximum takeoff weight. Small airplanes may weigh up to 12,500 pounds. Large airplanes weigh between 12,500 and 300,000 pounds. Heavy airplanes weigh 300,000 pounds or greater. (Also see table 2.) These classifications were established in 1970 after the FAA conducted flight tests to determine the wake vortex characteristics of existing jet aircraft. These classifications were used to establish aircraft separation standards. For example, a large airplane is required to be separated from another large airplane by 3 nm while on an instrument approach to landing. Before 1970, radar operating limits and, to a lesser extent, runway occupancy restrictions dictated separation standards; there were no aircraft separations imposed because of wake vortices.

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 discusses techniques for determining the relative flight paths of airplanes on approach to landing.

**Orlando, Florida.**—On March 1, 1993, a Delta Airlines McDonnell Douglas MD-88, operating under 14 CFR 121, was executing a visual approach to runway 18R at Orlando International Airport, Orlando, Florida, while following a B-757 to the airport.<sup>5</sup> The crew of the MD-88 reported that the airplane suddenly rolled right about 15°, and the pilot rapidly deflected both the wheel and rudder pedal to correct the uncommanded roll. Data from the digital flight data recorder (DFDR) indicate that at about 110 feet above ground level (AGL), the roll angle reached 13° right wing down and the ailerons and rudder were deflected about one-half of full travel, 10° and 23°, respectively. The crew regained control and the approach was continued to an uneventful landing. Recorded radar data show that at the point of upset, the MD-88 was about 2.5 nm (65 seconds) behind a Delta B-757 while the flight path of the MD-88 was slightly below that of the B-757. The flight path angle of both airplanes was 3°.

The MD-88 flightcrew was issued a visual approach clearance when the airplane was 4.5 nm from the leading B-757. However, the separation quickly reduced to 2.5 nm. Had the MD-88 flightcrew not accepted the visual approach, the required IFR separation distance of 3 nm would have provided an additional 13 seconds of separation. The MD-88 flightcrew told investigators that they thought they had a 4 nm separation at the time of the encounter.

**Denver, Colorado.**—On April 24, 1993, the flightcrew of a United Airlines B-737 reported a wake vortex encounter while executing a visual approach to runway 26L at Stapleton International Airport, Denver, Colorado.<sup>6</sup> The flightcrew reported that about 1,000 feet AGL, the airplane rolled left violently with no yaw, the pitch decreased 5°, and the airplane lost 200 feet altitude. To correct the uncommanded roll, the pilot rapidly deflected the wheel and rudder about 60° and 7°, respectively, according to the DFDR. A go-around was initiated, and the airplane landed without further incident. The DFDR data also indicate that at the point of upset, the B-737 was about 900 feet AGL; in 2 seconds, its roll angle reached 230 left wing down. Recorded radar data show that at the point of upset, the flight path of the B-737 was about 100 feet below the flight path of a B-757 that was landing on runway 26R. The B-737 was about 32 seconds and 1.35

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<sup>5</sup> NTSB incident DCA 93-I-A021.

<sup>6</sup> NTSB incident DEN 93-I-A044.

nm behind the B-757. The 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.

*Salt Lake City, Utah.*—On November 10, 1993, the pilot of a Cessna 182, N9652X, operating under 14 CFR 91, was executing a visual flight rules (VFR) approach to runway 32 at Salt Lake City International Airport, Utah.<sup>7</sup> The pilot reported that he was instructed by ATC to proceed “direct to the numbers” of runway 32 and pass behind a “Boeing” that was on final approach to runway 35. There is no evidence to suggest that the pilot was advised that the airplane was a B-757.<sup>8</sup> The Cessna pilot reported that while on final approach, the airplane experienced a “burble,” and then the nose pitched up and the airplane suddenly rolled 90° to the right. The pilot immediately put in full-left deflection of rudder and aileron and full-down elevator in an attempt to level the airplane and to get the nose down. As the airplane began to respond to the correct attitude, the pilot realized that he was near the ground and pulled the yoke back into his lap. The airplane crashed short of the threshold of runway 32, veered to the northeast, and came to rest on the approach end of runway 35. The pilot and the two passengers suffered minor injuries, and the airplane was destroyed. The wind was 5 knots from the south.

The approach ends of runways 32 and 35 are about 560 feet apart. Radar data show that the Cessna was at an altitude of less than 100 feet AGL when it crossed the flight path of the B-757 (see appendix F). The B-757 had passed the crossing position about 38 seconds prior to the Cessna 182. Trends in the recorded radar data suggest that the flight path of the Cessna was slightly above the flight path of the B-757 at the point of crossing. The exact position of the upset has not been determined. However, wake vortices tend to remain above the ground while in ground effect and translate outward at a speed of 3 to 5 knots plus the wind component. In ground effect, the left vortex from the B-757 typically would have translated 200 to 300 feet to the west. The vortex core may have been located about 75 feet above the ground, although researchers have said the vortex has the potential to “bounce” twice as high as the steady state height. In addition, the diameter of the vortex’s flow field is usually about equal to the wing span of the generating airplane. Thus, the Cessna 182 could have been affected by the vortex at any altitude between ground level and 200 feet AGL. Although the Cessna’s flight path was above that of the B-757, the pilot did not adequately compensate for the height of the vortex.

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<sup>7</sup> NTSB accident SEA 94-G-A024.

<sup>8</sup> At the time of the accident, there was no requirement for such an advisory. On December 22, 1993, the FAA issued a General Notice (GENOT) requiring wake turbulence advisories to airplanes operating behind B-757 airplanes. The FAA also issued a pilot bulletin cautioning pilots about the possibility of wake vortex encounters, especially when following a B-757. (See appendix E.) However, the separation distances were not changed.

*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.<sup>9</sup> 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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<sup>9</sup> NTSB accident LAX 94-F-A073.

The investigation disclosed that the company for which the crew were flying had not provided specific training regarding wake vortex movement and avoidance techniques. According to Safety Board investigators, the company's director of operations stated that any such training would have been included in the required windshear training. However, wake vortex avoidance was not discussed in the company's windshear training. Further, the Safety Board is unaware of any such training for Part 121 and 135 pilots.

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# Research and Data on Wake Vortices

## Research on Wake Vortex Detection and Prediction

The National Aeronautics and Space Administration (NASA), in conjunction with the FAA, is conducting an aggressive wake vortex research program related to the Terminal Area Productivity Program. According to the director of the NASA program, the purpose of the program is to increase airport capacity by accurately predicting safe separation distances using real-time data of atmospheric conditions and data specific to the airplane model. NASA envisions that the system would be backed up by real-time monitoring of wake vortex movements. The structure of the program is to parallel the highly successful windshear research program conducted by NASA several years ago. The multidisciplinary program will address training, risk characterization (of airplane pairs), defining atmospheric effects of wake transport and decay, and airborne or ground-based wake vortex detection systems. Once the positions of wake vortices can be accurately predicted and detected, NASA research reportedly will focus on developing systems for controllers that will enable airplanes to be safely spaced at smaller separation distances.

NASA has had recent success using a ground-based LIDAR radar to track wake vortices at Stapleton International Airport; NASA plans to continue the project, testing LIDAR radar at Memphis this summer. In addition, NASA plans to install LIDAR radar on its B-737 to study the feasibility of using the radar for airborne detection of wake vortices. A highly instrumented Ov10,<sup>10</sup> with variable roll inertia, will be flown in the wake of other airplanes. NASA has conducted wind tunnel tests using a model to create wake vortices and used another remote control model to fly in the test wake. NASA plans additional tests in the NASA Ames 80-foot by 120-foot wind tunnel, using a large size B-747 wind tunnel model. The Safety Board is encouraged that new technology being developed may find application in future airborne and ground-based systems to

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<sup>10</sup> The Rockwell OV-10 is a twin-engine turboprop airplane with a 40-foot wing span and a 9,900-pound gross weight.

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,<sup>11</sup> 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."<sup>12</sup>

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<sup>11</sup> 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.

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

**Table 2—Aircraft categories and weight range of aircraft in categories used by the International Civil Aviation Organization (ICAO), United Kingdom (U.K.), and United States (U.S.) as the basis for current separation standards established to avoid wake vortex encounters<sup>a</sup>**

*In pounds*

Category	ICAO	U.K.	U.S.
Heavy	>300,000	>300,000	>300,000
Large	NA	NA	<300,000
Medium	<300,000 to 15,000	<300,000 to 90,000	NA
Small	NA	<90,000 to 37,500	<12,500
Light	<15,000	<37,500	NA

NA = not applicable because category has not been designated.

<sup>a</sup>The weight categories are based on maximum takeoff weight of the aircraft.

The CAA continues to gather data on wake vortex encounters. An analysis of CAA wake vortex incidents reported between 1972 and 1990 found:

... the B-747 and B-757 airplanes appear to produce significantly higher incident rates than the other airplanes considered, indicating prima facie that they produce stronger and more persistent vortices than the other aircraft in their respective weight categories....The fact

that the B-747 is by far the heaviest in the 'heavy' wake vortex class (maximum take-off weight 371,000 Kg) is a likely explanation for its higher incident rates. However, the cause of the higher B-757 incident rates is uncertain.<sup>13</sup>

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.<sup>14</sup> 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.<sup>15</sup>

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

<sup>14</sup> National Air Traffic Services. Civil Aviation Authority, ATCEU Memorandum No. 177.

<sup>15</sup> ATCEU Memorandum No. 184.

## Discussion

The Safety Board's investigations of the preceding cases initially focused on why the B-757 appeared to be involved in a disproportionate number of wake vortex encounters. Several reports indicated that the B-757 generated wake vortices that were more severe than would be expected for an airplane of its weight. However, as a result of a thorough study and analysis of the issue, the Safety Board found little technical evidence to support the notion that the wake vortex of a B-757 is significantly stronger than indicated by its weight. Figure 1 presents the calculated initial relative vortex strength of the B-757 and other airplanes. The calculated initial vortex strength is closely related to the weight of the airplane. Of note, the B-757 is the heaviest airplane in its weight category, and there are no other airplanes of similar weight.

The current aircraft weight classification scheme was established in 1970 based on FAA flight tests to determine the wake vortex characteristics of existing jet aircraft. Based on these classifications, aircraft separation standards were established in 1970, with some modifications made in 1975. However, many transport category turbojet airplanes have been introduced into service since the implementation of the aircraft separation requirements.

The Safety Board's investigations, therefore, raised concerns about the adequacy of: (1) the current aircraft weight classification scheme to establish separation criteria to avoid wake vortex encounters; (2) air traffic control procedures related to visual approaches and VFR operations behind heavier airplanes; and (3) pilot knowledge related to the avoidance of wake vortices. Resolution of these concerns would address any concerns that were believed to have been specific to the B-757.

### Aircraft Separation Criteria Based on Weight

The wake vortex characteristics of transport category airplanes are not required to be determined at the time of airplane certification; airplane separation distances to avoid wake vortex encounters are based solely on weight. For example, not until 1992 did the National Oceanic and Atmospheric Administration (NOAA) and FAA conduct

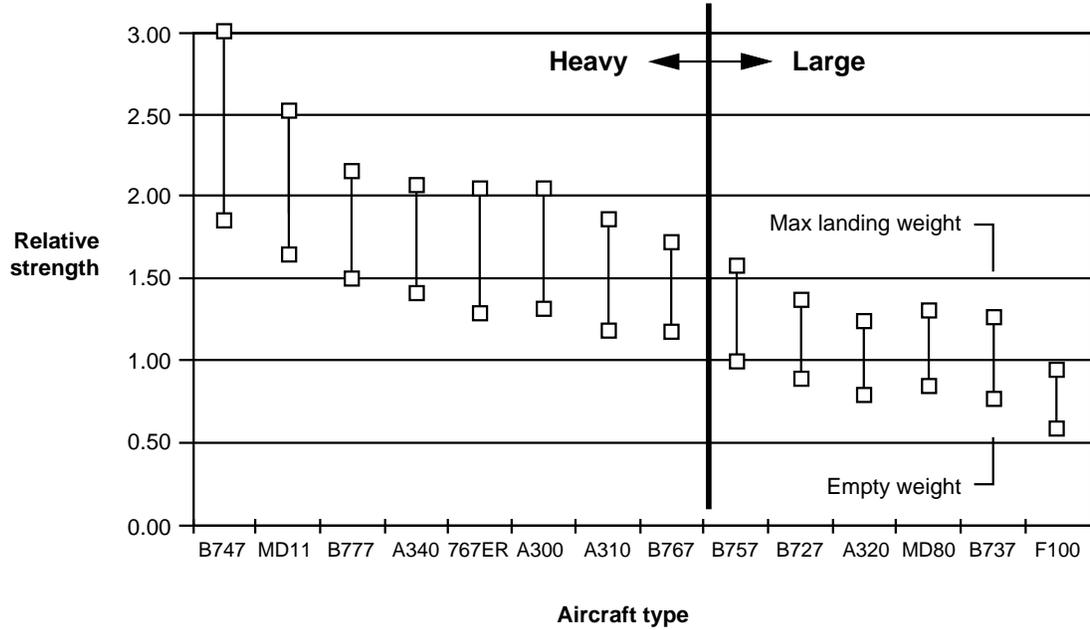


Figure 1—Calculated initial vortex strength of aircraft types. (Courtesy of the National Aeronautics and Space Administration.)

tower fly-by tests to determine the characteristics of wake vortices produced by the B-757; yet the airplane entered service in 1982, and there are 574 airplanes now in service. The testing has shown that the B-757 generated the highest vortex tangential velocity,<sup>16</sup> 326 feet per second, of any tested airplane, including heavy category B-747, B-767, and C-5A airplanes.<sup>17</sup> The vortex core radius was about 3 inches. Various theories have been offered as to why the tangential velocity was higher than previously measured. Although not proven, a number of researchers and engineers believe that the B-757 wing flap design is an important factor. Most of the larger transport category airplanes have gaps between the trailing edge flaps that disrupt the uniform development of the vortex. The B-757 flaps are continuous from the fuselage to the ailerons, a design that is believed to be more conducive to uniform development of the wake vortex.

More importantly, however, the high core velocity (within the small core radius) is not considered the primary factor in defining the risk associated with encountering the vortex. Researchers and engineers generally believe that the vortex circulation<sup>18</sup> is a more significant factor in the risk of a wake vortex encounter. The circulation theory has been verified and accepted for many years. The initial strength of a vortex can be accurately calculated and the fly-by test results have shown that the circulation of the B-757's wake is typical for its weight. The B-757's circulation was greater than that of a B-727 and less than that of a B-767. In addition, the data to date suggest that the longevity of the B-757 vortices is consistent with its wing span.

The January 1993 NOAA report did not recommend an increase in the separation distances behind the B-757, citing insufficient testing to determine the persistence of a B-757 vortex. The report did recommend additional testing to determine the persistence of and the effects of atmospheric conditions on B-757 vortices. The Safety Board concurs in this recommendation. However, the Board also believes, as discussed in

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<sup>16</sup> A vortex, a mass of rotating air, consists of a core and a flow field about the core. Lift is created by a pressure differential between the upper and lower surface of the wing. This pressure differential results in a rollup of the airflow aft of the wing, thus creating a vortex. The tangential velocities of the core are proportional to the distance from the center of the core whereas the tangential velocities in the flow field are generally inversely proportional to the square of the distance from the core.

<sup>17</sup> National Oceanic and Atmospheric Administration Technical Memorandum ERL ARL-199, January 1993.

<sup>18</sup> Circulation is a measure of the angular momentum of the air in the flow field and defines the strength of a vortex. The size and strength of the flow field determine the risk of upset posed to a following airplane.

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.<sup>19</sup> 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.

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<sup>19</sup> Canada has reclassified the B-757 as a heavy airplane when it is the leading airplane.

**Table 3—Separation distance between lead and following aircraft currently established by the International Civil Aviation Organization (ICAO), United Kingdom (U.K.), and United States (U.S.) to avoid wake vortex encounters**

Weight category <sup>a</sup> of-		Minimum separation distance, (nautical miles)		
Lead aircraft	Following aircraft	ICAO	U.K.	U.S.
Heavy	Heavy	4	4	4
Heavy	Large	NA	NA	5
Heavy	Medium	5	5	NA
Heavy	Small	NA	6	6
Heavy	Light	6	8	NA
Large	Large	NA	NA	3
Large	Small	NA	NA	4
Medium	Medium	3	3	NA
Medium	Small	NA	4	NA
Medium	Light	5	6	NA
Small	Light	NA	4	NA

NA = not applicable because category has not been designated.

<sup>a</sup> The weight categories are based on maximum takeoff weight of the aircraft.

The characteristics of certain airplane pairs were examined to determine the relative risks of upset by wake vortex encounters. The relative risk of wake vortex upsets is a function of the strength of a vortex generated by the leading airplane and the roll moment inertia of the trailing airplane. The vortex strength is generally defined as a function of weight divided by velocity and span. The roll moments of inertia are generally proportional to the weight of the airplane.<sup>20</sup>

<sup>20</sup> Roskam, Jan. 1982. Airplane flight dynamics and automatic flight controls. Ottawa, KS: Roskam Aviation and Engineering Corporation. (p. 19).

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 preferable 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.

The relative risk comparisons also indicate that the lighter weight airplanes in the large airplane category are at high risk of upset from the vortices generated from airplanes in the heavy category. Consequently, the Safety Board is concerned that the current separation requirements for IFR airplanes such as the Westwind and Citation when following heavy category airplanes are also inadequate.

The most significant problem related to establishing adequate separation standards is the great range of weights (12,500 to 300,000 pounds) in the large airplane category. 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. One possible means to minimize the risk of wake vortex encounters is simply to divide the large airplane category into two separate categories (for example, 12,500 to 150,000 pounds and 150,000 to 300,000 pounds), accompanied with increased separations between the newly created categories. However, a preferable approach would be to create four weight categories in which the ratios of the high and low weights in each category would be similar. For example: heavy (greater than 300,000 pounds), large (between 100,000 and 300,000 pounds), medium (between 30,000 and 100,000 pounds), and small (less than 30,000 pounds). The maximum ratio of weights within each category is about 3.

Appropriate separation distances, based on such a revised weight classification scheme, consistent with the separation distances discussed above, could be the following: for airplanes following a heavy category airplane, the separation distance should be 4 nm (heavy), 5 nm (large), 6 nm (medium), and 7 nm (small). For airplanes following a large category airplane, the separation distances should be 4 nm (large), 5 nm (medium), and 6 nm (small). Current data suggest that a separation distance of 3 nm may be adequate for a medium category airplane following another medium category airplane and for all airplanes following a small airplane. Such an approach would provide more separation because of the increased number of categories and would also reduce the weight disparity of the high and low weights within each category. Therefore, the Safety Board believes that the FAA should revise the airplane weight classification scheme to reduce the weight disparity of high and low weights within each category and to establish separation distances between the various weight categories, consistent with the separation distances discussed above (for airplanes trailing airplanes such as the B-757).

## **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,<sup>21</sup> 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.

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<sup>21</sup> 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.

In addition, although controllers receive initial training in these areas, the Safety Board believes that controllers should be provided annual refresher training related to 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 VFR or 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.<sup>22</sup>

The Safety Board is especially concerned that the GENOT and pilot bulletin issued on December 22, 1993, by the FAA are not likely to be effective in reducing wake turbulence encounters of pilots who accept a visual approach clearance or who follow closely behind a B-757 while on approach to the airport.<sup>23</sup> The GENOT and pilot bulletin, in essence, reiterate past practices. The only change is the requirement that wake turbulence cautionary advisories be issued to airplanes following a B-757. Pilots are not provided any additional guidance on how to adhere to the procedures defined in the AIM. Specifically, pilots are still not provided sufficient information to determine that adequate separation distances are being maintained or to determine that their flight path remains above the flight path of the preceding airplane.

Knowledge of the manufacturer and model would help the pilot determine a safe separation distance. For example, in the Salt Lake City and Santa Ana accidents, the pilots knew they would be operating behind a turbojet airplane. The controller, in each situation, had ample opportunity to advise the pilot, specifically, that he would be operating behind a Boeing 757. In addition, a pilot, if provided with a wake turbulence cautionary advisory and other information relevant to the avoidance of wake turbulence, such as separation distance and the existence of an overtaking situation, would be better able to maintain an adequate separation distance. Thus, the Safety Board believes that controllers should be required to provide this information, as a minimum, to pilots prior to allowing visual operations behind or in-trail of heavier, turbojet airplanes. Several of the 46 accidents and incidents from 1983 to 1993 that resulted from probable encounters

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<sup>22</sup> A review of ATC transcripts from some of the accidents and incidents which resulted from probable encounters with wake vortices revealed terminology used by controllers that would encourage pilots to violate separation requirements, such as "keep a tight pattern and follow the large airplane." In one instance, the controller requested a short approach but also cautioned about wake turbulence; in that instance the pilot encountered turbulence at 50 feet and crashed, sustaining serious injuries.

