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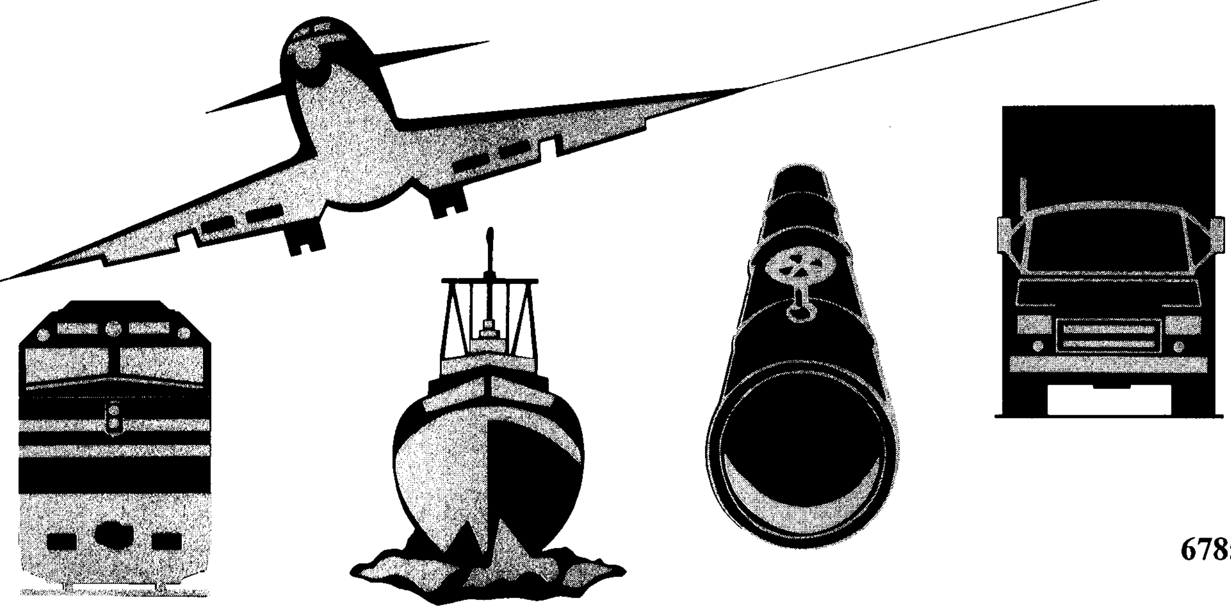
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

DESCENT BELOW VISUAL GLIDEPATH AND COLLISION WITH TERRAIN DELTA AIR LINES FLIGHT 554 MCDONNELL DOUGLAS MD-88, N914DL LAGUARDIA AIRPORT, NEW YORK OCTOBER 19, 1996



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Adopted: August 25, 1997
Notation 6785B

Abstract: This report explains the descent below visual glidepath and collision with terrain of Delta Air Lines flight 554 at LaGuardia Airport on October 19, 1996. The safety issues in this report focused on the possible hazards of monovision contact lenses, visual illusions encountered during the approach, non-instantaneous vertical speed information, the weather conditions encountered during the approach, the guidance in air carrier's manuals regarding flightcrew member duties, the stabilized approach criteria in air carrier's manuals, emergency evacuation procedures, special airport criteria and designation, and LaGuardia Airport issues/runway light spacing. Safety recommendations concerning these issues were addressed to the Federal Aviation Administration and to optometric associations.

EXECUTIVE SUMMARY

About 1638 eastern daylight time, on October 19, 1996, a McDonnell Douglas MD-88, N914DL, operated by Delta Air Lines, Inc., as flight 554, struck the approach light structure and the end of the runway deck during the approach to land on runway 13 at the LaGuardia Airport, in Flushing, New York. Flight 554 was being operated under the provisions of 14 CFR Part 121, as a scheduled, domestic passenger flight from Atlanta, Georgia, to Flushing. The flight departed the William B. Hartsfield International Airport at Atlanta, Georgia, about 1441, with two flightcrew members, three flight attendants, and 58 passengers on board. Three passengers reported minor injuries; no injuries were reported by the remaining 60 occupants. The airplane sustained substantial damage to the lower fuselage, wings (including slats and flaps), main landing gear, and both engines. Instrument meteorological conditions prevailed for the approach to runway 13; flight 554 was operating on an instrument flight rules flight plan.

The National Transportation Safety Board determines that the probable cause of this accident was the inability of the captain, because of his use of monovision contact lenses, to overcome his misperception of the airplane's position relative to the runway during the visual portion of the approach. This misperception occurred because of visual illusions produced by the approach over water in limited light conditions, the absence of visible ground features, the rain and fog, and the irregular spacing of the runway lights.

Contributing to the accident was the lack of instantaneous vertical speed information available to the pilot not flying, and the incomplete guidance available to optometrists, aviation medical examiners, and pilots regarding the prescription of unapproved monovision contact lenses for use by pilots.

The safety issues in this report focused on the possible hazards of monovision contact lenses, visual illusions encountered during the approach, non-instantaneous vertical speed information, the weather conditions encountered during the approach, the guidance in air carrier's manuals regarding flightcrew member duties, the stabilized approach criteria in air carrier's manuals, emergency evacuation procedures, special airport criteria and designation, and LaGuardia Airport issues/runway light spacing.

Safety recommendations concerning these issues were addressed to the Federal Aviation Administration and to optometric associations.

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1. FACTUAL INFORMATION

1.1 History of Flight

About 1638 eastern daylight time,[1] on October 19, 1996, a McDonnell Douglas MD-88, N914DL, operated by Delta Air Lines, Inc., as flight 554, struck the approach light structure and the end of the runway deck during the approach to land on runway 13 at the LaGuardia Airport (LGA), in Flushing, New York. Flight 554 was being operated under the provisions of Title 14 Code of Federal Regulations (CFR) Part 121, as a scheduled, domestic passenger flight from Atlanta, Georgia, to Flushing. The flight departed the William B. Hartsfield International Airport at Atlanta, Georgia, about 1441, with two flightcrew members, three flight attendants, and 58 passengers on board. Three passengers reported minor injuries; no injuries were reported by the remaining 60 occupants. The airplane sustained substantial damage to the lower fuselage, wings (including slats and flaps), main landing gear, and both engines. Instrument meteorological conditions (IMC) prevailed for the approach to runway 13; flight 554 was operating on an instrument flight rules (IFR) flight plan.

The accident occurred on the first leg of a scheduled three-leg trip for the MD-88 flightcrew. The pilots reported for duty at 1330 for the scheduled 1430 departure from Atlanta. According to the pilots, they received a thorough preflight weather briefing[2] as they prepared to depart. The weather briefing indicated that there was frontal activity in the New York area; the pilots stated in postaccident interviews that they believed the weather conditions could result in a bumpy flight or otherwise make for a more difficult approach at LaGuardia.

According to Delta dispatch records, the flight departed the gate at 1431 and took off about 1441, with the captain performing the pilot flying (PF) duties during the trip to LaGuardia. The pilots stated that the departure, climbout, and en route portions of the flight

[1] Unless otherwise indicated, all times are eastern daylight time, based on a 24-hour clock.

[2] For additional information concerning the weather information obtained by the flightcrew, see section 1.7.1, "Weather Information Provided to the Flightcrew by Delta."

proceeded uneventfully, although they experienced turbulence at their cruising altitude of flight level (FL) 370.[3]

The pilots stated that as they approached LaGuardia, they observed large areas of precipitation on the airplane's weather radar and encountered light-to-moderate turbulence and strong winds during the arrival to the New York area. According to flight and cabin crewmember statements, the captain had previously briefed the flight attendant in charge (FAIC) that their descent in the New York area might be bumpy. The flight attendants indicated that at the captain's suggestion, they prepared the cabin for landing and were seated in their jumpseats earlier than usual during the descent to land.

As the airplane approached LaGuardia, the pilots received radar vectors for the instrument landing system with distance measuring equipment (ILS DME) approach to runway 13.[4] At 1611:57, the cockpit voice recorder (CVR)[5] recorded the captain commenting about the 3° offset of the localizer course[6] as he began to brief the details of the ILS DME runway 13 approach. At 1612:39, New York air route traffic control center advised the pilots to contact New York terminal radar approach control (TRACON); the first officer acknowledged and complied with the instruction. At 1613:30, the captain finished the approach briefing, stating in part, "glide slope's unusable below two hundred feet...final approach course crosses runway centerline and twenty-seven hundred and fifty-four feet from threshold... ."

The first officer initiated the descent checklist at 1616:39, during which the pilots discussed the wind and rain conditions reported at LaGuardia with regard to their approach airspeeds. They determined that 131 knots would be their target airspeed for final approach to LaGuardia and completed the descent checklist. At 1617:32, the captain called for the approach checklist. At 1632:11, the captain asked the first officer if the approach checklist was completed, to which the first officer replied, "we're both identified ... approach check's complete."