<sup>23</sup> See appendix E for GENOT, pilot bulletin, and other related correspondence.

with wake vortices occurred during phases of operation other than the approach phase. Had the 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 vortices, 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<sup>24</sup> 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 movement of wake vortices in ground effect. In the accident at Salt Lake City, Utah, the Cessna 182 could have been affected by the vortex of the B-757 at any altitude between ground level and 200 feet AGL.

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<sup>24</sup> 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.

Although the Cessna's flight path was above that of the B-757, the pilot did not adequately compensate for the height of the vortex. Knowledge of or training specifically related to the height of wake vortices in ground effect likely would have prompted the Cessna pilot involved in the Salt Lake City accident to remain several hundred feet above the B-757 flight path. However, the Safety Board is not aware of any training related to wake vortex avoidance that is provided to pilots after they initially receive their pilot's license. Consequently, the Safety Board believes that the FAA should require 14 CFR 121 and 14 CFR 135 operators to implement training specifically related to the movement and avoidance of wake vortices and techniques to determine relative flight paths and separation distances. In addition, the FAA should revise the practical test standards for commercial, air transport pilot, and additional type ratings to place emphasis on wake turbulence avoidance.

Finally, the B-757 has the capability to fly steeper approaches at slower speeds than most other turbojet transport category airplanes at similar weights. The steeper approaches may be conducted for fuel conservation, noise abatement policies, or simply because the performance of the B-757 allows such approaches. As a result, smaller airplanes, while conducting a normal approach, may be faster and on lower flight paths than a B-757, thus increasing the risk of an encounter with the vortex of the B-757. The Safety Board believes that the FAA should establish air traffic control and operational procedures for the B-757 and other heavier large category airplanes or heavy category airplanes that would result in approaches being conducted in accordance with flight path guidance, when available, or on a standard flight path angle of about 3° when such airplanes are established on course to the runway and other airplanes are in-trail. In addition, the FAA should inform operators of the B-757 and other heavier large category airplanes or heavy category airplanes to instruct pilots of the importance (because of the potential for a strong wake) on approach to landing of maintaining a flight path in accordance with guidance, when available, or on a standard flight path angle of about 3°.

## 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.

TCAS II is required to be installed on Part 121 airplanes and TCAS I will be required to be installed on Part 135 airplanes by February 1995, although the FAA estimates that the compliance date will be extended by 1 or 2 years. Currently, more than 1,000 corporate airplanes have TCAS II installed. TCAS is now being installed during the manufacture of some corporate airplanes such as the Grumman Gulfstream IV and the Cessna Citation.

The Safety Board believes that TCAS may have the potential of providing useful range information to the pilot who has accepted a visual approach clearance while in-trail behind another airplane. Therefore, the Safety Board believes that the FAA, in conjunction with industry, should determine whether TCAS is appropriate for providing pilots with the separation distance to the preceding airplane during visual landing approaches. If appropriate procedures can be developed, the use of TCAS for establishing safe separation should be encouraged for the pilot of airplanes so equipped.

## 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.

# Recommendations

As a result of this special investigation, the National Transportation Safety Board made the following recommendations to the Federal Aviation Administration:

Establish the following interim wake vortex separation requirements for instrument flight rules airplanes following a Boeing 757 and other airplanes of similar weight: 4 nautical miles (nm) for airplanes such as the B-737, MD-80, and DC-9; 5 nm for airplanes such as the Westwind and Citation; and 6 nm for small airplanes. Maintain the current separation requirement of 5 nm when a B-757 or other airplane of a similar weight is following a heavy category airplane. (Class I, Urgent Action) (A-94-42)

Revise the airplane weight classification scheme to reduce the weight disparity of high and low weights within each category and to establish separation distances between the various weight categories, consistent with the interim separation distances outlined in Safety Recommendation A-94-42. (Class II, Priority Action) (A- 94-43)

Establish air traffic control and operational procedures for the Boeing 757 (B-757) and other heavier large category airplanes or heavy category airplanes that would result in approaches being conducted in accordance with flight path guidance, when available, or on a standard flight path angle of about 3° when such airplanes are established on course to the runway and other airplanes are in-trail. (Class II, Priority Action) (A-94-44)

Inform operators of the Boeing 757 (B-757) and other heavier large category airplanes or heavy category airplanes to instruct pilots of the importance (because of the potential for a strong wake) on approach to landing of maintaining a flight path in accordance with guidance, when available, or on a standard flight path angle of about 3° (Class II, Priority Action) (A-94-45)

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)

Expand the current guidance in the Airman's Information Manual and develop other training material to help pilots to determine that their flight path remains above the flight path of the leading airplane and that their separation distance remains consistent with that required for instrument flight rules operations. (Class II, Priority Action) (A-94-51)

Expand the information in the Airman's Information Manual and other training material to define the vertical movement of wake vortices in ground effect, such as vortex core height, upper and lower limits of the vortex flow field, and the potential to "bounce" twice as high as the steady state height. (Class II, Priority Action) (A-94-52)

Require 14 CFR 121 and 14 CFR 135 operators to provide training specifically related to the movement and avoidance of wake vortices and techniques to determine relative flight paths and separation distances. (Class II, Priority Action) (A-94-53)

Revise the practical test standards for commercial, air transport pilot, and additional type ratings to place emphasis on wake turbulence avoidance. (Class II, Priority Action) (A-94-54)

Conduct additional tests of the Boeing 757 to determine the persistence and strength of its wake vortex and the effects of atmospheric conditions on B-757 vortices. (Class II, Priority Action) (A-94-55)

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. (Class III, Longer Term Action) (A-94-56)

Require reporting of wake vortex encounters and establish a system to collect and analyze pertinent information, such as recorded radar data, atmospheric data, and operational information, including selected flight data recorder data. (Class III, Longer Term Action) (A-94-57)

Continue to sponsor research and development projects that may lead to technological or procedural solutions to reduce the hazards posed by wake vortices. (Class III, Longer Term Action) (A-94-58)

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)

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# By the National Transportation Safety Board

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**Adopted: February 15, 1994**

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# Appendix A

## Accidents and Incidents From 1983 To 1993 That Resulted From Probable Encounters With Wake Vortices

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

Date	Location	Leading aircraft	Trailing aircraft	Phase of operation	File No.
02/06/83	Tucson, AZ	B-727	Beech H-35	Approach	1928
05/13/83	Boston, MA	Airbus A-300	Cessna 402C	Cruise	5107
01/10/84	Los Angeles, CAL	L-1011	DC-9	Approach	6010
03/19/84	Riverton, WY	Convair 580	Piper PA-12-115	Approach	0407
06/21/84	Middle Town, PA	3-30 aircraft	Cessna 50M	Descent	1729
06/30/84	Grenada, MS	UH-1 helicopter	Cessna 172G	Approach	0899
10/04/84	Norfolk, VA	B-727	Cessna 172M	Descent	3297
10/13/84	Miles City, EL	Helicopter <sup>a</sup>	Piper J3C-65	Descent	2541
02/28/85	West Palm Beach, FL	Heavy jet <sup>a</sup>	Piper PA-32R	Cruise	1411
03/13/85	DEW Airport, TX	B-747	Beech A-36	Approach	5043
06/11/85	Belmar, NJ	Helicopter <sup>a</sup>	Cessna 152	Takeoff	0760
07/10/85	Rochester, MN	DC-9	Cessna 152	Landing	2305
12/19/85	Tucson, AZ	EC-130	Cessna 150L	Descent	2623
01/27/86	Reno, NV	B-737	Cessna TR182RG	Descent	0074
03/31/86	Boise, ID	Transport aircraft <sup>a</sup>	Cessna T210C	Landing	0225
05/17/86	Van Nuys, CA	C- 130	Aerospatiale TB20	Approach	2687
10/29/86	England AFB, LA	Four jet fighters <sup>a</sup>	Cessna 182J	Landing	1204
10/31/86	Ft. Pierce, FL	USCG helicopter <sup>a</sup>	Piper PA-28-181	Landing	1449
11/06/86	Tampa, FL	L-1011	Cessna 421C	Approach	1668

**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
11/08//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 <sup>a</sup>	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

**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.
01/21/91	Sacramento, CA	MD-80	Cessna 172P	Cruise	0270
02/04/91	Greensboro, NC	DC-9	Piper PA-28-180	Landing	1422
3/11/91	Santa Ana, CA	B-757	Cessna 152	Landing	0129
03/16/91	Pullman, WA	Swearingen	Cessna 140	Approach	0181
09/07/91	Marion, OH	Larger airplane <sup>a</sup>	5-7 Courier	Takeoff	2018
09/13/91	Prescott, AZ	Beech 1900	Cessna 172N	Takeoff	1901
11/20/91	Chicago, IL	Like aircraft <sup>a</sup>	Aerospatiale	Descent	5046
				ATR42-300	
10/27/92	Saipan, PO	DC-10	Cessna 310R	Takeoff	2992

<sup>a</sup> The make and model of the aircraft were not identified in the Safety Board's brief of the accident.

# Appendix B

## Summary of Safety Board Recommendations Addressing Wake Vortex Issues

**Safety Recommendation No.:** A-72-076  
**Date Issued:** June 30, 1972  
**Recipient:** Federal Aviation Administration  
**Status:** Closed–No Longer Applicable

**Subject:**

Reevaluate wake turbulence separation criteria for aircraft operating behind heavy jet aircraft.

**Safety Recommendation No.:** A-72-077  
**Date Issued:** June 30, 1972  
**Recipient:** Federal Aviation Administration  
**Status:** Closed–Acceptable Action

**Subject:**

Issue alert notices to all pilots and aircraft operators that will stress the urgent need to maintain an adequate separation from heavy jet aircraft.

**Safety Recommendation No.:** A-72-213  
**Date Issued:** December 20, 1972  
**Recipient:** Federal Aviation Administration  
**Status:** Closed–Acceptable Action

**Subject:**

Revise appropriate publications to assure that they describe more specifically the desirable avoidance techniques (e.g., following aircraft maintain approach path above VASI or ILS glide slope, extending downwind leg, etc.).

**Safety Recommendation No.:** A-72-214  
**Date Issued:** December 20, 1972  
**Recipient:** Federal Aviation Administration  
**Status:** Closed–Acceptable Action

**Subject:**

Define and publish the meteorological parameters which cause trailing vortices to persist in the vicinity of the landing runway.

**Safety Recommendation No.:** A-72-215  
**Date Issued:** December 20, 1972  
**Recipient:** Federal Aviation Administration  
**Status:** Closed–Unacceptable Action

**Subject:**

Include wake turbulence warnings on the ATIS broadcasts whenever the meteorological conditions identified in Recommendation A-72-214 indicate that vortices will pose an unusual hazard to other aircraft.

**Safety Recommendation No.:** A-88-140  
**Date Issued:** November 3, 1988  
**Recipient:** Federal Aviation Administration  
**Status:** Closed–Acceptable Action

**Subject:**

Initiate a research project to acquire data from dedicated sensors to determine what consideration, if any, should be given to wake vortices in a parallel offset runway situation.

**Safety Recommendation No.:** A-90-076  
**Date Issued:** June 4, 1990  
**Recipient:** Federal Aviation Administration  
**Status:** Closed-Unacceptable Action

**Subject:**

Amend the Air Traffic Control Handbook, 7110.65F, paragraph 3-106I, to require air traffic controllers to impose a 3-minute delay on the pilots of “small” category airplanes who intend to depart in the same direction from the same runway behind a “large” category airplane that is on takeoff or a low or missed approach, to separate the small airplane from wake turbulence.

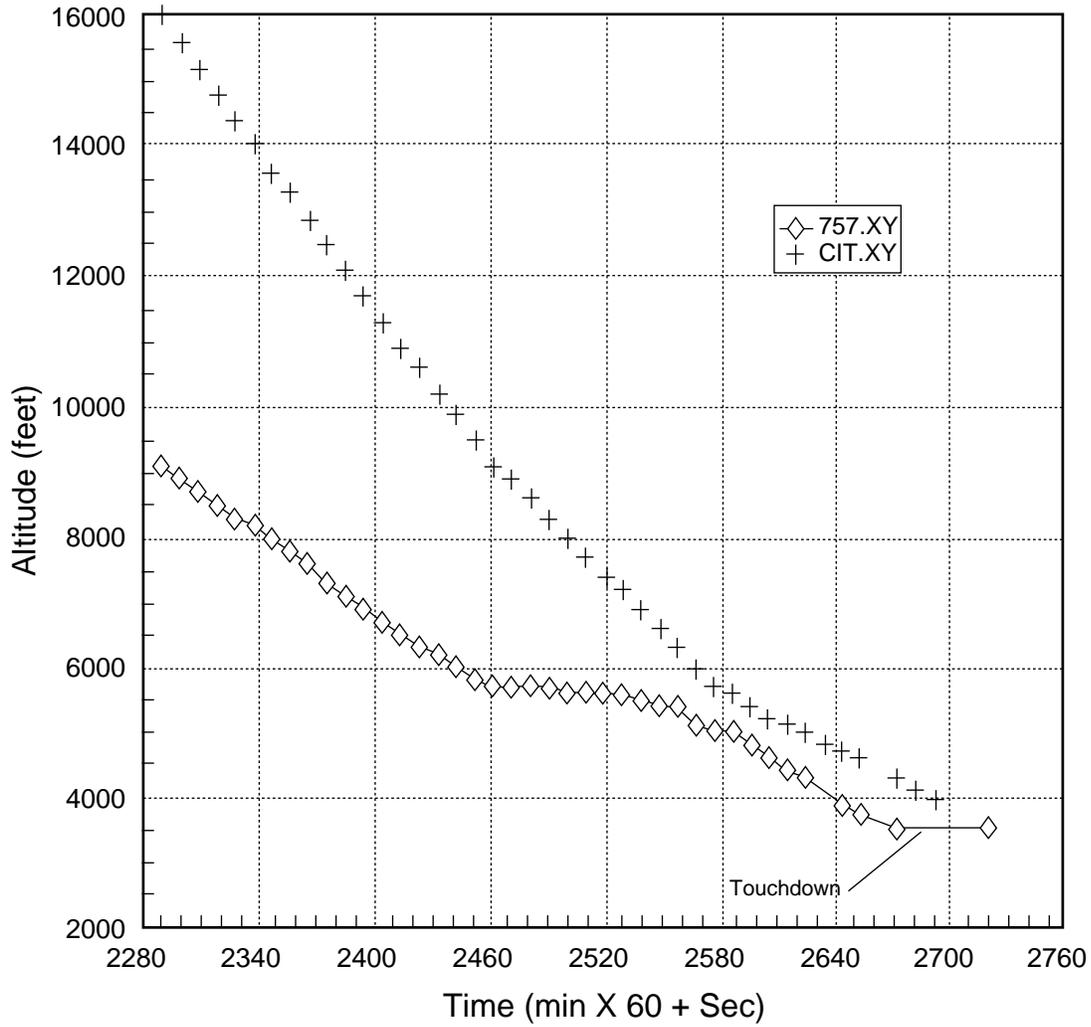
**Safety Recommendation No.:** A-90-077  
**Date Issued:** June 4, 1990  
**Recipient:** Federal Aviation Administration  
**Status:** Closed-Unacceptable Action

**Subject:**

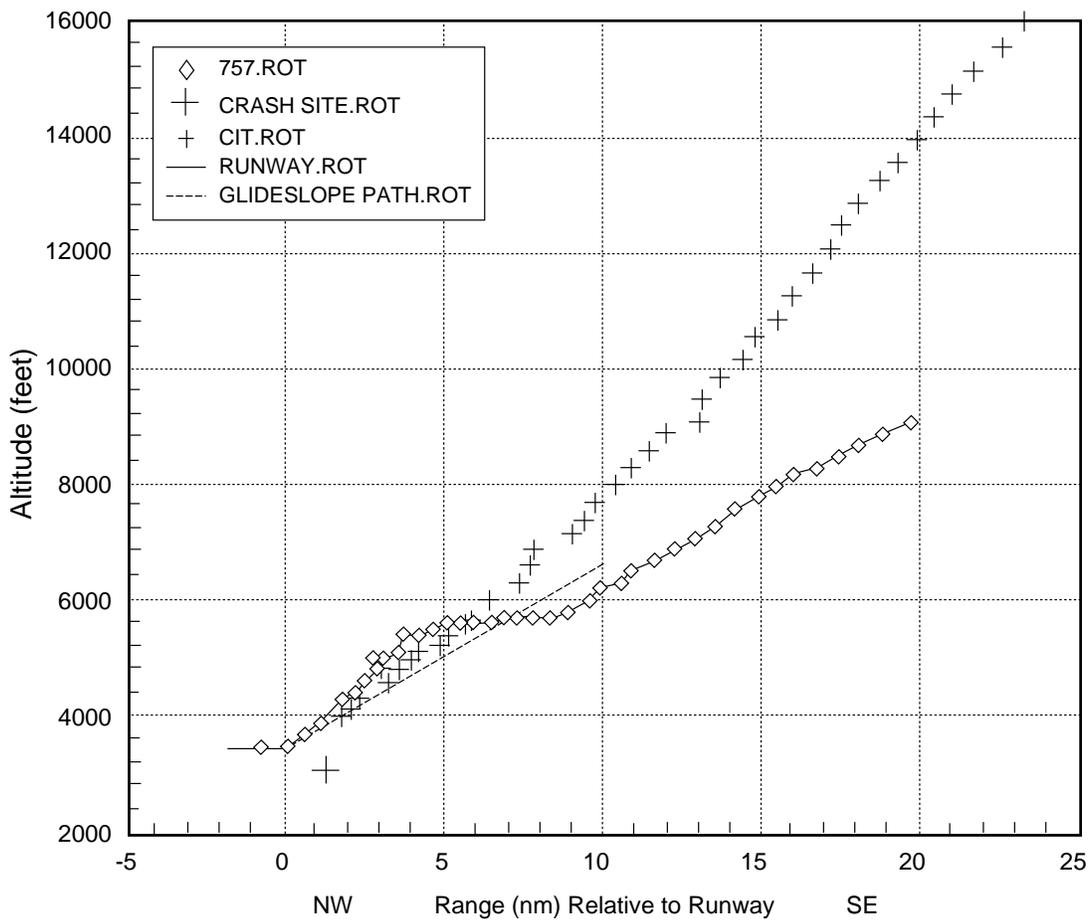
Amend the Purman’s Information Manual, paragraph 545, and Advisory Circular 90-23D to inform pilots of “small” category aircraft that under certain circumstances involving takeoff behind “large” category aircraft, they can expect that a 3-minute delay will be imposed by air traffic controllers in order to allow for the dissipation of the wake turbulence.

**Appendix C**  
**Altitude Profile of B-757 and Cessna Citation 550**  
**at Billings, Montana, on December 18, 1992**

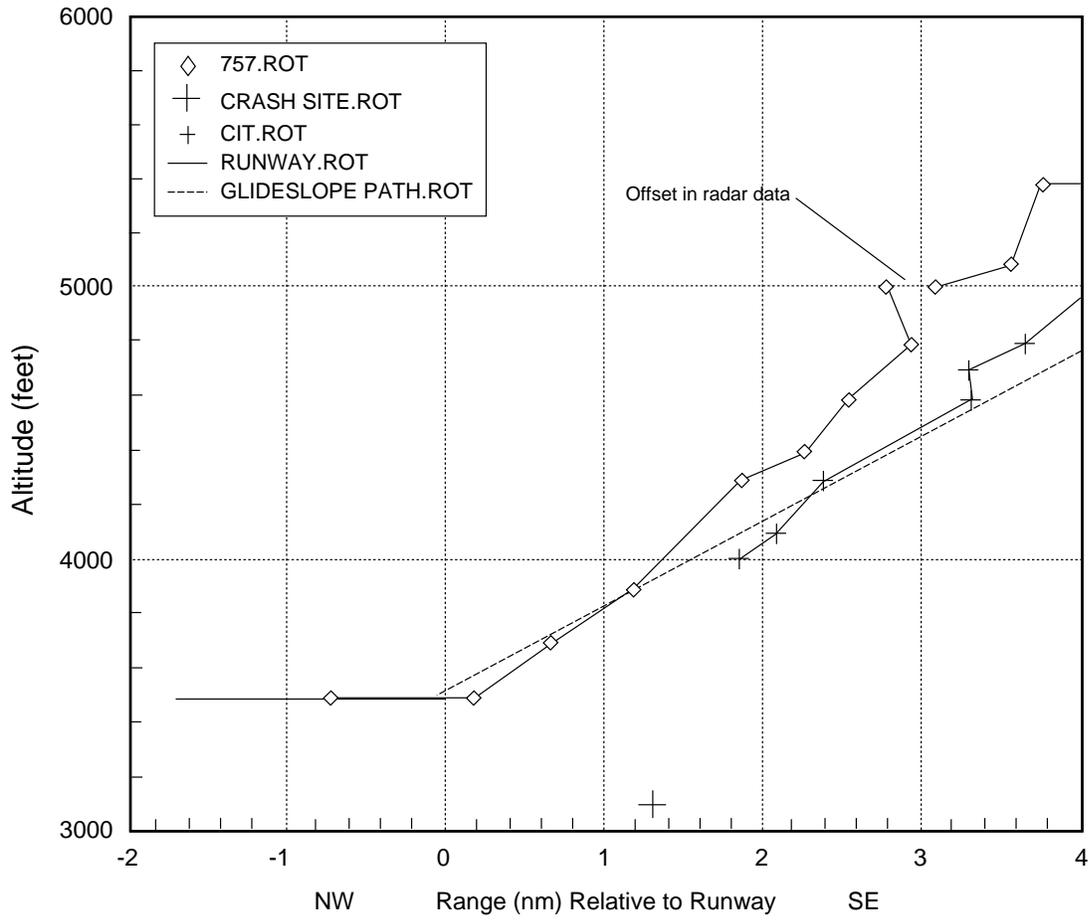
### Altitude and Time



Altitude Profile of 757 and Citation

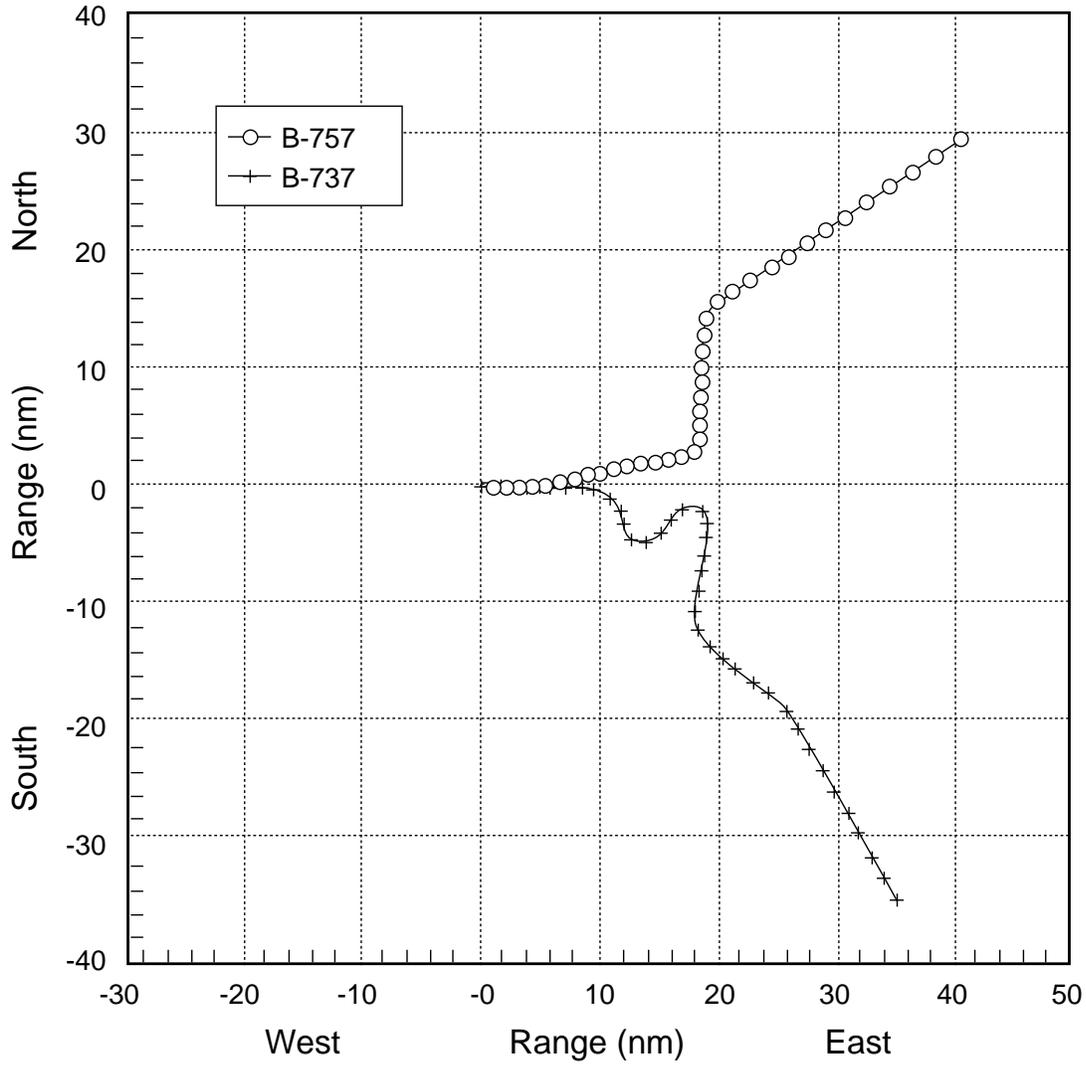


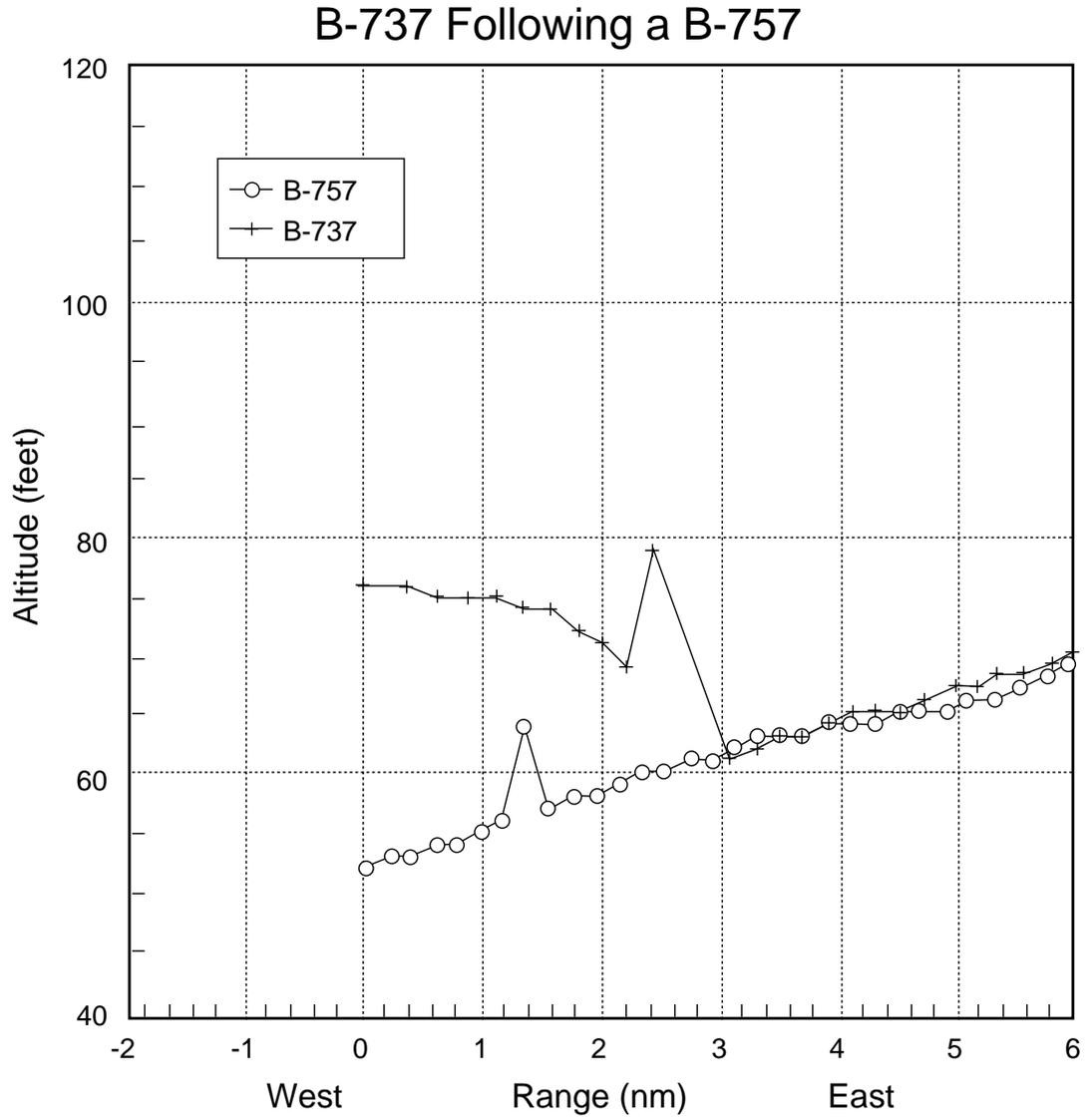
Altitude Profile of 757 and Citation



**Appendix D**  
**Ground Track of B-757 and B-737**  
**at Denver, Colorado, on April 24, 1993**

B-737 Following a B-757





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# **Appendix E**

## **FAA General Notice Issued on December 22, 1993, and Pilot Bulletin Regarding Wake Turbulence Advisories**

**TELEGRAPHIC MESSAGE**

<b>NAME OF AGENCY</b> FEDERAL AVIATION ADMINISTRATION 800 INDEPENDENCE AVE, SW WASHINGTON, DC 20591		<b>PRECEDENCE</b> PRIORITY	<b>SECURITY CLASSIFICATION</b> UNCLASSIFIED
<b>ACCOUNTING CLASSIFICATION</b>		<b>DATE PREPARED</b>	<b>FILE</b>
<b>FOR INFORMATION CALL</b>			
<b>NAME</b> PAUL EWING, ATF-121		<b>PHONE NUMBER</b> 267-8460	<b>TYPE OF MESSAGE</b> <input type="checkbox"/> SINGLE <input type="checkbox"/> BOOK <input type="checkbox"/> MULTIPLE-ADDRESS
<b>THIS SPACE FOR USE OF COMMUNICATION UNIT</b>			
<b>MESSAGE TO BE TRANSMITTED (Use double spacing and all capital letters)</b>			
<b>TO:</b>  KRWA NOU S2 _____  GENOT RWA _____ SVC B  NOTICE N7110. _____  GG ALRGNS 1/500 ALATFO AMA/1 ACT/1  <u>SUBJECT:</u> ORDER 7110.65H, AIR TRAFFIC CONTROL, PARAGRAPHS 2-20, WAKE TURBULENCE CAUTIONARY ADVISORIES; 3-122, SAME RUNWAY SEPARATION; AND 3-123, INTERSECTING RUNWAY SEPARATION. THIS GENOT APPLIES TO ALL AIR TRAFFIC CONTROL FACILITIES AND IS A MANDATORY BRIEFING ITEM.  CLN 12/1/94  CONTROLLERS ARE TO BE BRIEFED ON CHAPTER 7, SECTION 3, WAKE TURBULENCE OF THE AIRMAN'S INFORMATION MANUAL.			<b>SECURITY CLASSIFICATION</b>
<b>PAGE NO.</b> 1		<b>NO. OF PGS.</b> 5	<b>SECURITY CLASSIFICATION</b>

**TELEGRAPHIC MESSAGE**

NAME OF AGENCY		PRECEDENCE	SECURITY CLASSIFICATION
ACCOUNTING CLASSIFICATION		DATE PREPARED	FILE
FOR INFORMATION CALL			
NAME	PHONE NUMBER	TYPE OF MESSAGE <input type="checkbox"/> SINGLE <input type="checkbox"/> BOOK <input type="checkbox"/> MULTIPLE-ADDRESS	
THIS SPACE FOR USE OF COMMUNICATION UNIT			
MESSAGE TO BE TRANSMITTED (Use double spacing and all capital letters)			
TO:			
<p>ENSURE THESE BRIEFINGS ARE ENTERED IN ALL EMPLOYEES TRAINING AND PROFICIENCY RECORDS, 3120-1, WITHIN 30 DAYS OF RECEIPT. SEVERAL INCIDENTS INVOLVING AIRCRAFT FOLLOWING OR CROSSING THE FLIGHT PATH OF BOEING 757 (B-757) HAVE CREATED CONCERN FOR THE SAFETY OF AIRCRAFT IN CONNECTION WITH THE WAKE TURBULENCE CREATED BY THE B-757. ACCORDINGLY, TO ENSURE THAT PILOTS ARE AWARE OF THE POTENTIAL WAKE TURBULENCE HAZARD CREATED BY THE B-757, CONTROLLERS SHALL PROVIDE A WAKE TURBULENCE CAUTIONARY ADVISORY TO FOLLOWING AIRCRAFT.</p>			
		SECURITY CLASSIFICATION	
		PAGE NO. 2	NO. OF PGS. 5

**TELEGRAPHIC MESSAGE**

NAME OF AGENCY		PRECEDENCE	SECURITY CLASSIFICATION
ACCOUNTING CLASSIFICATION		DATE PREPARED	FILE
FOR INFORMATION CALL			
NAME		PHONE NUMBER	TYPE OF MESSAGE <input type="checkbox"/> SINGLE <input type="checkbox"/> BOOK <input type="checkbox"/> MULTIPLE-ADDRESS
THIS SPACE FOR USE OF COMMUNICATION UNIT			
MESSAGE TO BE TRANSMITTED (Use double spacing and all capital letters)			
<p><b>TO:</b></p>  <p>REPLACE ORDER 7110.65, PARAGRAPHS 2-20, 3-122, AND 3-123 WITH THE FOLLOWING:</p> <p>2-20 WAKE TURBULENCE CAUTIONARY ADVISORIES</p> <p>A. ISSUE WAKE TURBULENCE CAUTIONARY ADVISORIES AND THE POSITION, ALTITUDE IF KNOWN, AND DIRECTIONS OF FLIGHT OF THE HEAVY JETS <u>OR B-757'S</u> TO:</p> <p>2-20A REFERENCE. NO CHANGE</p> <p>1. TERMINAL: VFR AIRCRAFT NOT BEING RADAR VECTORED BUT ARE BEHIND HEAVY JETS <u>OR B-757'S</u>. (SEE FIGURE 2-20[1]).</p> <p>2. NO CHANGE</p> <p>3. NO CHANGE</p>			<p>SECURITY CLASSIFICATION</p>
		PAGE NO.	NO. OF PGS.
		3	5

**TELEGRAPHIC MESSAGE**

NAME OF AGENCY		PRECEDENCE	SECURITY CLASSIFICATION	
ACCOUNTING CLASSIFICATION		DATE PREPARED	FILE	
FOR INFORMATION CALL				
NAME		PHONE NUMBER	TYPE OF MESSAGE <input type="checkbox"/> SINGLE <input type="checkbox"/> BOOK <input type="checkbox"/> MULTIPLE-ADDRESS	
THIS SPACE FOR USE OF COMMUNICATION UNIT				
MESSAGE TO BE TRANSMITTED (Use double spacing and all capital letters)				
<p><b>TO:</b></p> <p>B. NO CHANGE</p> <p>3-122 SAME RUNWAY SEPARATION</p> <p>A. NO CHANGE</p> <p>1. THRU 3. NO CHANGE.</p> <p>B. ISSUE WAKE TURBULENCE CAUTIONARY ADVISORIES AND THE POSITION, ALTITUDE IF KNOWN, AND DIRECTION OF FLIGHT OF THE HEAVY JETS <u>OR B-757'S</u> TO AIRCRAFT LANDING BEHIND A DEPARTING/ARRIVING HEAVY JET <u>OR B-757'S</u> ON THE SAME OR PARALLEL RUNWAYS SEPARATED BY LESS THAN 2,500 FEET.</p> <p>3-122B REFERENCE. NO CHANGE.</p> <p>3-122B EXAMPLE 1. NO CHANGE.</p> <p>3-122B EXAMPLE 2.-</p> <p>"NUMBER TWO TO LAND, FOLLOWING A <u>BOEING 757</u> ON 2-MILE FINAL. CAUTION WAKE TURBULENCE."</p>				
			SECURITY CLASSIFICATION	
PAGE NO.		NO. OF PGS.		
4		5		

**TELEGRAPHIC MESSAGE**

NAME OF AGENCY		PRECEDENCE	SECURITY CLASSIFICATION
ACCOUNTING CLASSIFICATION		DATE PREPARED	FILE
FOR INFORMATION CALL			
NAME		PHONE NUMBER	TYPE OF MESSAGE <input type="checkbox"/> SINGLE <input type="checkbox"/> BOOK <input type="checkbox"/> MULTIPLE-ADDRESS
THIS SPACE FOR USE OF COMMUNICATION UNIT			
MESSAGE TO BE TRANSMITTED (Use double spacing and all capital letters)			
<p><b>TO:</b></p> <p>3-122 REFERENCE. NO CHANGE.</p> <p>3-123 INTERSECTING RUNWAY SEPARATION</p> <p style="padding-left: 40px;">A. THRU C. NO CHANGE.</p> <p style="padding-left: 40px;">D. ISSUE WAKE TURBULENCE CAUTIONARY ADVISORIES AND THE POSITION, ALTITUDE IF KNOWN, AND DIRECTION OF FLIGHT OF THE HEAVY JETS <u>OR B-757'S</u> TO:</p> <p style="padding-left: 40px;">1. THRU 2. NO CHANGE</p> <p>3-123D1 EXAMPLE. NO CHANGE.</p> <p>3-123D2 EXAMPLE.-</p> <p style="padding-left: 40px;">"RUNWAY NINER CLEARED TO LAND. CAUTION WAKE TURBULENCE, <u>BOEING 757</u> LANDING RUNWAY THREE SIX."</p> <p>3-123 REFERENCE. NO CHANGE.</p> <p style="margin-left: 20px;"><i>Harold W Becker</i>   SPECK, ATP-1</p>			
		SECURITY CLASSIFICATION	
		PAGE NO. 5	NO. OF PGS. 5

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 REVISED 11-80  
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U.S. Department  
of Transportation  
**Federal Aviation  
Administration**

Office of the Administrator

800 Independence Ave. S.W.  
Washington, D.C. 20591

DEC 22 1993

Dec. 22, 1993

All Pilots

Dear Fellow Pilots:

Wake Turbulence accidents/incidents following B-757 aircraft.

In the past year, there have been four accidents or incidents involving aircraft following a Boeing 757 under visual flight rules. These include a Cessna Citation at Billings, Montana; a Boeing 737 incident at Denver where the aircraft experienced an uncommanded roll; a Cessna 182 at Salt Lake City, Utah; and the most recent accident, an Israeli Westwind corporate jet at Santa Anna, California. Although the NTSB is still investigating these accidents and incidents, it is possible that one or more of them may have been caused, in part, by an encounter with wake turbulence from the preceding Boeing 757.

To reduce the possibility of these types of occurrences, Air Traffic will now issue "Wake Turbulence Cautionary Advisories" to aircraft following the B-757 under Visual Flight Rules. I am also asking that you pay special attention to existing guidance related to the avoidance of wake turbulence such as the following procedures found in the Airman's Information Manual;

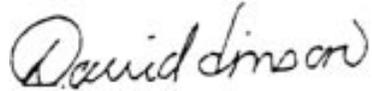
1. WHETHER OR NOT A WARNING HAS BEEN GIVEN. THE PILOT IS EXPECTED TO ADJUST HIS OR HER OPERATIONS AND FLIGHT PATH AS NECESSARY TO PRECLUDE SERIOUS WAKE ENCOUNTERS.
2. AVOID THE AREA BELOW AND BEHIND THE GENERATING AIRCRAFT, ESPECIALLY AT LOW ALTITUDE WHERE EVEN A MOMENTARY WAKE ENCOUNTER COULD BE HAZARDOUS.

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 **nonheavy** 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, 5 or 6 miles separation is provided. Chapter 7, Section 3 of the Airman's Information Manual provides additional information regarding air traffic wake turbulence separation. All pilots should become familiar and utilize this information when anticipating conditions conducive to wake turbulence.

There is activity underway in the agency at this time to study the wake turbulence characteristics of the Boeing 757. It will be some time before any definitive results are available from this research effort. Until such time, all pilots should review and become familiar with wake turbulence avoidance. Avoid the area below and behind the generating aircraft, and be particularly alert in calm wind conditions and situations where the vortices could drift on to parallel or crossing runways. Finally, pilots should envision the location of the vortex wake generated by larger (transport category) aircraft and adjust their flight path accordingly.

In closing, I urge all of you to take the time to re-educate yourselves on wake vortex characteristics and avoidance procedures. With proper emphasis and education, these types of accidents/incidents can be avoided.

Sincerely,

A handwritten signature in black ink that reads "David R. Hinson". The signature is written in a cursive, slightly slanted style.