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[3] 37,000 feet mean sea level (msl), based on an altimeter setting of 29.92 inches of mercury (Hg).

[4] For additional information concerning the ILS approach to runway 13 at LaGuardia, see section 1.10.1, "Runway 13 Information."

[5] See appendix B for a transcript of the CVR.

[6] According to the instrument approach chart used by the pilots of Delta flight 554 during their approach to runway 13, the localizer heading (132°) is offset 3° from the runway heading (135°); however, according to Federal Aviation Administration (FAA) personnel, the actual offset is 1.8°. Additionally, the instrument approach chart contains the remark, "Final approach course crosses runway centerline extended 2745 [feet] from [the runway] threshold." The ILS DME runway 13 approach contains a waiver for runway threshold crossing height. The FAA's requirement for electronic glideslope height at the point where it crosses the runway threshold is 45 feet; the threshold crossing height of the ILS DME runway 13 glideslope was 44.1 feet. According to FAA personnel, a new localizer for runway 13 should be commissioned by October 1997. The new localizer will not require the 3° offset.

At 1633:28, the captain stated, "Still showing sixty-three knots [of wind] now." At 1633:33, New York TRACON stated, "Delta five fifty-four, turn left heading one three zero...you're three miles from LYMPS,[7]...maintain three thousand until LYMPS...cleared ILS DME runway one three approach," and the first officer acknowledged the clearance. At 1633:55, the first officer stated, "Yeah, I guess the wind's gonna blow us over [to the localizer course]," and (at 1633:58) the captain responded, "I think you're right." (See figure 1 for a copy of the instrument approach chart used by the pilots of Delta flight 554.)

According to the CVR and pilot statements, about 1635, the flightcrew intercepted the localizer and glideslope and received air traffic control (ATC) instructions to contact LaGuardia tower. At 1635:23, the LaGuardia air traffic control tower (ATCT) transmitted, "Delta five five four, you're number two, traffic to follow...two mile final, the wind now one zero zero at one two...one departure prior to your arrival...braking action reported good by [a 737]...low level wind shear reported on final by [a 737]... ."[8] Within the next 25 seconds, the CVR recorded the captain calling for landing gear extension and the before-landing checklist. At 1636:18, as the flightcrew accomplished the before-landing checklist, LaGuardia ATCT advised, "Runway one three RVR [runway visual range] touchdown three thousand...rollout two thousand two hundred," and the captain commented, "must be raining hard at the airport." At 1636:25, the first officer announced, "Before landing check is complete...not cleared to land yet."

According to the pilots' statements, as they began their descent from 3,000 feet on the ILS DME approach to runway 13, the airplane was in the clouds, in what the pilots described as light-to-moderate precipitation. The pilots indicated that although strong, gusty surface winds and turbulence had been forecast for their arrival in the New York area, as they descended on the approach to the runway, LaGuardia ATCT reported steady surface winds out of the east at less than 15 knots, and the pilots reported that the turbulence lessened.

At 1636:46, the first officer called out "...a thousand feet above minimums,"[9] in accordance with Delta's procedural guidance.[10] As the airplane continued to descend in the clouds, the captain commented that the ceiling was lower than the 1,300 feet reported in the automatic terminal information service (ATIS) recording.[11]

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[7] LYMPS is the initial radar fix for the ILS DME approach to runway 13 at LaGuardia and is located 8.5 miles from the approach end of runway 13.

[8] According to ATC records, the most recent low level windshear report was reported by a Boeing 737 (at 1543:05), about 55 minutes before the accident occurred.

[9] The decision height (DH) ("minimums") for the ILS DME approach to runway 13 at LGA is 250 feet above ground level (agl) (263 msl).

[10] For additional information concerning procedural guidance contained in Delta's flight manuals, see section 1.17.1.

[11] LaGuardia ATIS information "Delta" was obtained by the pilots before they contacted New York TRACON (at 1612:52). For additional information on the weather, see section 1.7.