David R. Hinson  
Administrator

ORDER: 8400.10 and 8700.1

APPENDIX: 4

BULLETIN TYPE: Joint Publication of Flight Standards  
Information Bulletin (FSIB) for Air  
Transportation (FSAT) and General Aviation  
(FSGA)

BULLETIN NUMBER: FSAT 93-38 and FSGA 93-15

BULLETIN TITLE: Wake Turbulence Accident Prevention Program

EFFECTIVE DATE: 12-29-93

- 
1. PURPOSE. This Flight Standards Information Bulletin (FSIB) establishes an action program for Flight Standards Service to prevent Wake Turbulence Accidents. The bulletin contains information, direction, and guidance to inspectors and managers for completing this program.
2. BACKGROUND. In the past year there have been four accidents that were specifically related to Boeing 757 aircraft. These accidents occurred when the trailing aircraft were not being provided IFR traffic separation. The FAA is in the process of studying wake turbulence; however, it will be some time before the results will be known. To reduce the possibility of these types of occurrences, Air Traffic will now issue "Wake Turbulence Cautionary Advisories" to aircraft following B-757 aircraft under visual flight rules. Pilots of trailing aircraft at the same altitude or up to 1,000 feet below should maintain 5 to 6 miles separation.
- A. Pilots and operators should review information, procedures, and guidance contained in the Airman's Information Manual (AIM), Chapter 7, Section 3. To date no known wake turbulence accident has occurred when pilots have been observing AIM recommended procedures. Also see Advisory Circular (AC) 90-23D, "Aircraft Wake Turbulence."
- B. Wake turbulence is clearly not unique to the B-757. Pilots must avoid operating both behind and at or below the level of all heavier aircraft.
- C. Pilots should attempt to visualize the location of the vortex wake generated by larger aircraft when operating in the terminal area. They should be particularly alert in calm wind conditions and in situations where the wake could drift onto parallel or crossing runways.
- D. Pilots should be alert to the possibility that heavier aircraft may be using fuel conservation or noise abatement procedures and operating above the normal glideslope.

3. ACTION. The Administrator has directed that Flight Standards take immediate action to educate operators and the public to this hazard. On or before April 7, 1994, the following actions will be accomplished:

A. POI's. Each POI of a Part 121, 125, and 135 operator and Part 141 training school shall bring this bulletin to the attention of the operator. The material should be disseminated to flightcrews through bulletins or similar means. POI's shall ensure that wake turbulence awareness is included in operator training programs.

B. FSDO Managers. FSDO managers shall ensure that this bulletin is brought to the attention of Accident Prevention Program Managers (APPM) and the managers of non-certificated training centers operating under exemptions.

C. APPM's. APPM's shall disseminate this information to the aviation public.

4. INQUIRIES. This FSIB was developed by AFS-510. Any questions regarding this bulletin should be directed to AFS-510 at (703) 661-0333.

5. EXPIRATION. This FSIB will expire on June 30, 1994.

/s/ Edgar C. Fell

ORDER: 8400.10 and 8700.1

APPENDIX: 4

BULLETIN TYPE: Joint Flight Standards Information  
Bulletin (FSIB) for Air Transportation  
(FSAT) and General Aviation (FSGA)

BULLETIN NUMBER: FSAT 94-02 and FSGA 94-02

BULLETIN TITLE: Wake Turbulence Accident Prevention Program

EFFECTIVE DATE: 02-10-94

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1. PURPOSE. This FSIB establishes an action program for Flight Standards Service to prevent wake turbulence accidents. This FSIB provides information, direction, and guidance to be used by inspectors and managers for completing this program. This FSIB supersedes FSAT 93-38 and FSGA 93-15 of the same title.

2. BACKGROUND. There have been four accidents or incidents related to Boeing 757 wake turbulence. All of these events occurred when the trailing aircraft was not being provided instrument flight rules (IFR) traffic separation. To reduce the possibility of such occurrences, Air Traffic Control will now issue "Wake Turbulence Cautionary Advisories" to aircraft operating under visual flight rules (VFR) which are following B-757 aircraft. The FAA is presently studying wake turbulence to include pilot awareness, avoidance, and aircraft-specific procedures for a wake turbulence encounter.

A. Pilots and operators should review information, procedures, and guidance contained in Chapter 7, Section 3 of the Airman's Information Manual (AIM). We are not aware of any wake turbulence accidents occurring when pilots have observed AIM recommended procedures or utilized IFR traffic separation. Therefore, pilots may wish to apply the same separation to VFR operations as ATC applies to IFR traffic. This information is contained in paragraph 7-49 of the AIM. (Also see AC 90-23D, "Aircraft Wake Turbulence").

B. Wake turbulence is not unique to the B-757. All pilots should exercise caution when operating behind and/or below all heavier (or greater wing span) aircraft.

C. Pilots should attempt to visualize the location of the vortex wake generated by other aircraft when operating in the terminal area. They should be particularly alert for situations where the wake could remain over a runway or drift onto parallel/crossing runways.

D. We are not aware of any operator with "formal" procedures for

steep approach profiles, but pilots should be alert to the implications of a heavier aircraft operating above the normal glideslope.

3. ACTION. The Administrator has directed that Flight Standards take immediate action to ensure that operators and the public are educated on this hazard. The following actions will be accomplished on or before April 7, 1994:

A. Principal Operations Inspectors (POI). Each POI for a Federal Aviation Regulations (FAR) Part 121, 125 or 135 operator, and each responsible inspector for a FAR Part 141 training school shall bring this FSIB to the attention of the operator. The material should be disseminated to flightcrews through bulletins or similar means. POI's shall ensure that wake turbulence awareness is included in operator training programs.

B. Flight Standards District Office (FSDO) Managers. FSDO managers shall ensure that this FSIB is brought to the attention of Accident Prevention Program Managers (APPM) and the managers of non-certificated training centers operating under exemptions.

C. APPM's. APPM's shall disseminate this information to the aviation public.

4. INQUIRIES. This FSIB was developed by AFS-510. Any questions regarding this FSIB should be directed to AFS-510 at (703) 661-0333.

5. EXPIRATION. This FSIB will expire on June 30, 1994.

/s/ Edgar C. Fell

ORDER: 8400.10

APPENDIX: 3

BULLETIN TYPE: Flight Standards Handbook Bulletin  
for Air Transportation (HBAT)

BULLETIN NUMBER: HBAT 94-17\*

BULLETIN TITLE: Pilot Training in Heavy Wake Vortex  
Turbulence: Awareness and Containment

EFFECTIVE DATE: 12-29-94

TRACKING: NTSB RECOMMENDATION A-94-45

---

1. PURPOSE. This bulletin meets a National Transportation Safety Board (NTSB) recommendation pertaining to training in wake vortex turbulence containment by pilots of aircraft that may produce heavy wake, including Boeing 757 aircraft.

2. BACKGROUND. The NTSB recently completed a special investigation of accidents involving wake vortex turbulence encountered during visual approaches. The Board's work raised questions about various issues, notably pilot knowledge related to the containment of heavy wake vortex turbulence. The Board found that pilots of heavy aircraft, heavier large aircraft, and specifically the B-757 aircraft (the heaviest type in its weight category), may be unaware of wake turbulence in two respects:

A. The consequences of the heavy wake produced by their aircraft in respect to lighter, following aircraft

B. Measures that they may take to contain wake turbulence for the benefit of lighter, following aircraft.

3. The following actions are strongly recommended. Pilots of heavy aircraft and heavier large aircraft that may produce strong wake, including the B-757, should use the following procedures during an approach to landing. These procedures should establish a dependable baseline from which pilots of in-trail, lighter aircraft may reasonably expect to make effective flightpath adjustments to avoid serious wake vortex turbulence.

A. Make every attempt to fly on the established glidepath, or if glidepath guidance is not available, to fly as closely as possible to a "3-to-1" glidepath.

EXAMPLE: At 10 miles from the runway, the aircraft should be at 3000' above the touchdown zone elevation (TDZE); at 5 miles the

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\*HBAT 94-17 was not in the original report. It is included here to provide the reader with the most current information available at this time.

aircraft should be at 1500' above TDZE; at 4 miles, 1200'; at 3 miles, 900'; and so on, until a safe landing may be made. Techniques for deriving a "3-to-1" glidepath include using distance measuring equipment (DME), distance advisories provided by radar-equipped control towers, area navigation (RNAV) (exclusive of Omega navigation systems), global positioning system (GPS), and pilotage when familiar features on the approach course are visible to the pilot.

B. Fly as closely as possible to the approach course centerline, or to the extended centerline of the runway of intended landing, as appropriate to conditions.

C. Cross the runway threshold at a nominal height of 50' above TDZE.

D. Land within the touchdown zone.

4. POLICY. POI's are directed to ensure that initial, transition, and recurrent training programs for pilots of heavy category aircraft, heavier large category aircraft, and the Boeing 757 aircraft include discussion of the wake vortex turbulence hazard caused by such aircraft in respect to lighter, following aircraft. Those training programs also should include the wake vortex turbulence containment procedures recommended in this bulletin.

5. INQUIRIES. This FSIB was developed by AFS-210. Any questions may be directed to AFS-210 at (202) 267-3718.

6. LOCATION IN HANDBOOK. The material covered in this handbook bulletin will be incorporated by AFS-200 in volume 3, chapter 2, section 3, of FAA Order 8400.10, "Air Transportation Operations Inspector's Handbook." Until the handbook is updated, inspectors should make written reference to this bulletin in the margin of the indicated section.

/s/ David R. Harrington

# NBAAALERTBULLETIN

ROUTE TO:

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 \_\_\_\_\_  
 \_\_\_\_\_  
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AB #93-20  
 DECEMBER 22, 1993

SUBJECT: WAKE TURBULENCE

## BACKGROUND

Last year, seven people were killed when a Cessna Citation crashed into an industrial section east of Billings, Montana after encountering wake turbulence from a Boeing 757.

Earlier this year, a Boeing 737 following a Boeing 757 into Denver apparently was turned on its side after encountering the wake of the larger jet. The aircraft landed safely.

Last week, an IAI Westwind crashed approximately two miles out from the Santa Ana Airport, killing all five aboard. It was on approach behind a Boeing 757.

Wake turbulence may have been a key factor in all of these incidents.

## THE ISSUE

As a party to the investigation of the Westwind accident, NBAA is prohibited from speculation as to the specific causal factors involved. However, the National Aeronautics and Space Administration (NASA), the Volpe National Transportation System Center (VNTSC), the British Civil Aviation Authority (CAA), and the Federal Aviation Administration (FAA) are currently examining data which may or may not require procedural changes for flight into areas prone to wake turbulence. The aviation industry is engaged in a joint program with the aforementioned agencies to improve our knowledge of wake vortex behavior and the potential of wake vortex hazards for all aircraft types.

## MEMBERSHIP ACTION

The *Airman's Information Manual (AIM)* covers wake turbulence operational procedures in a clear and concise manner. A thorough review by all crew members of Chapter 7, Section 3 is strongly recommended. This contains information necessary to alert pilots to the hazard, as well as proper vortex avoidance procedures. Sections of the AIM are attached for your convenience. Please review them thoroughly.

For more information, please call Paul H. Smith, NBAA manager, air traffic services, at (202)783-9255

(REMEMBER THE NBAA BULLETIN BOARD (202) 331-7968)



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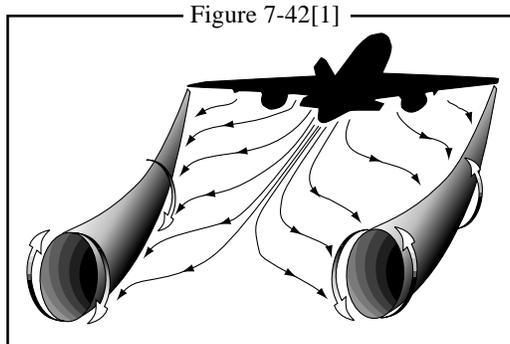
## Section 3. WAKE TURBULENCE

### 7-41. GENERAL

a. Every aircraft generates a wake while in flight. Initially, when pilots encountered this wake in flight, the disturbance was attributed to “prop wash.” It is known, however, that this disturbance is caused by a pair of counter rotating vortices trailing from the wing tips. The vortices from larger aircraft pose problems to encountering aircraft. For instance, the wake of these aircraft can impose rolling moments exceeding the roll-control authority of the encountering aircraft. Further, turbulence generated within the vortices can damage aircraft components and equipment if encountered at close range. The pilot must learn to envision the location of the vortex wake generated by larger (transport category) aircraft and adjust the flight path accordingly.

b. During ground operations and during takeoff, jet engine blast (thrust stream turbulence) can cause damage and upsets if encountered at close range. Exhaust velocity versus distance studies at various thrust levels have shown a need for light aircraft to maintain an adequate separation behind large turbojet aircraft. Pilots of larger aircraft should be particularly careful to consider the effects of their “jet blast” on other aircraft, vehicles, and maintenance equipment during ground operations.

### 7-42. VORTEX GENERATION



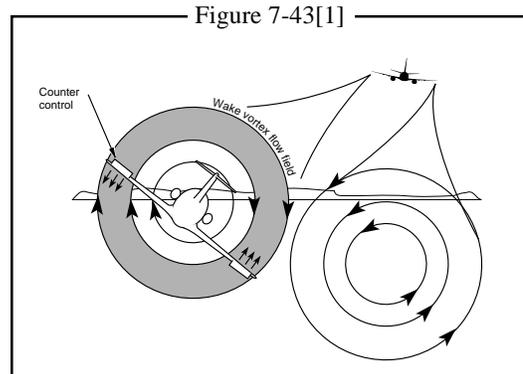
Lift is generated by the creation of a pressure differential over the wing surface. The lowest pressure occurs over the upper wing surface and the highest pressure under the wing. This pressure differential triggers the roll up of the airflow aft of the wing resulting in swirling air masses trailing downstream of the wing tips. After the roll up is completed, the wake consists of two counter rotating

cylindrical vortices. (See Figure 7-42[1].) Most of the energy is within a few feet of the center of each vortex, but pilots should avoid a region within about 100 feet of the vortex core.

### 7-43. VORTEX STRENGTH

a. The strength of the vortex is governed by the weight, speed, and shape of the wing of the generating aircraft. The vortex characteristics of any given aircraft can also be changed by extension of flaps or other wing configuring devices as well as by change in speed. However, as the basic factor is weight, the vortex strength increases proportionately. Peak vortex tangential speeds exceeding 300 feet per second have been recorded. The greatest vortex strength occurs when the generating aircraft is HEAVY, CLEAN, and SLOW.

### b. INDUCED ROLL



1. In rare instances, a wake encounter could cause in-flight structural damage of catastrophic proportions. However, the usual hazard is associated with induced rolling moments which can exceed the roll-control authority of the encountering aircraft. In flight experiments, aircraft have been intentionally flown directly up trailing vortex cores of larger aircraft. It was shown that the capability of an aircraft to counteract the roll imposed by the wake vortex primarily depends on the wingspan and counter-control responsiveness of the encountering aircraft.

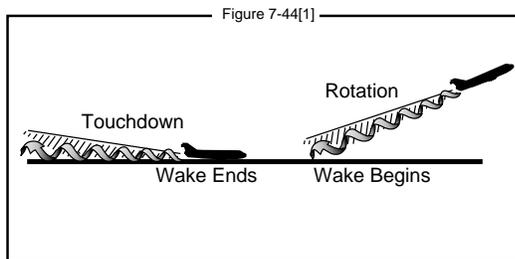
2. Counter control is usually effective and induced roll minimal in cases where the wingspan and ailerons of the encountering aircraft extend beyond the rotational flow field of the vortex. It is more difficult for aircraft with short wingspan (relative to the generating aircraft) to counter the imposed roll induced by vortex flow. Pilots of short

span aircraft, even of the high performance type, must be especially alert to vortex encounters. (See Figure 7-43[1].)

3. The wake of larger aircraft requires the respect of all pilots.

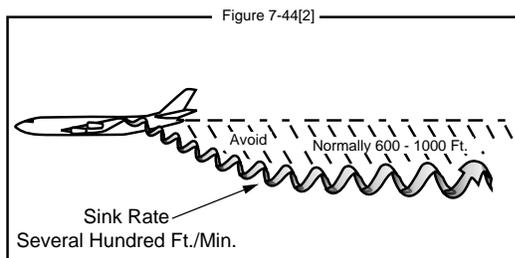
#### 7-44. VORTEX BEHAVIOR

a. Trailing vortices have certain behavioral characteristics which can help a pilot visualize the wake location and thereby take avoidance precautions.



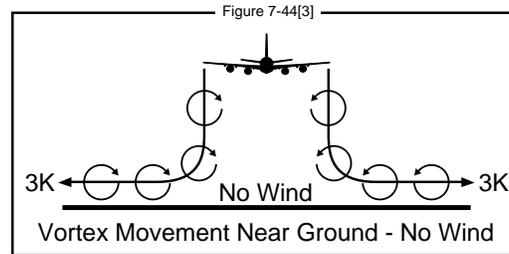
1. Vortices are generated from the moment aircraft leave the ground, since trailing vortices are a by-product of wing lift. Prior to takeoff or touchdown, pilots should note the rotation or touchdown point of the preceding aircraft. (See Figure 7-44[1][Wake Begins/Ends].)

2. The vortex circulation is outward, upward and around the wing tips when viewed from either ahead or behind the aircraft. Tests with large aircraft have shown that the vortices remain spaced a bit less than a wingspan apart, drifting with the wind, at altitudes greater than a wingspan from the ground. In view of this, if persistent vortex turbulence is encountered, a slight change of altitude and lateral position (preferably upwind) will provide a flight path clear of the turbulence.

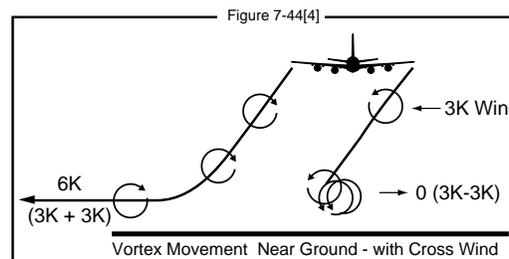


3. Flight tests have shown that the vortices from larger (transport category) aircraft sink at a rate of several hundred feet per minute, slowing their descent and diminishing in strength with time and distance behind the generating aircraft. Atmospheric turbulence hastens breakup. Pilots should fly at or above the preceding aircraft's flight path, altering course as necessary to avoid the area behind and below the generating aircraft.

(See Figure 7-44[2][Vortex Flow Field].) However, vertical separation of 1,000 feet may be considered safe.



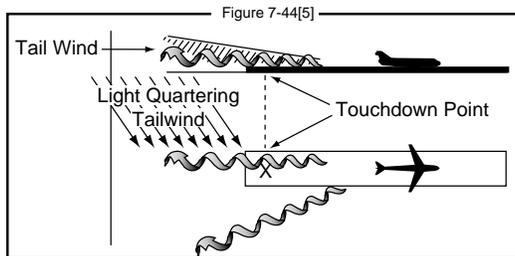
4. When the vortices of larger aircraft sink close to the ground (within 100 to 200 feet), they tend to move laterally over the ground at a speed of 2 or 3 knots. (See Figure 7-44[3][Vortex Sink Rate].)



b. A crosswind will decrease the lateral movement of the upwind vortex and increase the movement of the downwind vortex. Thus, a light wind with a cross runway component of 1 to 5 knots could result in the upwind vortex remaining in the touchdown zone for a period of time and hasten the drift of the downwind vortex toward another runway. (See Figure 7-44[4][Vortex Movement in Ground Effect (No Wind)].) Similarly, a tailwind condition can move the vortices of the preceding aircraft forward into the touchdown zone. **THE LIGHT QUARTERING TAILWIND REQUIRES MAXIMUM CAUTION.** Pilots should be alert to large aircraft upwind from their approach and takeoff flight paths. (See Figure 7-44[5][Vortex Movement in Ground Effect(Wind)].)