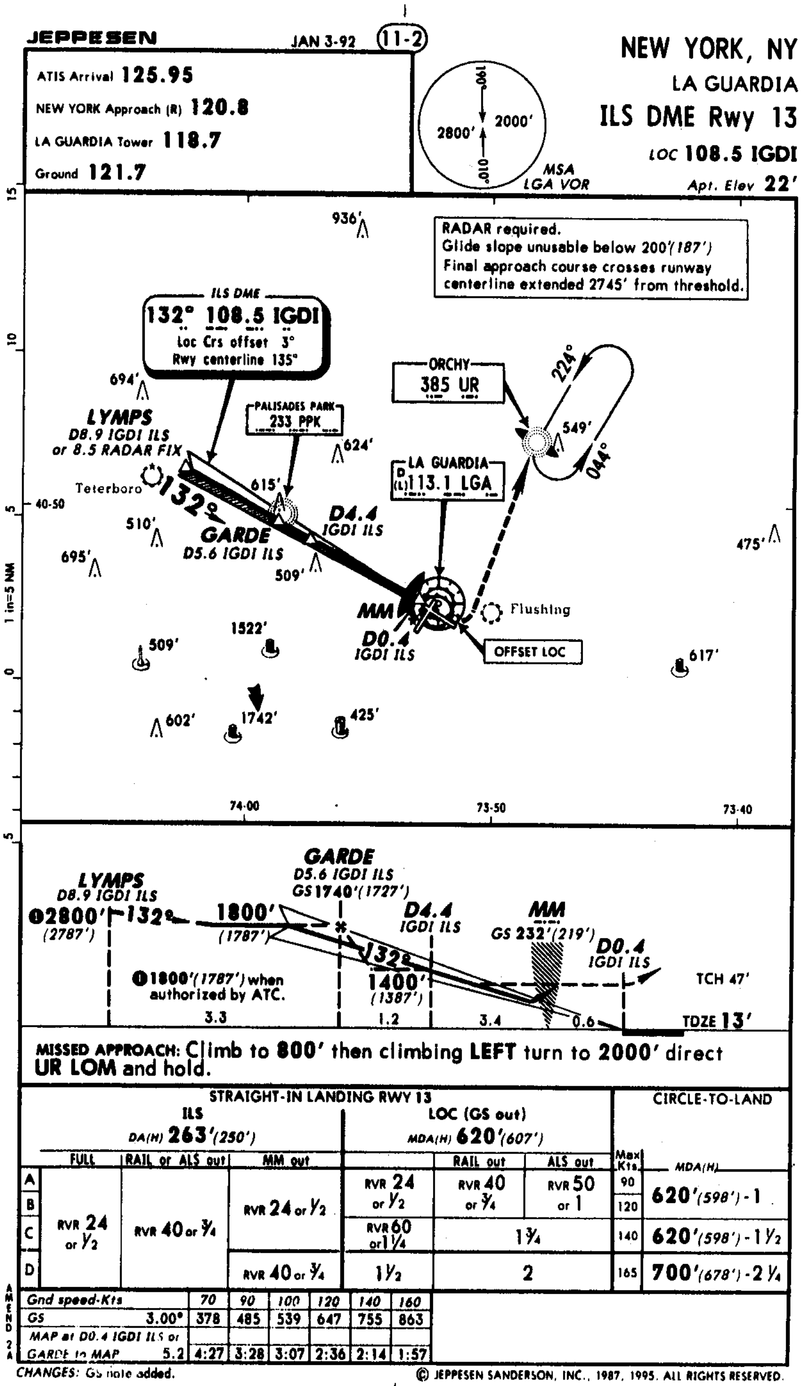

Figure 1—Instrument approach chart
(reproduced with the permission of Jeppeson Sanderson, Inc.)

At 1637:08, LaGuardia ATCT instructed a TWA airplane at LaGuardia, "TWA eighty-six thirty, wind one zero zero at one two, runway one three cleared for takeoff, traffic [on] three mile final runway one three."[12] The pilots of TWA 8630 acknowledged the takeoff clearance and advised that they were "rolling," and at 1637:22, LaGuardia ATCT cleared Delta flight 554 to land. Two seconds after he acknowledged the landing clearance, the first officer advised the captain that he was "starting to pick up some ground contact."[13]

At 1637:29, the pilots of TWA 8630 indicated that they were rejecting the takeoff and needed to turn off the runway. LaGuardia ATCT responded, "TWA eighty-six thirty, make the first right turn, runway four two two...can you do that for me, sir?" then stated, "...if you could expedite, traffic on a two mile final...prevent him from going around."[14] According to CVR and pilot statement information, simultaneous with this transmission, the captain turned off the autopilot and advised the first officer "I've got the jet" (indicating that he was taking manual control of the airplane).

At 1637:41, one of the pilots of TWA 8630 stated, "TWA eighty-six thirty's turning off," and LaGuardia ATCT responded, "Thank you very much...say the reason for the abort, sir?" Five seconds later LaGuardia ATCT stated, "Just continue down the runway...make the first right turn on taxiway golf...when you get a chance let me know the reason for the abort."[15] At 1637:52, as the airplane descended through about 492 feet agl, flight 554's CVR recorded an expletive on the captain's channel, and the airplane's descent rate (calculated from FDR data) shallowed briefly. During postaccident interviews, the captain stated that at the time of the expletive comment he was concerned that they might have to perform a missed approach because the TWA flight had aborted its takeoff, and he believed that it had not yet cleared the runway.