#### 7-45. OPERATIONS PROBLEM AREAS

a. A wake encounter can be catastrophic. In 1972, at Fort Worth, a DC-9 got too close to a DC-10 (two miles back), rolled, caught a wingtip, and cartwheeled coming to a rest in an inverted position on the runway. All aboard were killed. Serious and



even fatal GA accidents induced by wake vortices are not uncommon. However, a wake encounter is not necessarily hazardous. It can be one or more jolts with varying severity depending upon the direction of the encounter, weight of the generating aircraft, size of the encountering aircraft, distance from the generating aircraft, and point of vortex encounter. The probability of induced roll increases when the encountering aircraft's heading is generally aligned with the flight path of the generating aircraft.

b. **AVOID THE AREA BELOW AND BEHIND THE GENERATING AIRCRAFT, ESPECIALLY AT LOW ALTITUDE WHERE EVEN A MOMENTARY WAKE ENCOUNTER COULD BE HAZARDOUS.** This is not easy to do. Some accidents have occurred even though the pilot of the trailing aircraft had carefully noted that the aircraft in front was at a considerably lower altitude. Unfortunately, this does not ensure that the flight path of the lead aircraft will be below that of the trailing aircraft.

c. Pilots should be particularly alert in calm wind conditions and situations where the vortices could:

1. Remain in the touchdown area.
2. Drift from aircraft operating on a nearby runway.
3. Sink into the takeoff or landing path from a crossing runway.
4. Sink into the traffic pattern from other airport operations.
5. Sink into the flight path of VFR aircraft operating on the hemispheric altitude 500 feet below.

d. Pilots of all aircraft should visualize the location of the vortex trail behind larger aircraft and use proper vortex avoidance procedures to achieve safe operation. It is equally important that pilots of larger aircraft plan or adjust their flight paths to minimize vortex exposure to other aircraft.

#### 7-46. VORTEX AVOIDANCE PROCEDURES.

a. Under certain conditions, airport traffic controllers apply procedures for separating IFR aircraft. The controllers will also provide to VFR aircraft, with whom they are in communication and which in the tower's opinion may be adversely affected by wake turbulence from the larger aircraft, the position, altitude and direction of flight of larger aircraft followed by the phrase "CAUTION-WAKE TURBULENCE." WHETHER OR NOT A WARNING HAS BEEN GIVEN, HOWEVER, THE PILOT IS EXPECTED TO ADJUST HIS OR HER OPERATIONS AND FLIGHT PATH AS NECESSARY TO PRECLUDE SERIOUS WAKE ENCOUNTERS.

b. The following vortex avoidance procedures are recommended for the various situations:

1. Landing behind a larger aircraft—same runway: Stay at or above the larger aircraft's final approach flight path—note its touchdown point—land beyond it.

2. Landing behind a larger aircraft—when parallel runway is closer than 2,500 feet: Consider possible drift to your runway. Stay at or above the larger aircraft's final approach flight path—note its touchdown point.

3. Landing behind a departing larger—crossing runway: Cross above the larger aircraft's flight path.

4. Landing behind a departing larger aircraft—same runway: Note the larger aircraft's rotation point—land well prior to rotation point.

5. Landing behind a departing larger aircraft—crossing runway: Note the larger aircraft's rotation point—if past the intersection—continue the approach—land prior to the intersection. If a larger aircraft rotates prior to the intersection, avoid flight below the larger aircraft's flight path. Abandon the approach unless a landing is ensured well before reaching the intersection.

6. Departing behind a larger aircraft: Note the larger aircraft's rotation point—rotate prior to larger aircraft's rotation point—continue climb above the larger aircraft's climb path until turning clear of his wake. Avoid subsequent heading which will cross below and behind a larger aircraft. Be alert for any critical takeoff situation which could lead to a vortex encounter.

7. Intersection takeoffs—same runway: Be alert to adjacent larger aircraft operations, particularly upwind of your runway. If intersection takeoff clearance is received, avoid subsequent heading which will cross below a larger aircraft's path.

8. Departing or landing after a larger aircraft executing a low approach, missed approach or touch-

and-go landing: Because vortices settle and move laterally near the ground, the vortex hazard may exist along the runway and in your flight path after a larger aircraft has executed a low approach, missed approach or a touch-and-go landing, particular in light quartering wind conditions. You should ensure that an interval of a least 2 minutes has elapsed before your takeoff or landing.

9. En route VFR (thousand-foot altitude plus 500 feet): Avoid flight below and behind a large aircraft's path. If a larger aircraft is observed above on the same track (meeting or overtaking) adjust your position laterally, preferably upwind.

#### 7-47. HELICOPTERS

In a slow hover taxi or stationary hover near the surface, helicopter main rotor(s) generate downwash producing high velocity outwash vortices to a distance approximately three times the diameter of the rotor. When rotor downwash hits the surface, the resulting outwash vortices have behavioral characteristics similar to wing tip vortices produced by fixed wing aircraft. However, the vortex circulation is outward, upward, around, and away from the main rotor(s) in all directions. Pilots of small aircraft should avoid operating within three rotor diameters of any helicopter in a slow hover taxi or stationary hover. In forward flight, departing or landing helicopter produce a pair of strong, high-speed trailing vortices similar to wing tip vortices of larger fixed wing aircraft. Pilots of small aircraft should use caution when operating behind or crossing behind landing and departing helicopters.

#### 7-48 PILOT RESPONSIBILITY

a. Government and industry groups are making concerted efforts to minimize or eliminate the hazards of trailing vortices. However, the flight disciplines necessary to ensure vortex avoidance during VFR operations must be exercised by the pilot. Vortex visualization and avoidance procedures should be exercised by the pilot using the same degree of concern as in collision avoidance.

b. Wake turbulence may be encountered by aircraft in flight as well as when operating on the airport movement area. (Reference-Pilot/Controller Glossary, Wake Turbulence).

c. Pilots are reminded that in operations conducted behind all aircraft, acceptance of instructions from ATC in the following situations is an acknowledgement that the pilot will ensure safe takeoff and landing intervals and accept the responsibility of providing his own wake turbulence separation.

1. Traffic information,
2. Instructions to follow an aircraft, and
3. The acceptance of a visual approach clearance.

d. For operations conducted behind heavy

aircraft, ATC will specify the word "heavy" when this information is known. Pilots of heavy aircraft should always use the word "heavy" in radio communications.

#### 7-49. AIR TRAFFIC WAKE TURBULENCE SEPARATIONS.

a. Because of the possible effects of wake turbulence, controllers are required to apply no less than specified minimum separation for aircraft operating behind a heavy jet and, in certain instances, behind large nonheavy aircraft.

1. Separation is applied to aircraft operating directly behind a heavy jet at the same altitude or less than 1,000 feet below:

- (a) Heavy jet behind heavy jet—4 miles.
- (b) Small/large aircraft behind heavy jet—5 miles.

2. Also, separation, measured at the time the preceding aircraft is over the landing threshold, is provided to small aircraft:

- (a) Small aircraft landing behind heavy jet—6 miles.
- (b) Small aircraft landing behind large aircraft—4 miles.

7-49a2b Note-34. See Pilot/Controller Glossary, Aircraft Classes.

3. Additionally, appropriate time or distance intervals are provided to departing aircraft:

(a) Two minutes or the appropriate 4- or 5-mile radar separation when takeoff behind a heavy jet will be:

- from the same threshold
- on a crossing runway and projected flight paths will cross
- from the threshold of a parallel runway when staggered ahead of that of the adjacent runway by less than 500 feet and when the runways are separated by less than 2,500 feet.

7-49a3a Note—Pilots, after considering possible wake-turbulence effects, may specifically request waiver of the 2-minute interval by stating, "request waiver of 2-minute interval" or a similar statement. Controllers may acknowledge this statement as pilot acceptance of responsibility for wake turbulence separation and, if traffic permits, issue takeoff clearance.

b. A 3-minute interval will be provided when a small aircraft will takeoff.

1. From an intersection on the same runway (same or opposite direction) behind a departing large aircraft.

2. In the opposite direction on the same runway behind a large aircraft takeoff or low/missed approach.

7-49b2 Note—This 3-minute interval may be waived upon specific pilot request.

c. A 3-minute interval will be provided for all aircraft taking off when the operations are as described in b(1) and (2) above, the preceding aircraft is a **heavy** jet, and the operations are on either the same runway or parallel runways separated by less than 2,500 feet. Controllers may not reduce or waive this interval.

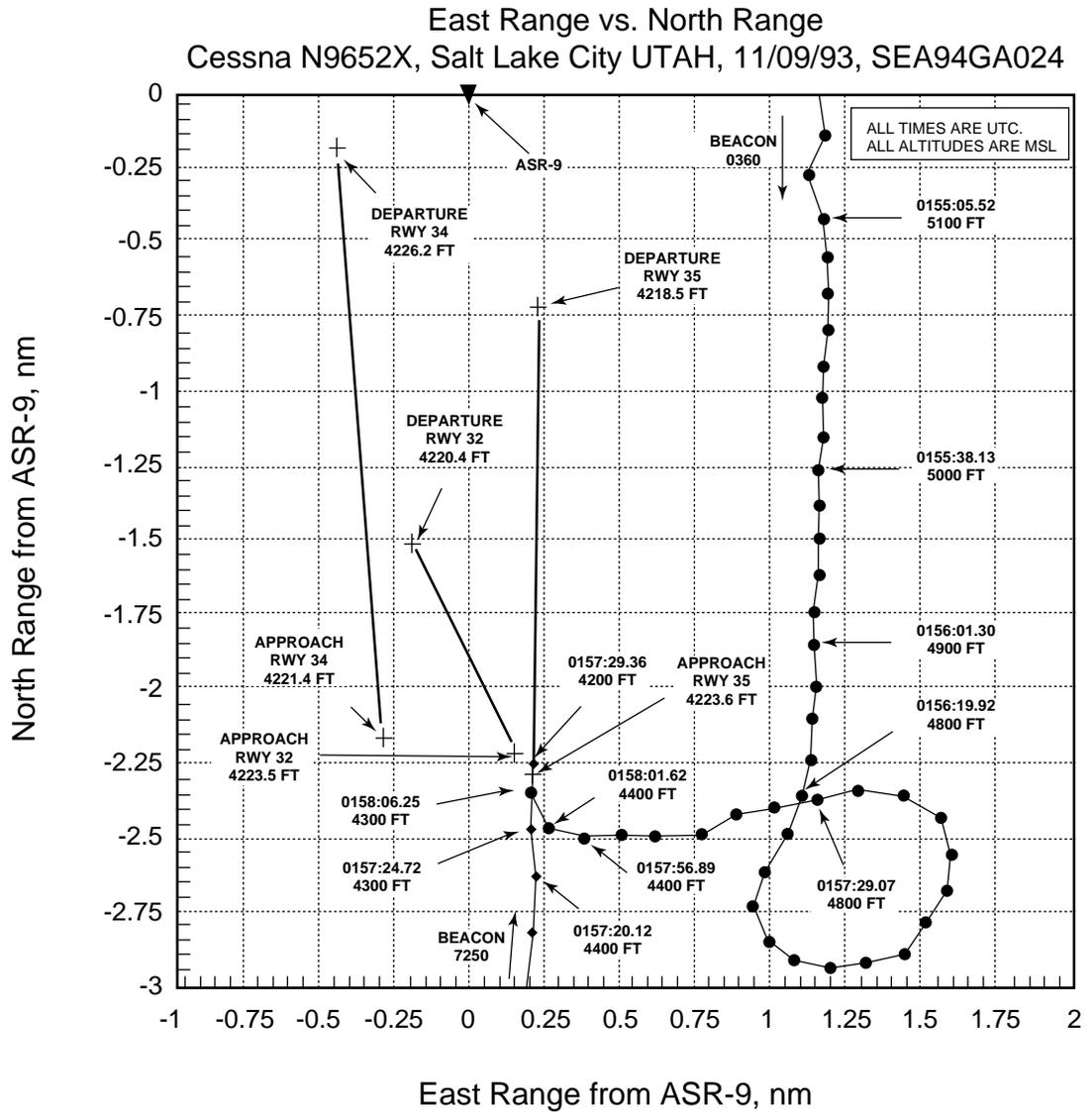
d. Pilots may request additional separation i.e., 2 minutes instead of 4 or 5 miles for wake turbulence avoidance. This request should be made as soon as practical on ground control and at least before taxiing onto the runway.

7-49d Note-FAR 91.3(a) states: “The pilot in command of an aircraft is directly responsible for and is the final authority as to the operation of that aircraft.”

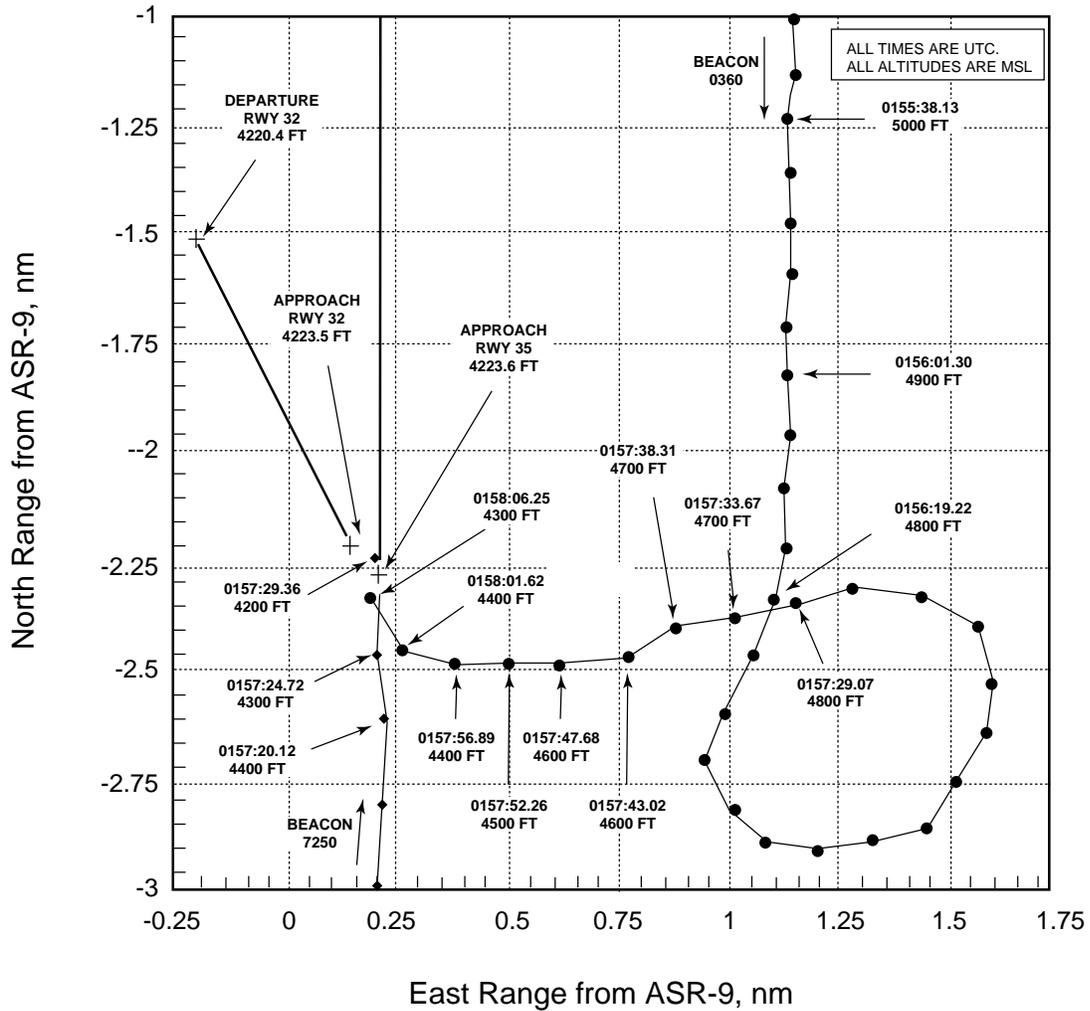
e. Controllers may anticipate separation and need not withhold a takeoff clearance for an aircraft departing behind a **large/heavy** aircraft if there is reasonable assurance the required separation will exist when the departing aircraft starts takeoff roll.

7-50 thru 7-60. RESERVED

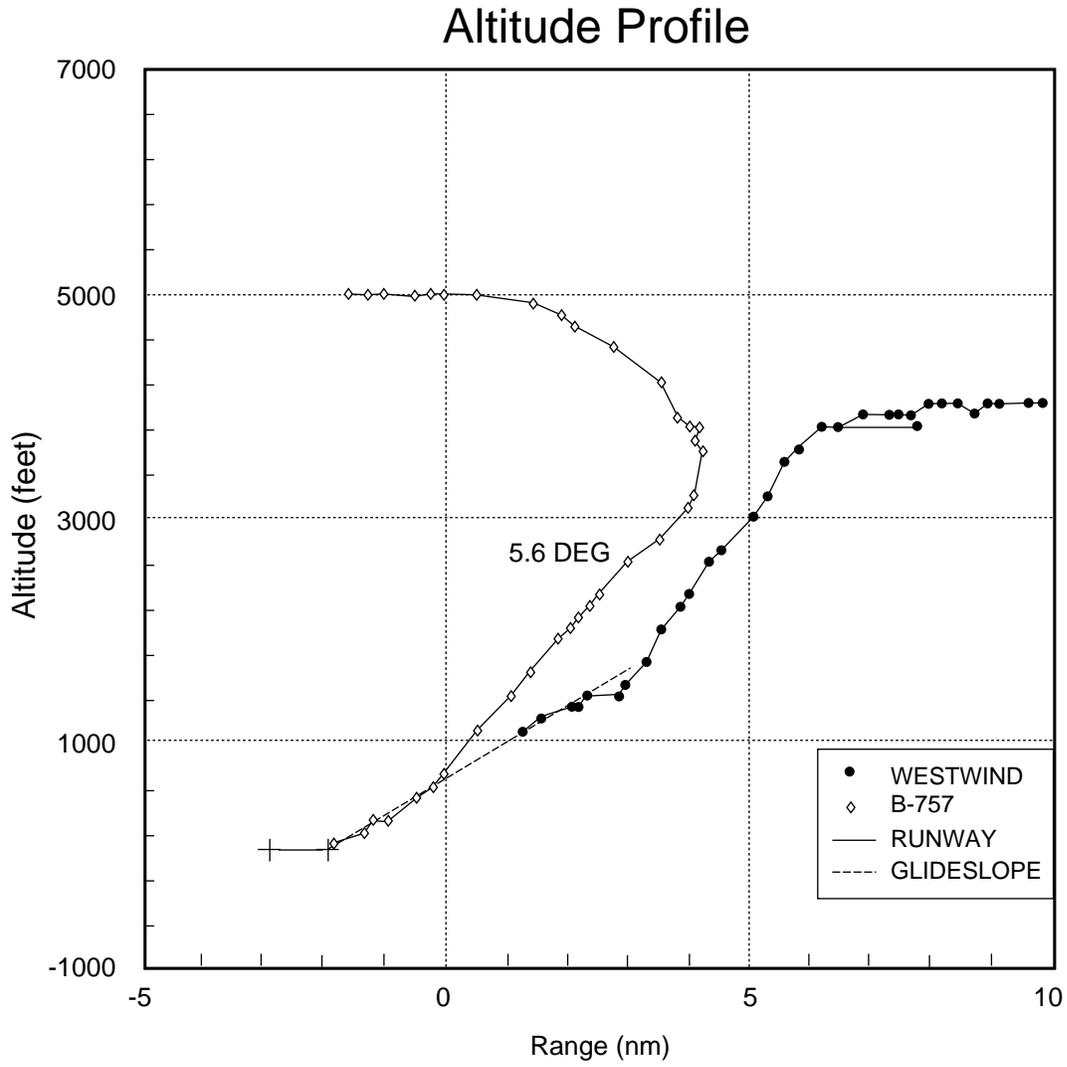
**Appendix F**  
**Ground Track of Cessna 182 and B-757**  
**at Salt Lake City, Utah, on November 10, 1993**

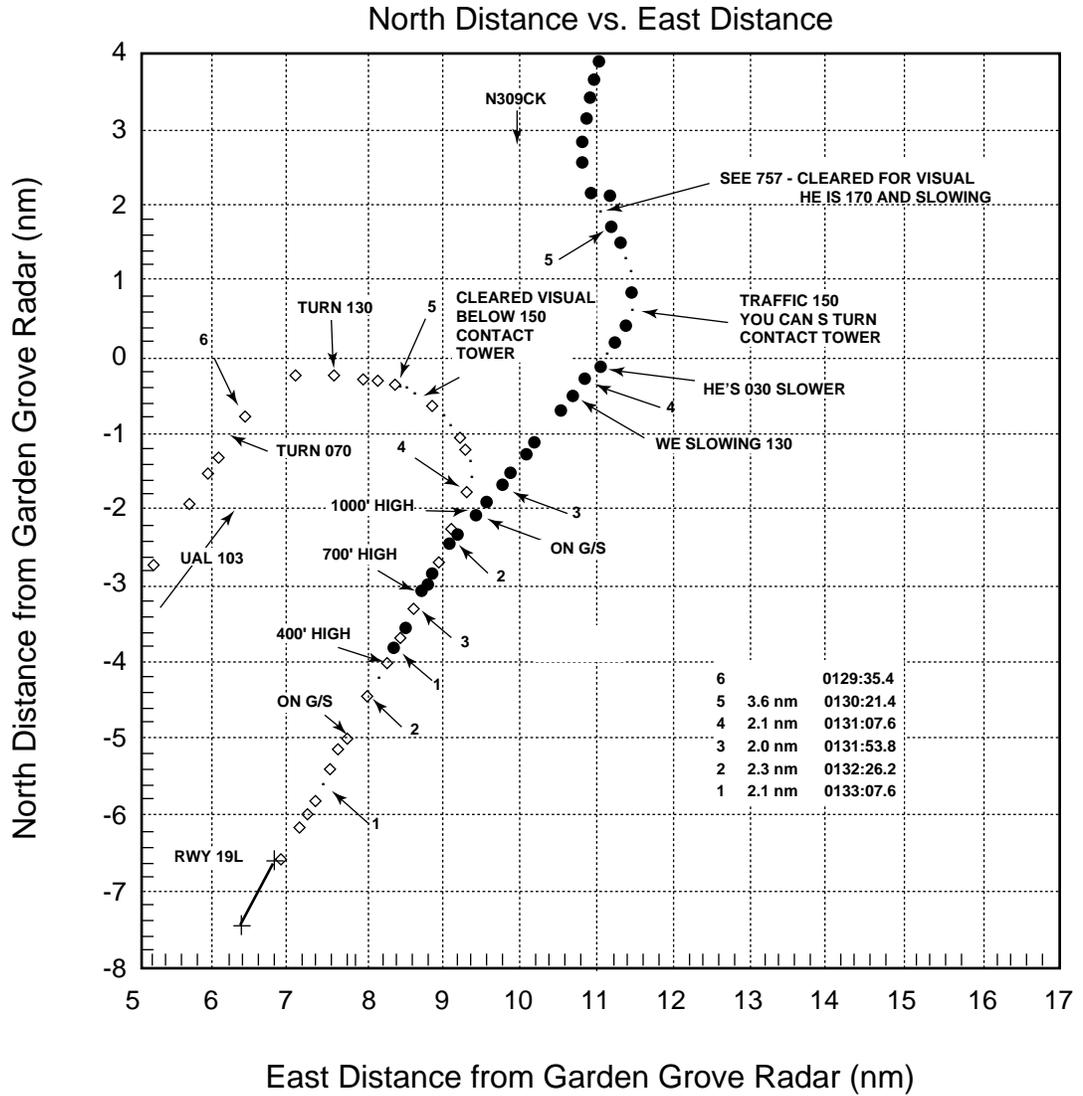


East Range vs. North Range  
 Cessna N9652X, Salt Lake City UTAH, 11/09/93, SEA94GA024



**Appendix G**  
**Ground Track and Altitude Profile of Westwind**  
**and B-757 at John Wayne Airport,**  
**Santa Ana, California, on December 15, 1993**





# Appendix H

## Aviation Safety Reporting System Reports of Wake Vortex Encounters

National Aeronautics and  
Space Administration

**Ames Research Center**  
Moffett Field, CA 94035-1000



Reply to attn of FL:262-1

MEMORANDUM FOR: Recipients of Aviation Safety Reporting System Data

SUBJECT: Data Derived from ASRS Reports

The attached material is furnished pursuant to a request for data from the NASA Aviation Safety Reporting System (ASRS). Recipients of this material are reminded of the following points which must be considered when evaluating these data.

ASRS reports are submitted voluntarily. The existence in the ASRS database of reports concerning a specific topic cannot, therefore, be used to infer the prevalence of that problem within the national aviation system.

Reports submitted to ASRS may be amplified by further contact with the individual who submitted them, but the information provided by the reporter is not investigated further. Such information may or may not be correct in any or all respects. At best, it represents the perception of a specific individual who may or may not understand all of the factors involved in a given issue or event.

After preliminary processing, all ASRS reports are deidentified. There is no way to identify the individual who submitted a report. All ASRS records systems are designed to prevent any possibility of identifying individuals submitting, or other names, in ASRS reports. There is, therefore, no way to verify information submitted in an ASRS report after it has been deidentified.

The National Aeronautics and Space Administration and its ASRS contractor, Battelle Memorial Institute, specifically disclaim any responsibility for any interpretation which may be made by others of any material or data furnished by NASA in response to queries of the ASRS database and related materials.

A handwritten signature in black ink, appearing to read "W. Reynard".

William Reynard, Director  
Aviation Safety Reporting Systems

## CAVEAT REGARDING STATISTICAL USE OF ASRS INFORMATION

Certain caveats apply to the use of ASRS statistical data. All ASRS reports are voluntarily submitted, and thus cannot be considered a measured random sample of the full population of like events. For example, we receive several thousand altitude deviation reports each year. This number may comprise over half of all the altitude deviations which occur, or it may be just a small fraction of total occurrences. We have no way of knowing which.

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 to us. Thus, the data reflect **reporting biases**. These biases, which are not fully known or measurable, distort ASRS statistics. A safety problem such as near midair collisions (NMACS) may appear to be more highly concentrated in area "A" than area "B" simply because the airmen who operate in area "A" are more supportive of the ASRS program and more inclined to report to us should an NMAC occur.

Only one thing can be known for sure from ASRS statistics—they represent the **lower measure** of the true number of such events which are occurring. For example, if ASRS receives 300 reports of track deviations in 1993 (this number is purely hypothetical), then it can be known with certainty that at least 300 such events have occurred in 1993.

Because of these statistical limitations, we believe that the **real power** of ASRS lies in the **report narratives**. Here pilots, controllers, and others, tell us about aviation safety incidents and situations in detail. They explain what happened, and more importantly, **why** it happened. Using report narratives effectively requires an extra measure of study, the knowledge derived is well worth the added effort.

Your printout from the ASRS includes information on the following categories. Please note-each entry in a category is separated by a semicolon (e.g., two SMAs in one incident would be coded as "SMA;SMA;" in the Aircraft Type category.

Accession Number - a unique, sequential number assigned to each report.

Date of Occurrence - the date of the occurrence/situation in the form of a year and a month; e.g., 9304 represents April 1993.

Reported by - role of the person who reported the occurrence/situation. Codes used are: FLC-flight crew, PLT-pilot; CRM-crew member; CTLR-Air Traffic Controller; PAX-passenger; OBS-observer; AFC (or AIR)-Air Force; NVY-Navy; UNK-unknown.

Persons Functions - description of a person's function at the time of the occurrence. Codes used are:

FLC	PIC	- Pilot in command as determined by official designation, prior consensus, or actually controlling the aircraft	
	CAPT	- Captain role in a multi-person flight crew	
	FO	- First Officer/Copilot role in a multi-person flight crew.	
	SO	- Second Officer/Flight Engineer role in a multi-person flight crew	
	OTH	- Additional crew member (e.g., navigator) in a multi-person flight crew.	
	CKP	- Check pilot (essential flight crew member occupying a crew position/role)	
	ISTR	- Legally qualified flight instructor who is giving instruction at the time of the occurrence/situation	
	PLT TRNEE	- Pilot in a single-person crew - Flight crew member in training	
TWR	LC	- Local controller	COORD - Coordinator position
	GC	- Ground controller	CD - Clearance delivery
	FD	- Flight data position	SUPVR - Supervisor
	OTH	- Other	TRNEE - Trainee
TRACON	AC	- Approach controller	COORD - Coordinator position
	DC	- Departure controller	SUPVR - Supervisor
	RHO	- Radar hand-off position	OTH - Other
	FD	- Flight data position	TRNEE - Trainee
ARTCC	M	- Manual controller	COORD - Coordinator position
	R	- Radar controller	SUPVR - Supervisor
	H	- Hand-off position	OTH - Other
	D	- Assistant or data man	TRNEE - Trainee
MIL	PAR	- Precision approach radar	OTH - Other
	RSU	- Runway supervisory unit	
MISC	FSS	- Fix service station specialist	DISP - Dispatcher
	ACI	- Air Carrier inspector	CENR - Company enroute check personnel
	UNI	- Unicom operator	
	FBO	- Fixed base operator/employee	TADV - Tower advisory
	CAB	- Cabin attendant	AMGR - Airport manager
	VD	- Vehicle driver	OBS - Observer
	PAX	- Passenger	SUPVR - Supervisor
	CGP	- Company ground personal	OTH - Other

Flight Conditions - the weather environment at the time of the occurrence or situation in terms of the conventional definition for flight conditions. Codes used are: VMC-visual meteorological conditions; IMC-instrument meteorological conditions; MXD-mixed flight conditions (both VMC and IMC); MVI-marginal VFR; SVF-special VFR.

Reference Facility ID (or LOC ID) - the standard three-letter (or letter-number combination) location identifier associated with an airport or navigational facility as referenced in the FAA Order 7350.5Z series entitled "Location Identifiers."

Facility Identifier - the standard three-letter (or letter-number combination) location identifier associated with an ATC facility as referenced in the FAA Order 7350.5Z series entitled "Location Identifiers."

Aircraft Type - the aircraft type involved in the incident differentiated by arbitrary gross takeoff weight ranges (military aircraft type are differentiated by function). Codes used re:

- SMA - small aircraft (less than 5000 lbs)
- SMT - small transport (5001 - 14,500 lbs)
- LTT - light transport (14,501 - 30,000 lbs)
- MDT - medium transport (30,001 - 60,000 lbs)
- MLG - medium large transport (60,001 - 150,000 lbs)
- LRG - large transport (150,001 - 300,000 lbs)
- HVT - large transport (over 300,000 lbs)
- WDB - wide-body (over 30,000 lbs)
- ULT - ultralight (including hang gliders)
- SPB - sailplane/glider
- SPC - special purpose
- FGT - fighter
- BMB - bomber
- MLT - military transport
- MTR - military trainer

Anomaly (Descriptions, Detector, Resolution, Consequences) - short summary of a standard chain of sub-events within a reported incident.

Situation Report Subjects - description(s) of a static hazard which creates a safety problem.

**ANOMALY DEFINITIONS**

- ACFT EQUIPMENT PROBLEM/CRITICAL** - Aircraft equipment problem that is vital to the safety of the flight.
- ACFT EQUIPMENT PROBLEM/LESS SEVERE** - Not qualifying as a critical aircraft equipment problem.
- ALT DEVIATION** - A departure from or failure to attain or failure to maintain an ATC assigned altitude. It does not include an injudicious or illegal altitude in VFR flight where no altitude has been assigned by ATC or specified in pertinent charts.
- ALT DEV/OVERSHOOT** - An aircraft climbs or descends through the assigned altitude.
- ALT DEV/UNDERSHOOT ON CLD OR DES** - An aircraft fails to reach an assigned altitude during climb or descent.
- ALT DEV/EXCURSION FROM ASSIGNED** - An aircraft departs from level flight at an assigned altitude.
- ALT DEV/XING RESTRICTION NOT MET** - Charted or assigned altitude crossing restriction is not met.
- ALT-HDG RULE DEVIATION** - Cruise flight contrary to the altitudes specified in FAR 91.159
- CONFLICT/NMAC (NEAR MIDAIR COLLISION)** - a conflict is defined as the existence of a perceived separation anomaly such that the pilot(s) of one or both aircraft take evasive action; or are advised by ATC to take evasive action; or experience doubt about assurance of continuing separation from the viewpoint of one or more of the pilots or controllers involved. A near midair collision is when the flight crew reports, either directly or as quoted by the controller, that the reported miss distance is less than 500 feet.
- CONFLICT/AIRBORNE LESS SEVERE** - a conflict not qualifying as a NMAC
- CONFLICT/GROUND CRITICAL** - A ground occurrence that involves (1) two or more aircraft, at least one of which is on the ground at the time of the occurrence, or (2) one or more aircraft conflicting with a ground vehicle. The flight crew reports, either directly or as quoted by a controller, that they took evasive action to avoid a collision (emergency action go-around, veering on runway or taxiway, takeoff abort, or emergency braking), and the balance of the report, including the narrative is judged consistent with a critical occurrence.
- CONFLICT/GROUND LESS SEVERE** - a ground conflict not qualifying as critical.
- CONTROLLED FLT TOWARD TERRAIN** - Flying at an altitude that would, if continued, result in contact with terrain.
- ERRONEOUS PENETRATION OF OR EXIT FROM AIRSPACE** - Self-explanatory.
- IN-FLT ENCOUNTER/OTHER** - In-flight encounter (e.g., bird strikes, weather balloons).
- IN-FLT ENCOUNTER/WX** - In-flight encounter with weather (e.g., wind shear, turbulence, clouds, high winds, storms).
- LESS THAN LEGAL SEPARATION** - Less than standard separation between two airborne aircraft (as standard separation is defined for the airspace involved).
- LOSS OF ACFT CONTROL** - Self-explanatory.
- NON-ADHERENCE LEGAL RQMT/CLNC** - Non-adherence to an ATC clearance.
- NON-ADHERENCE LEGAL RQMT/FAR** - Non-adherence to a Federal Aviation Regulation.
- NON-ADHERENCE LEGAL RQMT/PUBLISHED PROC** - Non-adherence to approach procedure, standard instrument departure, STAR, profile descent, or operational procedure as described in the AIM or ATC facility handbook.
- NON-ADHERENCE LEGAL RQMT/OTHER** - Non-adherence to SOPs for aircraft, company SOPs, etc.
- RWY OR TXWY EXCURSION** - An aircraft exits the runway or taxiway pavement.
- RWY TRANSGRESS/OTHER** - The erroneous or improper occupation of a runway or its immediate environs by an aircraft or other vehicle so as to pose a potential collision hazard to other aircraft using the runway, even if no such other aircraft were actually present.
- RWY TRANSGRESS/UNAUTH LNDG** - A runway transgression specifically involving landing without a landing clearance or landing on the wrong runway.
- SPEED DEVIATION** - Aircraft speed contrary to FARs or controller instruction.
- TRACK OR HDG DEVIATION** - Self-explanatory.
- UNCTRL ARPT TRAFFIC PATTERN DEVIATION** - Failure to fly the prescribed rectangular pattern or failure to enter on a 45 degree angle to the downwind leg.
- VFR IN IMC** - Flight conducted under Visual Flight Rules (VFR) into Instrument Meteorological Conditions (IMC) when not on an instrument flight plan and/or when not qualified to fly under Instrument Flight Rules (IFR).

ACCESSION NUMBER : 72048  
DATE OF OCCURRENCE : 8707  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT; FLC,PIC.CAPT;TWR,  
LC;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : ATL  
FACILITY STATE : GA  
FACILITY TYPE : TWR; ARPT;  
FACILITY IDENTIFIER : ATL; ATL;  
AIRCRAFT TYPE : MLG; LRG;  
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; LOSS OF ACFT  
CONTROL;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : FLC EXECUTED GAR OR MAP; FLC REGAINED  
ACFT CONTROL; ACFT EXITED ADVERSE ENVIRONMENT;  
ANOMALY CONSEQUENCES : NONE;  
NARRATIVE : VECTORED FOR A VISUAL APCH AT 5000' 10  
MI FROM ARPT. INSTRUCTED TO MAINTAIN 180 KTS TO MARKER AND  
FOLLOW AN LGT "20 KTS FASTER". THROTTLES WERE AT IDLE, FLAPS 15  
DEG, AND GEAR DOWN. GLIDE SLOPE WAS SHOWING FULL DOWN  
INDICATION. JUST OUTSIDE OUTER MARKER, AS THROTTLES WERE  
RETURNED TO APPROX 1.15 EPR, WE BEGAN TO ENCOUNTER "LIGHT" WAKE  
TURB. NEAR OUTER MARKER AT APPROX 2000' AGL (STILL FULL DOWN  
DEFLECTION ON GLIDE SLOPE) ACFT BEGAN ROLL TO RIGHT, FULL  
OPPOSITE AILERON WAS APPLIED, WITH BOTH PLTS ON CONTROLS. ACFT  
CONTINUED TO ROLL TO A BANK ANGLE EXCEEDING 75 DEG OF BANK,  
STICK SHAKER AND GND PROX WARNING SYSTEM SOUNDED AND THROTTLES  
WERE ADVANCED TO FIREWALL THRUST. AIRSPEED AT THIS TIME WAS  
170-180 KIAS. MISSED APCH WAS EXECUTED AND WE WERE VECTORED FOR  
A SECOND APCH AND UNEVENTFUL LNDG.  
SYNOPSIS : MLG ENCOUNTERS WAKE TURBULENCE ON FINAL  
APCH BEHIND AN LGT.  
REFERENCE FACILITY ID : ATL  
FACILITY STATE : GA  
AGL ALTITUDE : 5,,E  
MSL ALTITUDE : 3000, 3000

ACCESSION NUMBER : 107506  
DATE OF OCCURRENCE : 8812  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PIC.CAPT;FLC,  
FO;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : DFW  
FACILITY STATE : TX  
FACILITY TYPE : TWR; ARPT;  
FACILITY IDENTIFIER : DFW; DFW;  
AIRCRAFT TYPE : MLG; LRG;  
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; OTHER;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : NOT RESOLVED/ANOMALY ACCEPTED;  
ANOMALY CONSEQUENCES : NONE;  
SITUATION REPORT SUBJECTS : AN ACFT TYPE;  
NARRATIVE : LGT WAS CLRED FOR TKOF. ONCE HE WAS  
AIRBORNE, WE WERE CLRED FOR TKOF. IMMEDIATELY AFTER TKOF WE  
ENCOUNTERED THE LGT WAKE TURB. IT TOOK ALMOST FULL AILERON  
INPUT TO KEEP FROM ROLLING PAST 45 DEGS. THE LGT IS NOT  
CONSIDERED A HVY CATEGORY ACFT. THE WAKE I ENCOUNTERED WAS  
CONSIDERABLY MORE THAN NORMAL. SUGGEST THERE BE AN INTERMEDIATE  
CATEGORY WITH SOME TIMING RESTRICTIONS, ESPECIALLY FOR LNDG. IF  
MORE INFO IS NEEDED, PLEASE CALL.  
SYNOPSIS : MLG EXPERIENCED WAKE TURBULENCE  
FOLLOWING A NEW TYPE MLG NOT DESIGNED AS HVY.  
REFERENCE FACILITY ID : DFW  
FACILITY STATE : TX  
AGL ALTITUDE : 0,350  
MSL ALTITUDE : 100,100

ACCESSION NUMBER : 149927  
DATE OF OCCURRENCE : 9006  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,CAPT.PIC; FLC,FO; TWR,LC; FLC, PIC.  
CAPT;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : ORD  
FACILITY STATE : IL  
FACILITY TYPE : TWR; ARPT;  
FACILITY IDENTIFIER : ORD; ORD;  
AIRCRAFT TYPE : MLG; LRG;  
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; LOSS OF ACFT  
CONTROL;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : FLC REGAINED ACFT CONTROL  
ANOMALY CONSEQUENCES : NONE;  
SITUATION REPORT SUBJECTS : AN ACFT TYPE; PROC OR POLICY/FAA;  
NARRATIVE : I AM CAPT OF AN MLG. TOLD TO EXPEDITE  
TKOF BEHIND LGT ON RWY 32L AT ORD. WE BEGAN TKOF ROLL AS LGT  
ROTATED. HE WENT STRAIGHT OUT<sup>1</sup> AND WE WERE TO TURN TO 180 DEGS.  
WE STARTED THE TURN AT 300' AGL WITH 15 DEGS ANGLE OF BANK. WE  
WERE VIOLENTLY INCREASED TO 30 DEGS ANGLE OF BANK FROM THE  
APPARENT WAKE TURB OF THE LGT. THE COPLT COVERED SMOOTHLY AND NO  
ONE WAS INJURED. I WONDERED IF THE FAA OR ACFT MFR HAD  
CONSIDERED INCREASED SEP BEHIND LGT ACFT BECAUSE OF WING DESIGN.  
SYNOPSIS : FLT CREW OF MLG DEPARTING ORD ENCOUNTERS  
WHAT THEY BELIEVED TO BE THE WAKE TURBULENCE OF A LGT THAT  
DEPARTED JUST BEFORE THEM.  
REFERENCE FACILITY ID : ORD  
FACILITY STATE : IL  
AGL ALTITUDE : 300,000

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<sup>1</sup>Handwritten note: 40 - 50 sec.