At 1637:57, the CVR recorded the first officer's callout—"two hundred above [minimums]." Four seconds later the first officer advised the captain, "speed's good, sink [rate]'s good." At 1638:07, the captain stated, "no contact yet." According to the CVR, at

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[12] According to FAA Order 7110.65, "Air Traffic Control," controllers should, "Separate a departing aircraft from an arriving aircraft on final approach by a minimum of 2 miles...this procedure permits a departing aircraft to be released so long as an arriving aircraft is no closer than 2 miles from the runway...at the time the departing aircraft commences [its] takeoff roll." According to FDR data, Delta flight 554 was located 3.28 miles from the threshold of runway 13 at 1637:08.

[13] FDR data indicated that at this time the airplane was about 600 feet above minimums, or 850 feet agl.

[14] According to FAA Order 7110.65, "Air Traffic Control," controllers should, "separate an arriving aircraft from another aircraft using the same runway by ensuring that the arriving aircraft does not cross the landing threshold until...the other aircraft...is clear of the runway."

[15] Postaccident interviews with ATC and the pilots of TWA 8630 indicated that at this time, TWA 8630 had turned off of runway 13 at runway 22 and was taxiing to the southwest on runway 22 towards taxiway Golf.

1638:10, the first officer called out "one hundred above [minimums]," and at 1638:11, the captain stated, "I got the (REIL [runway end identifier lights])...approach lights in sight."

At 1638:13, the first officer advised the captain, "You're getting a little bit high...a little bit above [the] glide slope...approach lights, we're left of course." The FDR data indicated that at 1638:13, the airplane was 1.39 dots high on the electronic glideslope and 0.39 dots left of the localizer, at 306 feet agl (319 msl). At 1638:18, LaGuardia ATCT stated, "You are cleared to land, Delta five fifty-four," and the first officer acknowledged the reissued landing clearance. According to FDR data, at that time the autothrottle was disconnected and the captain reduced power manually. At 1638:20.6, the CVR recorded the sound of the ground proximity warning system (GPWS) announcing "minimums," followed by, according to the CVR transcript, a "sound similar to that of windshield wipers increasing to full speed." About 1 second later, the captain restated that he had the approach lights in sight.

The captain began to reduce the engine power, and at 1638:25.6, the first officer stated, "speed's good" and then, about 1 second later, "sink's seven hundred."[16] At 1638:30.1, the captain stated, "I'll get over there," which he later explained referred to the airplane's alignment with the runway.[17] One second later, the first officer stated, "a little bit slow, a little slow." According to postaccident interviews, the captain stated that the approach seemed normal until about 4 to 5 seconds before the initial impact, when "all of a sudden, [the] aim point shifted down into the lights." About 1638:33, as the captain was adding power and pitching up, the first officer stated, "Nose up," and then at 1638:34.3, stated, "Nose up" again. At 1638:34.2 and 1638:35.7, the CVR recorded the sound of the GPWS "sink rate" warning,[18] followed by sounds of impact at 1638:36.5.

The airplane struck the approach light structure and the vertical edge of the concrete runway deck, and then skidded approximately 2,700 feet down runway 13 on its lower fuselage and nose landing gear before it came to a stop. (See figure 2 – an overhead photograph of LaGuardia Airport, with runway 13 approach lights, the point of initial impact, and the point where the airplane came to rest on runway 13 depicted.) The nose landing gear came to a stop on the pavement, with the fuselage oriented on a 345° heading; the left wing extended towards the runway centerline, and the right wing extended over the wet, grassy area next to the runway. According to flight and cabin crewmember statements, after the airplane came to a stop, the pilots began to assess the damage to the airplane and determine whether an emergency evacuation was warranted, while the flight attendants picked up their interphone handsets and awaited instructions. About 74 seconds after the airplane came to a stop (about 94 seconds after

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[16] For additional vertical speed information, see sections 1.6.2, 1.11.2, 2.2, and 2.5.

[17] The captain indicated that after he saw the approach lights, he made a right correction to align the airplane with the runway; then the airplane drifted to the right, so he made a correction to the left. The captain reported that he recalled a drift correction of about 10° during the final approach.

[18] The warnings annunciated in accordance with the manufacturer's specifications.