ACCESSION NUMBER : 156250  
DATE OF OCCURRENCE : 9008  
REPORTED BY : FLC; ; ; ;  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC, SO; FLC,  
PIC.CAPT; TWR,LC; TRACON,DC;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : LAX  
FACILITY STATE : CA  
FACILITY TYPE : ARPT; TWR; TRACON;  
FACILITY IDENTIFIER : LAX; LAX; LAX;  
AIRCRAFT TYPE : LRG; LRG;  
ANOMALY DESCRIPTIONS : OTHER;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : FLC REGAINED ACFT CONTROL;  
ANOMALY CONSEQUENCES : NONE;  
SITUATION REPORT SUBJECTS : PROC OR POLICY/FAA; AN ACFT TYPE;  
NARRATIVE : WE WERE CLRED ONTO RWY 25L AT LAX. THE  
SKY WAS CLR AND WINDS WERE 250 DEGS AT 9 KTS. AN LGT ADVANCED  
WAS ON ITS TKOF ROLL. WE WERE FLYING AN LGT WITH -15 ENGS AND  
RELATIVELY LIGHT AT ABOUT 140000#. AS THE LGT ADVC STARTED ITS  
ROTATION, WE WERE CLRED FOR TKOF. WE STARTED OUR TKOF ROLL RIGHT  
AFTER RECEIVING THE CLRNC, NOT MAKING ANY ALLOWANCES FOR THE LGT  
ADVNC. RIGHT AFTER LIFTOFF AT ABOUT 100' AGL, WE ENCOUNTERED THE  
WAKE VORTICES OF THE LGT ADVNC AND WE WERE IN THEM UNTIL ABOUT  
2000' MSL. DURING THAT TIME WE EXPERIENCED VERY RAPID ROLL  
RATES, WITH THE ACFT ROLLING 45 DEGS LEFT AND RIGHT, AND FULL  
AILERON OFTEN REQUIRED TO KEEP THE ACFT RIGHT SIDE UP. WITH NO  
SEP REQUIREMENTS FOR THE LGT ADVNC MANDATED BY THE FAA AT THIS  
TIME, THIS PLT WILL BE REQUESTING ADDITIONAL SEP FROM LGT ADVNC  
ACFT AND STRONGLY SUGGESTS THE FAA CONSIDER TREATING THE LGT  
ADVNC AS A HVY FOR SEP REQUIREMENTS.  
SYNOPSIS : FLT CREW OF LGT MAKING SHORT INTERVAL  
TKOF BEHIND ADVANCED LGT EXPERIENCED WAKE TURBULENCE FORM TKOF  
UP TO 2000' FOLLOWING THE ADVANCED LGT.  
REFERENCE FACILITY ID : LAX  
FACILITY STATE : CA  
DISTANCE & BEARING FROM REF. : 3,250  
AGL ALTITUDE : 0,2000

ACCESSION NUMBER : 167185  
 DATE OF OCCURRENCE : 9101  
 REPORTED BY : CTLR; ; ;  
 PERSONS FUNCTIONS : TWR,LC; FLC,PIC.CAPT; FLC,FO; FLC, PIC.  
 CAPT;  
 FLIGHT CONDITIONS : VMC  
 REFERENCE FACILITY ID : BOS  
 FACILITY STATE : MA  
 FACILITY TYPE : TWR;  
 FACILITY IDENTIFIER : BOS;  
 AIRCRAFT TYPE : LRG; LTT;  
 ANOMALY DESCRIPTIONS : OTHER; CONFLICT/AIRBORNE LESS SEVERE;  
 LESS THAN LEGAL SEPARATION; NON ADHERENCE LEGAL  
 RQMT/PUBLISHED PROC;  
 ANOMALY DETECTOR : COCKPIT/FLC;  
 ANOMALY RESOLUTION : CTLR ISSUED NEW CLNC; FLC EXECUTED GAR  
 OR MAP; ACFT EXITED ADVERSE ENVIRONMENT;  
 ANOMALY CONSEQUENCES : NONE;  
 NARRATIVE : ACR X WAS ON FINAL (ILS/DME) TO RWY 33L  
 AT BOS. ACR X SLOWED TO 120 KTS ON A 3 MI FINAL. LTT Y WAS ON  
 APCH 3-4 MI IN TRAIL 170 KTS. (ALL SPDS ARE ARTS GENERATED IN  
 THE DATA BLOCKS.) LTT Y WAS TOLD HE WAS INDICATING 50 KTS FASTER  
 THAN ACR X. ACR X WAS TOLD THAT TFC WAS SPACED ON HIM. WITH ACR  
 X LESS THAN A 1 MI FINAL AND LTT Y 2 1/2 MI IN TRAIL, LTT Y  
 INFORMED ME HE WAS UNABLE TO FOLLOW ACR X AND WAS ABORTING THE  
 APCH. WHEN I ASKED TO SAY AGAIN, THE PLT STATED HE WAS IN A  
 RIGHT TURN. I ASKED THE PLT IF HE WAS ABLE RWY 27, AND HE STATED  
 AFFIRMATIVE. THE PLT WAS ISSUED LNDG CLRNC FOR RWY 27. DURING  
 THE SEQUENCE OF EVENTS, THE PLT OF LTT Y NEVER REDUCED HIS  
 AIRSPD AND NEVER INFORMED ACR X (HE INFORMED THE GND CTLE OF THE  
 WAKE TURB PROB). BOS TWR IS ALLOWED REDUCED SEP INSIDE THE OM  
 (PER FAA HANDBOOK 7110.65, PARAGRAPH 5-72F) TO 2.5 MI. HVY ACFT  
 CAN PARTICIPATE AS TRAILING ACFT ONLY. SINCE LTT Y RPTED ACR X  
 IN SIGHT, I ASSUMED HE WAS PROVIDING HIS OWN VIS SEP (I HAD BOTH  
 ACFT IN SIGHT). HAD I KNOWN THAT THE WAKE TURB FROM THE ACR  
 CREATED SUCH A PROB FOR THE LTT, I WOULD HAVE TAKEN MORE  
 POSITIVE ACTION (I.E., INSTRUCTED LTT Y TO REDUCE TO HIS FINAL  
 APCH SPD, IF PRACTICAL) TO MAINTAIN AS MUCH SEP AS POSSIBLE.  
 SYNOPSIS : LTT Y HAD LESS THAN STANDARD SEPARATION  
 FROM ACR X. SYSTEM ERROR.  
 REFERENCE FACILITY ID : BOS  
 FACILITY STATE : MA  
 DISTANCE & BEARING FROM REF. : 5,,NE  
 AGL ALTITUDE : 300,1100



ACCESSION NUMBER : 210179  
DATE OF OCCURRENCE : 9205  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PIC,CAPT;  
TRACON,AC;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : ORD  
FACILITY STATE : IL  
FACILITY TYPE : TRACON; ARPT;  
FACILITY IDENTIFIER : ORD; ORD;  
AIRCRAFT TYPE : LTT; LRG;  
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; LOSS OF ACFT  
CONTROL;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : FLC REGAINED ACFT CONTROL;  
ANOMALY CONSEQUENCES : NONE;  
NARRATIVE : DURING A VECTOR FROM THE S, WE WERE  
SEQUENCED BEHIND AN ACR LGT Y. JUST AS FINAL WAS INTERCEPTED,  
THE WAKE WAS ENCOUNTERED. WE ROLLED UNCTLABLE INTO 80 DEG BANK.  
WE COULDN'T CTL FOR 2-3 SECONDS. THE LGT Y PUTS OUT MORE WAKE  
THAN ANY ACFT I HAVE EVER ENCOUNTERED.  
SYNOPSIS : A COMMUTER ACFT ENCOUNTERS WAKE TURB  
WHEN SEQUENCED BEHIND AN ACR LGT ON FINAL AT ORD. REFERENCE  
FACILITY ID : ORD  
FACILITY STATE : IL  
DISTANCE & BEARING FROM REF. : 10,,SW  
MSL ALTITUDE : 4000,4000

ACCESSION NUMBER : 218953  
 DATE OF OCCURRENCE : 9208  
 REPORTED BY : FLC; FLC; ; ; ;  
 PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PIC.CAPT;  
 FLC,FO; TWR, LC;  
 FLIGHT CONDITIONS : MVF  
 REFERENCE FACILITY ID : ATL  
 FACILITY STATE : GA  
 FACILITY TYPE : ARPT; TWR; TRACON;  
 FACILITY IDENTIFIER : ATL; ATL; ATL;  
 AIRCRAFT TYPE : LTT; LRG;  
 ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; LOSS OF  
 ACFT CONTROL; OTHER;  
 ANOMALY DETECTOR : COCKPIT/FLC;  
 ANOMALY RESOLUTION : FLC EXECUTED GAR OR MAP;  
 ANOMALY CONSEQUENCES : NONE;  
 SITUATION REPORT SUBJECTS : OTHER; PROC OR POLICY/ATC FACILITY; PROC  
 OR POLICY/FAA;  
 NARRATIVE : WE HAD BEEN CLRED FOR AN ILS TO 27L IN  
 ATL. WE JOINED THE FINAL AT 3500 FT AND, AS THE GS STARTED TO  
 MOVE, WE GOT HIT BY WAKE TURB THAT BANKED THE ACFT ABOUT 45 DEGS  
 TO THE R. WE RECOVERED AND CONTINUED. WE ASKED APCH FOR THE TYPE  
 OF ACFT WE WERE FOLLOWING. HE STATED THAT WE WERE 3 1/2 MI  
 BEHIND AN LGT. WE INTERCEPTED THE GS AND GOT HIT AGAIN BY WAKE  
 TURB ALTHOUGH NOT AS BAD. WE HAD THE ARPT IN SIGHT AND DECIDED  
 TO STAY ABOVE THE GS TO AVOID THE WAKE. WE WERE ABOUT 1 1/2 DOTS  
 HIGH, ABOVE THE GS WHEN WE HIT EXTREME WAKE TURB, THE ACFT  
 VIOLENTLY ROLLED INTO A 90 DEG BANK TO THE R, PITCHED 10 TO 12  
 DEGS DOWN, AND THE IAS WENT TO ZERO IN LESS THAN 5 SECONDS. IT  
 TOOK BTWN 130-140 PERCENT TORQUE TO RECOVER AND START FLYING  
 AGAIN. WE INITIATED A GAR AND ADVISED THE TWR. WE RETURNED FOR A  
 NORMAL LNDG. AFTER LNDG, WE LEARNED FROM ANOTHER COMPANY PLT  
 THAT, BEFORE WE SWITCHED TO THE TWR FREQ, THE LGT HAD RPTED TO  
 THE TWR THAT HE WAS FULL DEFLECTION ABOVE THE GS BECAUSE OF WAKE  
 TURB FROM A WDB. THE TWR CLRED THE LGT FOR A VISUAL APCH AFTER  
 THE LGT SAID HE SAW THE ARPT. THE LGT MADE A QUICK DSCNT AND  
 LANDED. BECAUSE OF THIS, OUR NORMAL PROC OF STAYING ABOVE THE GS  
 TO STAY OUT OF HARM'S WAY DID NOT WORK. THE TWR SHOULD HAVE TOLD  
 US THAT THE LGT WENT HIGH. I WOULD HAVE ABANDONED THE APCH. IN  
 ATL, WE FOLLOW MANY DIFFERENT TYPES OF LARGE ACFT AND THE LGT  
 HAS THE WORST WAKE TURB. I THINK THAT THE LGT SHOULD BE  
 CLASSIFIED AS A HEAVY SO WE COULD GET HVY SEPARATION. 3 MI  
 BEHIND AN LGT IS TOO CLOSE.  
 SYNOPSIS : AN LTT ACR HAD AN ENCOUNTER WITH SEVERE  
 WAKE TURB REQUIRING A GAR.  
 REFERENCE FACILITY ID : ATL  
 FACILITY STATE : GA  
 DISTANCE & BEARING FROM REF. : 5,,E  
 MSL ALTITUDE : 2500,3500

ACCESSION NUMBER : 49847  
DATE OF OCCURRENCE : 8601  
REPORTED BY : FLC  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC, FO;FLC,SO;TWR,LC  
FLIGHT CONDITIONS : VMC  
AIRCRAFT TYPE : LRG  
NARRATIVE : DURING TAXI OUT FOR TKOF ON 32R AT ORD  
WE HEARD THE TWR CLEAR AN ACFT FOR TKOF BEHIND A HEAVY JET. THE  
PLT OF THE ACFT CLRD FOR TKOF BEHIND THE HEAVY JET ASKED FOR  
ADDITIONAL TIME AS HE "DID NOT WANT TO TKOF SO CLOSE TO THE  
HEAVY JET." WE WERE ALSO IN LINE BEHIND A HEAVY JET AND CLRD  
INTO POSITION WHEN THE WDB WAS CLRD FOR TKOF. WE TIMED THE TKOF  
ROLL OF THE WDB AND AT 50 SECS AFTER BEGINNING OF THE WDB TKOF  
ROLL WE WERE CLRD FOR TKOF. THE REPORTED WIND WAS 290 DEG/6 KTS.  
WE ADVISED THE TWR THAT WE WANTED MORE SEPARATION BETWEEN US AND  
THE PRECEDING WDB. THE TWR ADVISED US WE HAD 5 MILES SEPARATION  
WITH THE WDB (WHICH WAS IMPOSSIBLE. THE WDB WAS JUST AIRBORNE  
AND THE RWY 32R IS 10,003' IN LENGTH. THE TWR THEN PROCEEDED TO  
TELL US THE NEXT TIME WE WANTED MORE SEPARATION BEHIND A HEAVY  
WE SHOULD ADVISE THEM BEFORE TAXIING INTO POSITION AND THEY  
WOULD SEQUENCE US ACCORDINGLY. THE TWR THEN ADVISED US TO TAXI  
DOWN THE RWY AND EXIT THE RWY AT THE 9L/27R PARALLEL. BY THE  
TIME THE TWR WAS THRU WITH THEIR ADVICE AND INSTRUCTIONS ENOUGH  
TIME HAD PASSED (APPROX 1 MIN 50 SECS) SO THAT WE FELT  
COMFORTABLE IN TKOF AND ADVISED THE TWR THAT WE WERE READY FOR  
TKOF. THE TWR THEN CLRD US FOR TKOF. AS WE STARTED THE TKOF ROLL  
THE TWR CANCELLED THE TKOF CLRNC DUE TO AN ACFT LNDG ON 27R.  
THIS WAS NO PROBLEM FOR US AS WE WERE JUST COMMENCING THE ROLL.  
AFTER THE ACFT LANDED ON 27R WE WERE RECLRD FOR TKOF BY THE TWR  
ALONG WITH THE ADVICE THAT IN THE FUTURE IF WE NEED MORE  
SEPARATION THAN THEY ALLOWED US IN THIS CASE WE SHOULD ADVISE  
THEM AND THEY WOULD SEQUENCE US ACCORDINGLY. AS WE ROLLED DOWN  
THE RWY WE HEARD OVER THE RADIO SOMEONE COMMENT TO THE TWR THAT  
"IT IS PRESSURING LIKE THAT THAT CAUSES ACCIDENTS". I GUESS THE  
TWR OPERATOR WAS TRYING TO DO HER JOB OF MOVING TFC, HOWEVER, IN  
NO WAY DID WE HAVE THE SEPARATION AS OUTLINED IN OUR FOM. EVERY  
SITUATION IS DIFFERENT AND BRINGS INTO PLAY THE JUDGEMENT FACTOR  
AND PAST EXPERIENCE AND IN THIS CASE (WIND 290/6, 50 SECS AFTER  
BEGINNING OF TKOF ROLL OF WDB WE WERE CLRD FOR TKOF, 2 MILES  
SEPARATION--NOT FIVE MILES SEPARATION) WE FELT IT WAS MORE  
PRUDENT TO DELAY TKOF UNTIL WE HAD ADDITIONAL SEPARATION. WE  
FELT THE TWR WAS APPLYING UNDUE PRESSURE AND DID NOT PROVIDE  
PROPER SEPARATION.

SYNOPSIS : ALLEGED IMPROPER WAKE TURB SEPARATION  
CRITERION FOR TKOF.  
CALLBACK/COMMENTS : NONE  
LOC ID (LOCATION IDENTIFIER) : ORD;ORD

ACCESSION NUMBER : 58754  
 DATE OF OCCURRENCE : 8610  
 REPORTED BY : FLC; ; ; ;  
 PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PIC.CAPT;  
 TRACON,AC; TWR,LC;  
 FLIGHT CONDITIONS : MXD  
 REFERENCE FACILITY ID : ORD  
 FACILITY STATE : IL  
 FACILITY TYPE : TRACON; TWR; ARPT;  
 FACILITY IDENTIFIER : ORD; ORD; ORD;  
 AIRCRAFT TYPE : MLG; LRG;  
 ANOMALY DESCRIPTIONS : CONFLICT/AIRBORNE LESS SEVERE; LESS THAN  
 LEGAL SEPARATION; SPEED DEVIATION; NON ADHERENCE LEGAL RQMT/  
 CLNC;  
 ANOMALY DETECTOR : ATC/CTLR;  
 ANOMALY RESOLUTION : CTLR INTERVENED; CTLR ISSUED NEW CLNC;  
 ANOMALY CONSEQUENCES : FLC/ATC REVIEW;  
 SITUATION REPORT SUBJECTS : PROC OR POLICY/ATC FACILITY; PROC OR  
 POLICY/FAA;  
 NARRATIVE : THE SUPVR SAID "NO FURTHER ACTION WOULD  
 BE TAKEN UNLESS SOMETHING ELSE WOULD COME UP". THESE HIGH ALT,  
 250 KT LOCALIZER INTERCEPTS AT LESS THAN 15 DMF FROM THE FIELD,  
 WITH ONLY 5 DME ACFT SEPARATION, ARE NOT SAFE! THERE JUST IS NOT  
 ENOUGH CUSHION FOR ACFT SLOWING CAPABILITIES, CREW REACTIONS AND  
 DUTIES, WEATHER, AND OVERLOADED COMMUNICATIONS. AT ORD THERE IS  
 LITTLE 2 WAY COMMUNICATIONS AS WE ARE GUILTY OF BEING  
 INTIMIDATED BY APCH CONTROL INTO JUST LISTENING. THIS LETS THEM  
 TALK CONTINUOUSLY AND CROWD MORE PLANES IN BY NOT TAKING THE  
 TIME FOR QUESTIONS OR REPORTS FROM PLTS. THEY NORMALLY DO A  
 GREAT JOB UNDER THE CIRCUMSTANCES, BUT LATELY THIS "JAMMING"  
 TREND HAS STARTED AGAIN! ON FINAL APCH CONTROL, 90 DEG ABEAM  
 FIELD, 7000', 250 KTS, 15 DME OUT, SOLID UNDERCAST, F/O FLYING,  
 BEHIND HEAVY PLANE, FOR ILS 9R AT ORD. HEAVY TURNED IN, APPEARED  
 TO BE SLOWING, WERE CONCERNED WITH CLOSURE RATE (5 DME  
 SEPARATION), AND HE DESCENDED INTO CLOUDS. F/O STARTED SLOWING  
 AND I AGREED BEING VERY CONCERNED WITH CLOSURE RATE, WAKE  
 TURBULENCE, AND CTLR OVERLOAD. NON STOP TALKING BY CTLR  
 PREVENTED ME INFORMING HIM OF OUR SLOWING. HE THEN ASKED OUR  
 SPEED, 210 KTS REPORTED, AND HE YELLED FOR US TO PICK BACK UP TO  
 250 KTS AND WE DID. HEARD PLANE BEHIND US SLOW TO 180 KTS AND A  
 RIGHT TURN. CTLR STARTED TURNING US IN, SLOW TO 180 KTS, NEXT  
 BREATH THEN SLOW TO 160 KTS, AND WE OVERSHOT THE LOCALIZER. AT  
 LOM CALLED TWR, INFORMED #2 FOR 9R, BROKE OUT OF CLOUDS, SAW  
 HEAVY LANDING CONFIRMING MY LESS THAN 5 DME SEPARATION. TWR  
 INFORMED THAT A LIGHT TWIN WAS 3 DME AHEAD OF US BETWEEN US AND  
 THE HEAVY! RAPID FLAP DEPLOY NARROWLY PREVENTED US GOING AROUND  
 BECAUSE OF LIGHT PLANE CLEAR 9R. GROUND CONTROL GAVE US A PHONE  
 NUMBER TO CALL. APCH CONTROL SUPVR CHEWED ME OUT FOR NOT TELLING  
 THEM OF OUR SLOWING AND CLAIMED THE LGT B BEHIND US CAME WITHIN  
 1 DME OF US. I TOLD HIM WE COULDN'T GET A WORD IN AND MY CONCERN  
 FOR OUR CLOSURE ON THE HEAVY. THE LGT B CAPT CAME IN AND ALSO  
 TALKED TO THE SUPVR AND TOLD HIM THERE WAS NO PROBLEM AS HE WAS  
 VISUALLY WHAT WAS HAPPENING TO US. THIS CAPT TOLD ME APCH WAS  
 DIVING HIM IN BEHIND US AT LESS THAN 5 DME, WHICH HAD HAPPENED  
 TO ME THERE OFTEN.  
 SYNOPSIS : MLG FLT CREW CONCERNED OVER SPACING AND  
 WAKE TURBULENCE SEPARATION BEHIND A HEAVY ACFT SLOWED FROM

ACCESSION NUMBER : 119921  
DATE OF OCCURRENCE : 8908  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT; FLC,PIC.CAPT; TWR,  
LC;  
FLIGHT CONDITIONS : IMC  
REFERENCE FACILITY ID : CVG  
FACILITY STATE : OH  
FACILITY TYPE : TWR;  
FACILITY IDENTIFIER : CVG;  
AIRCRAFT TYPE : MLG; MLG;  
ANOMALY DESCRIPTIONS : ALT DEV/EXCURSION FROM ASSIGNED; LOSS OF  
ACFT CONTROL; OTHER;  
ANOMALY DETECTOR : ATC/CTLR; COCKPIT/FLC;  
ANOMALY RESOLUTION : PLC REGAINED ACFT CONTROL;  
ANOMALY CONSEQUENCES : NONE;  
SITUATION REPORT SUBJECTS : AN ACFT TYPE; PROC OR POLICY/FAA;  
NARRATIVE : AT 250' AGL ON THE CAT II ILS RWY 36  
APCH TO CVG, WE ENCOUNTERED MOD WAKE TURBULENCE FROM A WDB THAT  
HAD LANDED IN FRONT OF US. ALTHOUGH WE HAD LEGAL IFR SEPARATION,  
A LARGE POWER INCREASE AND SIGNIFICANT CONTROL WHEEL INPUT WAS  
REQUIRED TO MAINTAIN A STABILIZED FLT PATH. IF THE RWY  
ENVIRONMENT HAD NOT BEEN IN SIGHT, A GO AROUND WOULD HAVE BEEN  
REQUIRED. THE TWR CTLR HAD WARNED US OF POSSIBLE WAKE TURBULENCE  
AT 1 NM ON THE APCH. THIS WARNING ALSO CONTRIBUTED TO A SAFE  
LNDG RATHER THAN A MISSED APCH. RECOMMEND INCREASING REQUIRED  
IFR SEPARATION BEHIND WDB ACFT TO 5 NM VICE THE PRESENT 3 NM TO  
PRECLUDE RECURRENCE OF THIS WAKE TURBULENCE HAZARD.  
SYNOPSIS : MLG FOLLOWING A NEWER MLG TYPE  
ENCOUNTERED WAKE TURBULENCE.  
REFERENCE FACILITY ID : CVG  
FACILITY STATE : OH  
DISTANCE & BEARING FROM REF. : 1,180  
AGL ALTITUDE : 250,250

ACCESSION NUMBER : 188899  
DATE OF OCCURRENCE : 9109  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; TWR,LC;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : ORD  
FACILITY STATE : IL  
FACILITY TYPE : ARPT; TWR;  
FACILITY IDENTIFIER : ORD; ORD;  
AIRCRAFT TYPE : MLG; LRG;  
ANOMALY DESCRIPTIONS : CONFLICT/AIRBORNE LESS SEVERE; IN-FLT  
ENCOUNTER/OTHER; LOSS OF ACFT CONTROL; OTHER;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : FLC AVOIDANCE-EVASIVE ACTION; FLC  
EXECUTED GAR OR MAP;  
ANOMALY CONSEQUENCES : NONE;  
NARRATIVE : AS CAPT AND PF I WAS VECTORED FOR  
PARALLEL VISUAL ORD USING 14L AND 14R. WAS CLRED FOR VISUAL. I  
WAS FLYING GS DOWN. EXPERIENCED MORE WAKE TURB FROM PRECEDING  
ACFT THAN WAS USUAL. TCASII SHOWED ABOUT 3.5 MI BEHIND. I  
ELECTED TO FLY ABOUT 1 DOT HIGH AND STAY OUT OF HIS WAKE AND TO  
LAND PAST HIS TOUCHDOWN POINT. AIR WAS FAIRLY SMOOTH AT 1 DOT  
HIGH. SAW MY INNER MARKER LIGHT FLASH AND THEN EXTINGUISH, WAS  
NOW 1/2 DOT HIGH. AT APPROX 50 FT AGL ACFT ROLLED RAPIDLY R THEN  
VIOLENTLY L. COUNTERED WITH FULL R AILERON. ACFT CONTINUED L  
ROLL. WENT TO MAX PWR THEN FIREWALL PWR. WE ACCELERATED THROUGH  
WAKE ZONE. ON GAR TWR ADVISED OF CONFLICTING TFC THAT HAD  
DEPARTED 22L. WE HAD A VISUAL ON HIM AND TCASII NEVER ISSUED ANY  
ADVISORY. I DID NOT CONSIDER HIM A THREAT AT HE WAS IN EXCESS OF  
3 MI. NEVER IN 27 YRS HAVE I EXPERIENCED SUCH WAKE TURB. ACFT WE  
WERE FOLLOWING WAS LGT. WE ARE MLG. FOR A PERIOD OF A COUPLE  
SECONDS MY ACFT WAS OUT OF CTL DUE TO THE SEVERITY OF WAKE. NO  
RECOMMENDATIONS AS I SAID 3.5 IN TRAIL. WIND WAS 170 DEG/7.  
SYNOPSIS : FLC OF MLG FOLLOWING AN LGT ON APCH FOR  
LNDG 3 PT 5 MI IN TRAIL, FLEW HIGH AS AWARE OF POSSIBLE WAKE  
TURB. 50 FT AGL ENCOUNTERED STRONG WAKE TURB. ACFT MOMENTARILY  
OUT OF CTL, FULL THRUST, FULL AILERON RECOVERY, GAR.  
REFERENCE FACILITY ID : ORD  
FACILITY STATE : IL  
AGL ALTITUDE : 0,50

ACCESSION NUMBER : 195104  
DATE OF OCCURRENCE : 9111  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PIC.CAPT;  
TRACON,AC;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : ORD  
FACILITY STATE : IL  
FACILITY TYPE : TRACON; ARPT;  
FACILITY IDENTIFIER : ORD; ORD;  
AIRCRAFT TYPE : MDT; LRG;  
ANOMALY DESCRIPTIONS : OTHER;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : FLC REGAINED ACFT CONTROL;  
ANOMALY CONSEQUENCES : NONE;  
NARRATIVE : AFTER DEERE INTXN CLRED ORD VOR AT 7000  
ENCOUNTERED WAKE FROM PRECEDING LGT AT SAME ALT APPROX VISUALLY  
APPEARED TO BE THE REQUIRED 3 MI SEPARATION BY ATC. ACFT STARTED  
ROLL TO THE L AND STARTED BUFFETING. AUTOPLT, YAW DAMPER AND ADU  
FAILED, NEGATIVE G'S WERE FELT AND COCKPIT AND CABIN ITEMS WERE  
DISLODGED AND A VERY ROUGH SHAKING WAS EXPERIENCED. FLT  
ATTENDANT WAS HURT, MINOR INJURIES. ACFT WAS INSPECTED FOR  
DAMAGE. THE ONLY DAMAGE I'M AWARE OF WAS INSIDE THE ACFT FROM  
THE FLT ATTENDANT BEING TOSSED AROUND AND BENT CURTAIN ROD. THE  
CONDITIONS OF FLT WERE SMOOTH AIR AND THE LEGAL SEPARATION DOES  
NOT APPEAR TO BE ADEQUATE UNDER SOME ATMOSPHERIC CONDITIONS SUCH  
AS SMOOTH AIR. AT THIS POINT IN TIME I UNDERSTAND THIS IS  
CLASSIFIED AS AN INCIDENT AND THE NTSB IS INVESTIGATING IT.  
SYNOPSIS : MDT ENCOUNTERS WAKE TURB EVEN THOUGH  
PROPER 3 MI SPACING EXISTED.  
REFERENCE FACILITY ID : ORD  
FACILITY STATE : IL  
DISTANCE & BEARING FROM REF. : 15,,NE  
MSL ALTITUDE : 7000,7000

ACCESSION NUMBER : 227217  
DATE OF OCCURRENCE : 9211  
REPORTED BY : FLC; ; ;  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PIC.CAPT;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : ATL  
FACILITY STATE : GA  
FACILITY TYPE : TRACON; ARPT;  
FACILITY IDENTIFIER : ATL; ATL;  
AIRCRAFT TYPE : LTT; LRG;  
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; OTHER;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : NOT RESOLVED/ANOMALY ACCEPTED;  
ANOMALY CONSEQUENCES : NONE;  
NARRATIVE : UPON TURNING ONTO THE LOC FOR THE  
VISUAL APCH TO ATL'S RWY 27L, APCH CTL ADVISED THAT WE WERE 4 MI  
BEHIND OUR TFC, AN LGT Y. WE THEN HIT 6 STRONG JOLTS OF WAKE  
TURB, AFTER WHICH OUR RIDE RETURNED TO SMOOTH. NO ONE WAS HURT.  
WAKE TURB IS A PROBLEM. IT IS SO COMMON IN THE ATL ARR AREA THAT  
WE TEND TO IGNORE IT, ACCEPTING IT AS A REGULAR PART OF FLYING.  
I HIT IT ON AN AVERAGE OF ONCE EVERY 10 APCHS TO ATL, OR ONCE  
EVERY 2 TO 3 'FLT DAYS.' USUALLY, BEHIND AN MLG OR LGT Y, IT IS  
3 MEDIUM JOLTS IN WHICH NOTHING IN THE ACFT IS DISTURBED. BUT,  
BEHIND AN LGT Y, WAKE TURB IS ALWAYS STRONG -- MUCH STRONGER  
THAN OTHER 'NON HVY' ACFT. RECOMMENDATION: ASSIGN 'HVY' ACFT  
SEPARATION STANDARDS FOR LGT Y ACFT.  
SYNOPSIS : LTT EXPERIENCES WAKE TURB WHEN 4 MI  
BEHIND LGT ON APCH.  
REFERENCE FACILITY ID : ATL  
FACILITY STATE : GA  
DISTANCE & BEARING FROM REF. : 6,,E  
MSL ALTITUDE : 3500,3500

ACCESSION NUMBER : 235192  
DATE OF OCCURRENCE : 9303  
REPORTED BY : FLC; FLC; ; ;  
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT; FLC,PIC.CAPT; TWR,  
LC;  
FLIGHT CONDITIONS : VMC  
REFERENCE FACILITY ID : MCO  
FACILITY STATE : FL  
FACILITY TYPE : TWR; ARPT;  
FACILITY IDENTIFIER : MCO; MCO;  
AIRCRAFT TYPE : MLG; LRG;  
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER;  
ANOMALY DETECTOR : COCKPIT/FLC;  
ANOMALY RESOLUTION : FLC RETURNED ACFT TO ORIGINAL CLNC OR  
INTENDED COURSE; ACFT EXITED ADVERSE ENVIRONMENT;  
ANOMALY CONSEQUENCES : NONE;  
NARRATIVE : LNDG BEHIND AN LGT. ON FINAL APCH AT  
APPROX 200 FT AGL, WE EXPERIENCED WAKE TURB FROM THE LGT WHO WAS  
ABOUT 4 MI AHEAD. OUR ACFT EXPERIENCED A ROLL TO THE R OF ABOUT  
15 DEGS. IT WAS NOT AN ABRUPT OR TURBULENT ROLL, BUT A STEADY,  
SMOOTH ROLL. THE CAPT ADDED PWR AND ROLLED WINGS LEVEL AND OUR  
ACFT RECOVERED IMMEDIATELY. A GAR WAS NOT DEEMED NECESSARY DUE  
TO THE FACT THAT WE RECOVERED IMMEDIATELY AND WERE IN A SAFE POS  
TO LAND. THE REMAINDER OF THE LNDG AND ROLLOUT WAS UNEVENTFUL.  
UPON LNDG, WE ASKED TWR OUR SEPARATION ON THE LGT AND THEY  
CONFIRMED 4 MI. SUPPLEMENTAL INFO FROM ACN 235322: WHEN WE  
ENCOUNTERED THE WAKE TURB, I WAS SOMEWHAT SURPRISED, SINCE WE  
HAD SUCH GOOD SPACING BEHIND THE LGT. HOWEVER, ATIS WAS RPTING A  
WIND OF 340/4 KTS WHICH I'M SURE KEPT THE WAKE VORTEX RIGHT IN  
THE APCH PATH. BECAUSE OF OUR 'SLAM DUNK' APCH, WE WERE  
PREOCCUPIED WITH GETTING THE ACFT DOWN AND WERE DISTRACTED FROM  
THINKING ABOUT OR DISCUSSING THE POSSIBILITY OF WAKE TURB.  
SYNOPSIS : MLG ENCOUNTERS WAKE TURB WHEN LNDG  
BEHIND AN LGT.  
REFERENCE FACILITY ID : MCO  
FACILITY STATE : FL  
DISTANCE & BEARING FROM REF. : 1,,N  
AGL ALTITUDE : 200,200

ACCESSION NUMBER : 238067  
 DATE OF OCCURRENCE : 9304  
 REPORTED BY : FLC; ; ; ;  
 PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,~IC.CAPT; FLC,  
 PIC.CAPT; TWR,LC;  
 FLIGHT CONDITIONS : VMC  
 REFERENCE FACILITY ID : DFW  
 FACILITY STATE : TX  
 FACILITY TYPE : ARPT; TWR;  
 FACILITY IDENTIFIER : DFW; DFW;  
 AIRCRAFT TYPE : LTT; MLG; LRG;  
 ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; LOSS OF ACFT  
 CONTROL; OTHER;  
 ANOMALY DETECTOR : COCKPIT/FLC;  
 ANOMALY RESOLUTION : FLC EXECUTED GAR OR MAP; CTLR ISSUED NEW  
 CLNC; FLC BECAME REORIENTED;  
 ANOMALY CONSEQUENCES : NONE;  
 SITUATION REPORT SUBJECTS : PROC OR POLICY/FAA; OTHER;  
 NARRATIVE : APCHING DFW FROM THE NW FOLLOWING MLG  
 TFC WHEN CTLR SAW AN OPPORTUNITY TO ALLOW US TO LAND RWY 35R. WE  
 WERE 3000 FT MSL AT 210 KIAS ASSIGNED AIRSPD WHEN TOLD TO FOLLOW  
 LGT OVER LOM FOR RWY 35R. CROSSED BEHIND MLG ON FINAL FOR RWY  
 36L STILL AT 3000 FT AND INTERCEPTED LOC FOR RWY 35R. SWITCHED  
 TO TWR FREQ AND WERE TOLD WE HAD A 70 KT OVERTAKE ON LGT AND  
 BEGAN SLOWING. BEGAN DSCNT FROM 3000 FT NOTING WE WERE FULL  
 DEFLECTION ABOVE GS. I JUDGED THIS TO BE PERFECTLY ACCEPTABLE  
 KNOWING THE NASTY REPUTATION THE LGT HAS FOR GENERATING WAKE  
 TURB AND, IN FACT, FULLY INTENDED TO REMAIN HIGH ON FINAL. TWR  
 ADVISED 'CLRED TO LAND FOLLOWING TFC 2 1/2 AHEAD, CAUTION WAKE  
 TURB.' I THOUGHT WE WOULD BE SAFELY ABOVE HIS WAKE. SHORTLY  
 AFTER, MY ACFT (LTT) ROLLED TO THE R TO AN ANGLE OF APPROX 100  
 DEGS (MORE THAN 90 DEGS). FULL OPPOSITE CTL INPUT DID NOT HAVE  
 ANY AFFECT IN STOPPING THIS ROLL. IAS BEGAN DROPPING AND  
 THROTTLES WERE THEN FIREWALLED. AS WE ROLLED R, WE HAD ALSO  
 TURNED SLIGHTLY IN THAT DIRECTION AND I ASSUME WE FLEW OUT OF  
 THAT VORTEX AND WERE ABLE TO RIGHT THE ACFT. THEN WE HIT WHAT I  
 ASSUME WAS HIS R WING VORTEX AND THE ACFT (MINE) BEGAN TO ROLL  
 L. WE FLEW THROUGH THIS VORTEX FAIRLY QUICKLY, PROBABLY DUE TO  
 OUR NEW (UNCOMMANDED) HDG, AND OUR BANK DID NOT EXCEED 60 DEGS.  
 WE RECOVERED FROM THIS ROLL ON A HDG OF ABOUT 080 DEGS AND  
 DECLARED A MISSED APCH. TWR ASKED IF WE COULD ENTER A BASE FOR  
 RWY 31R AND LAND. WE DID, AND LANDED WITHOUT FURTHER INCIDENT.  
 THE LGT HAD OBVIOUSLY BEEN VERY HIGH ON HIS APCH FOR SOME  
 REASON, POSSIBLY AN EARLIER TCASII RESOLUTION. OUR ATTN HAD  
 BEEN FOCUSED ON THE MLG WE WERE ORIGINALLY FOLLOWING, THUS I WAS  
 UNAWARE OF THE LGT'S GLIDE PATH. I FEEL SOMEONE (CTLR) SHOULD  
 HAVE NOTICED THIS AND REALIZED A WAKE ENCOUNTER WAS INEVITABLE.  
 SECONDLY, I FEEL THE LGT SHOULD BE CLASSIFIED AS A 'HVY' JET AND  
 INCREASED SPACING SHOULD BE USED.  
 SYNOPSIS : AN LTT WAS NEARLY UPSET BY THE WAKE TURB  
 OF AN LGT IN THE NIGHT TFC PATTERN.  
 REFERENCE FACILITY ID : DFW  
 FACILITY STATE : TX  
 DISTANCE & BEARING FROM REF. : 4,,SO  
 MSL ALTITUDE : 3000,3000

ACCESSION NO. : 261809  
DATE OF OCCURRENCE : 9401  
REPORTED BY : FLC  
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; TWR,SUPVR;  
FLIGHT CONDITIONS : IMC  
REFERENCE FACILITY ID : DCA  
FACILITY STATE : DC  
FACILITY TYPE : TWR  
FACILITY IDENTIFIER : DCA  
AIRCRAFT TYPE : MDT, B757 OR A320  
ANOMALY DESCRIPTIONS : LOSS OF ACFT CONTROL  
ANOMALY DETECTOR : COCKPIT/FLC  
ANOMALY RESOLUTION : FLC REGAINED ACFT CONTROL  
ANOMALY CONSEQUENCES : NONE  
NARRATIVE : AFTER AN OTHERWISE NORMAL ILS APCH,  
WE[MDT] EXPERIENCED RATHER SEVERE WAKE TURB AT APPROX 100 FT  
AGL. FULL AILERON DEFLECTION WAS NECESSARY TO CORRECT FOR THE  
ROLL AND GAR MANEUVER, [WHICH] WAS IMMEDIATELY EXECUTED. THE  
PRECEDING ACFT (TYPE UNKNOWN) WAS WELL CLR OF THE RWY AND THE  
APCH SPACING SEEMED ADEQUATE, BASED UPON TCAS II INDICATIONS.  
THE WX AT THE TIME WAS 400 FT CEILING, 2 MI VISIBILITY AND CALM  
WINDS. I SUBSEQUENTLY BECAME AWARE OF OTHER RPTS, AND EVEN  
ACCIDENTS, CAUSED BY B757 TYPE ACFT. PERHAPS THIS OCCURRENCE  
SHOULD BE ADDED TO THE LIST. (AFTER SPEAKING WITH THE DCA TWR  
SUPVR LATER THAT EVENING, HE SAID THAT THERE WAS NO WAY TO  
DETERMINE THE TYPE OF ACFT THAT WE FOLLOWED FROM AN OP EARLIER  
THAT DAY. HOWEVER, I DO RECALL SEEING A HVY TYPE ACFT (I.E.,  
B757, A320, ETC.) ON DOWNWIND PRIOR TO STARTING THE APCH.)

[MDT CLASSIFICATION - 2-ENGINE, TURBOJET, 43K WEIGHT CLASSIFICATION]  
HandwrittenAnnotation

# Appendix I

## Risk Analysis of Airplane Pairs

A simplified approach for determining the relative risk of wake vortex upset for various airplane pairs is presented. It is assumed that the airplanes in each pair are separated by the same distance. A risk factor is calculated by dividing the circulation of the leading airplane by the weight of the trailing airplane. The calculated risk factors are then compared.

$$R_F = \frac{\Gamma_F \text{ leader}}{W \text{ follower}}$$

$$\Gamma_F = \frac{W}{Vb}$$

$R_F$  = risk factor  
 $\Gamma_F$  = circulation factor  
 $W$  = landing weight (lbs)  
 $V$  = velocity (knots)  
 $b$  = wing span (ft)

Airplane	W	b	V	$\Gamma_F$	$R_F \times 1000$
747	564,000	196	140	20.55	0.104 <sup>1</sup>
757	198,000	125	140	11.31	0.838
Citation	13,500				

The risk of a wake vortex upset for Citation 3 nm behind a B-757 is 8.05 (0.838/0.104) times greater than the risk for a B-757 that is 3 nm behind a B-747.

<sup>1</sup>  $R_F \times 1000 = (20.55/198,000) \times 1,000 = 0.104$ .

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