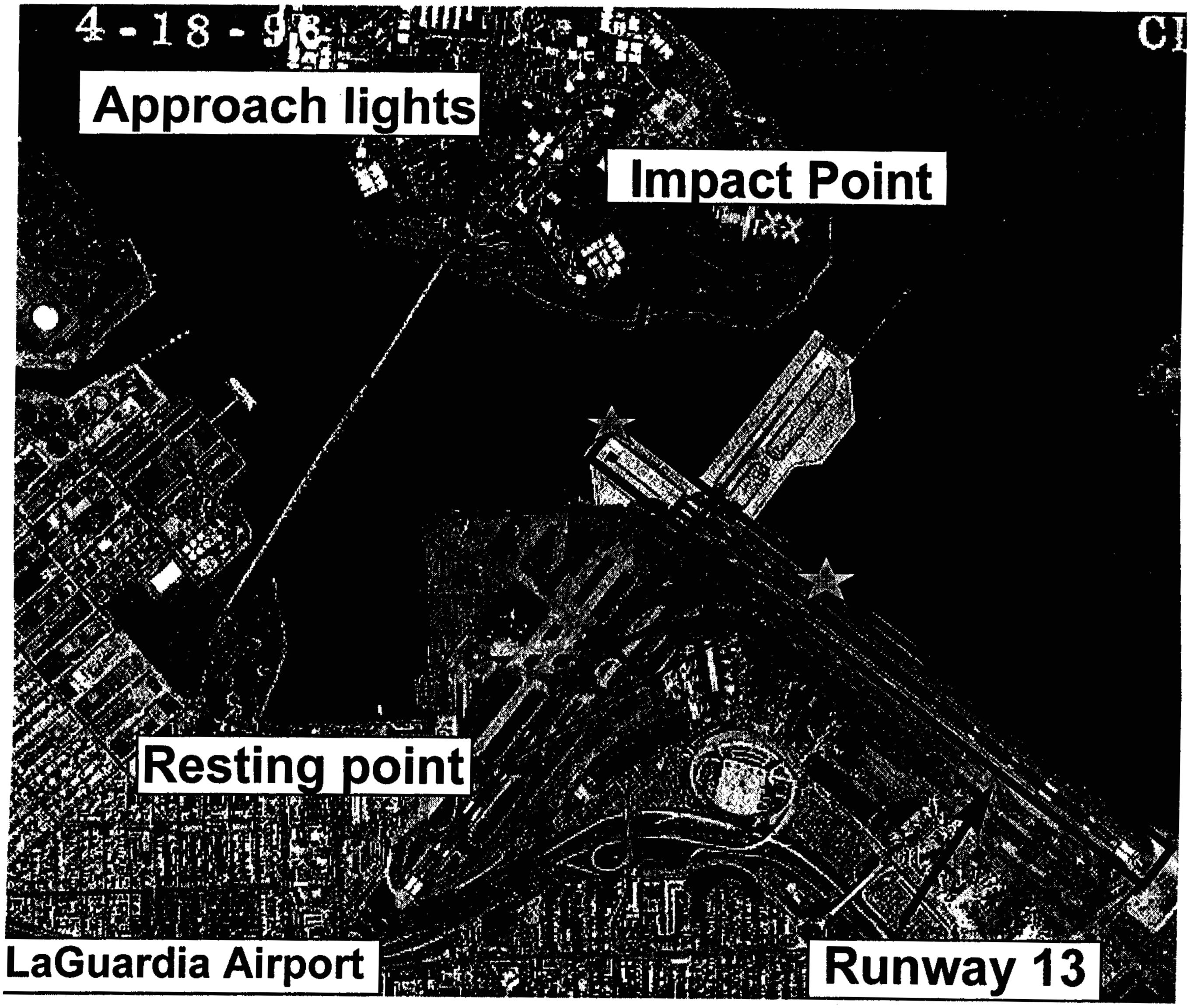

Figure 2—LaGuardia Airport, with runway 13 approach lights, the point of initial impact, and the point where the airplane came to rest on runway 13 depicted

impact), the captain issued the emergency evacuation command[19] after a non-revenue Delta pilot and the FAIC reported that they smelled jet fuel fumes in the cabin. All aircraft occupants exited through the left front door (L-1) slide.[20]

The accident occurred during daytime hours, at approximately 40°, 46 minutes, 94 seconds North latitude, and 73°, 52 minutes, 73 seconds West longitude.

1.2 Injuries to Persons

Injuries	Flightcrew	Cabin Crew	Passengers	Other	Total
Fatal	0	0	0	0	0
Serious	0	0	0	0	0
Minor	0	0	3	0	3
None	2	3	55	0	60
Total	2	3	58	0	63

1.3 Damage to Airplane

The MD-88 received substantial damage to its lower fuselage, main landing gear, slats, flaps, and both engines. The estimated cost to repair the airplane was about $14 million.

1.4 Other Damage

The metal runway approach light structure and the wooden catwalk that accessed it were damaged when the airplane struck the approach light structure. The approach end of the runway deck and the runway/pier support stanchions were also damaged. The estimated cost to repair the damage to airport property was about $240,000.

1.5 Personnel Information

The flightcrew consisted of the captain and the first officer. The captain and the first officer had been paired together as a crew on one previous occasion, in January 1996. Three flight attendants were aboard the airplane.

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[19] At 1640:10, the CVR recorded the captain's evacuation command, "Ladies and gentlemen, we're going to evacuate the airplane...please follow the flight attendants instructions right now."

[20] For additional information on the emergency evacuation, see section 1.15, "Survival Aspects," and 1.15.2, "Crewmember Responsibilities During an Emergency Evacuation."

1.5.1 The Captain

The captain, age 48, was hired by Delta Air Lines on September 5, 1978. He held an airline transport pilot (ATP) certificate with airplane multiengine land and instrument ratings, a commercial pilot certificate with airplane single-engine land privileges, and MD-88 and Cessna 500 type ratings. The captain's most recent first-class medical certificate was issued on October 8, 1996, and contained the restriction, "Must have glasses available for near vision." The captain was wearing monovision (MV)[21] contact lenses for vision correction when the accident occurred. The captain's vision and MV contact lenses are discussed further in sections 1.18.1, "FAA Oversight of Airman Medical Certification (Vision)," and 1.18.2, "Information on Monovision (MV) Contact Lenses."

The captain had about 10 years of civilian and military flight experience before he joined Delta Air Lines, including 3,320 total flight hours in military aircraft. He was upgraded to a captain on the MD-88 in June 1990. His most recent proficiency check, which included crew resource management (CRM) training, was completed on September 18, 1996, in the MD-88. According to company records, at the time of the accident, the captain had accumulated 10,024 total flight hours, with about 3,756 hours as pilot-in-command in the MD-88.

The captain had been off duty for 3 days before the day of the accident. He reported that during the 3 off-duty days, he performed routine activities at home and received about 8 to 9 hours of sleep each night, which he indicated was a normal amount of sleep for him. On the day of the accident, the captain was not scheduled to fly, but was available in reserve status;[22] he was called for flight 554 at 1145 and reported for duty in Atlanta about 1330. The captain had landed at LaGuardia on numerous occasions; however, he had landed on runway 13 on only two occasions before the accident flight. Both of the previous approaches occurred in visual meteorological conditions (VMC); the captain had not performed an instrument approach to runway 13 before the day of the accident.

During postaccident interviews, the first officer described the captain as "quiet," "easy to get along with," and "by the book, procedurally." Two other first officers who had flown with the captain before the accident described him in similar terms; they indicated that he made first officers feel at ease and was open to criticism. A review of Delta's personnel records for the captain revealed no problems.

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[21] MV contact lenses are prescribed by optometrists for patients who require both near and distant vision correction and who would otherwise be considered candidates for bifocal glasses. MV contact lenses apply distance vision correction to one eye, and near vision correction to the other eye. According to the FAA's "Guide for Aviation Medical Examiners," MV contact lenses are not approved for use by pilots when performing flight duties.

[22] A pilot in reserve status is on standby duty for assignment to flights.

1.5.2 The First Officer

The first officer, age 38, was hired by Delta Air Lines on May 30, 1988. He held an ATP certificate with airplane multiengine land and instrument ratings. He had commercial pilot privileges for airplane single-engine land. His most recent first-class medical certificate was issued on February 15, 1996, with no restrictions or limitations. The first officer's vision did not require the use of, nor was he using, corrective lenses or glasses when the accident occurred.

Before he joined Delta Air Lines, the first officer had approximately 6 years of military flight experience in the U.S. Air Force. He began his career with Delta Air Lines as a flight engineer on the Boeing 727 and performed flightcrew member duties in the L-1011 and DC-9 aircraft before he transitioned to first officer on the MD-88 in November 1992. His most recent proficiency check, which included CRM training, was completed on October 17, 1996, in the MD-88. According to company records, the first officer had accumulated about 6,800 total flight hours, with 2,220 hours in the MD-88, all as first officer.

The first officer had been off flight-line duty for 3 days before the day of the accident; however, on October 16 and 17 he underwent 2 days of recurrent simulator training. He reported that during the 3 days before the accident, he received about 7½ hours of sleep each night, which he indicated was a normal amount of sleep for him. On the day of the accident, he reported for duty in Atlanta at about 1330. The first officer had never landed on runway 13 at LaGuardia before the accident flight.

During postaccident interviews, the captain described the first officer as "very competent" and "fun to be with." The Safety Board interviewed another captain who had flown with the first officer before the accident; the captain described the first officer as a "fine first officer" who "did everything a captain would expect from a first officer and more." A review of Delta's personnel records for the first officer revealed no problems.

1.5.3 Flight Attendants

The FAIC occupied the aft-facing jumpseat (adjacent to the L-1 door) in the forward cabin at the time of the accident. She had more than 7 years of service with Delta and had completed her most recent recurrent training before the accident on October 11, 1996. The second flight attendant was seated in the forward-facing jumpseat on the left side of the airplane, forward of the aft galley. She had almost 5 years of service with Delta and had completed her most recent recurrent training before the accident in February 1996. The third flight attendant was seated in the forward-facing rear cabin jumpseat. She had 5 years of service with Delta and had completed her most recent recurrent training in September 1996. According to company records, all three flight attendants had satisfactorily completed Delta's initial flight attendant training program and were qualified on the MD-88 aircraft.

1.6 Aircraft Information

1.6.1 General

N914DL, a McDonnell Douglas MD-88, serial number (SN) 49545, was operated by Delta Air Lines, Inc. The airplane was purchased from the Douglas Aircraft Company and was put into service as part of Delta's fleet in June 1988. The airplane was powered by two Pratt & Whitney JT8D-219 turbofan engines.

No noteworthy discrepancies were found in the maintenance log, and the pilots did not note any maintenance irregularities before or during their flight from Atlanta to LaGuardia.

At the time of the accident, the airplane had an estimated operating weight of 109,295 pounds. The maximum landing weight of this MD-88 was 130,000 pounds. The estimated center of gravity was 15.6 percent of the mean aerodynamic chord, which was within limits.

1.6.2 Vertical Speed Information

The accident airplane was equipped with a traffic advisory/vertical speed indicator (TA/VSI), which displayed vertical speed information with a permitted lag time of up to 4 seconds. According to the manufacturer, the TA/VSI unit could be rewired to display real-time (instantaneous) vertical speed information to the flightcrew if an inertial reference unit (IRU) was installed in the airplane. Although Delta was replacing the altitude/heading reference systems (AHRSs) with IRUs throughout the MD-88 fleet, at the time of the accident, the accident airplane's AHRS had not been replaced.

Several of the MD-88 check airmen and flight instructors interviewed during the investigation stated that they believed that most Delta line pilots were unaware that the VSIs in the MD-88 were not instantaneous.

1.7 Meteorological Information

According to the National Weather Service (NWS), on the day of the accident the weather in the New York area was being influenced by a low pressure center located in central New Jersey and a weak occluded front[23] extending to the east and southeast from the low pressure center; strong easterly winds and rain were noted to the north and northeast of the low pressure center. The terminal forecast for LaGuardia, issued by the NWS forecast office in Upton, New York, and valid at the time of the accident, predicted strong, gusty winds out of the east, a 400-foot cloud ceiling, and visibility of 1 mile in moderate rain and mist.

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[23] According to FAA weather publications, occluded fronts occur when a fast-moving cold front catches up to a slow-moving warm front.

Although VMC prevailed when Delta flight 554 departed Atlanta, the flightcrew stated that when the flight arrived in the New York area, it encountered the forecast IFR conditions. The pilots obtained ATIS information "Delta" during their approach to LaGuardia. It indicated winds out of 120° at 16 knots, visibility of 1¼ miles in heavy rain and mist, and an overcast cloud layer at 1,300 feet. It also advised that the ILS DME approach was in use, with airplanes landing and departing on runway 13.

Weather observations made at LaGuardia between 1627 and 1651 indicated a broken cloud layer at 800 feet, visibility between ½ and 1 mile in heavy rain and fog or mist, and easterly winds at 12 to 14 knots.

Automated surface weather observation system weather data obtained for the period approximately 13 minutes before to 7 minutes after the accident indicated the following conditions:

Time	Winds	Precipitation	Visibility
1625	080° @ 17 knots	Heavy rain	1 ¼ miles
1635	090° @ 11 knots	Heavy rain	½ mile
1645	060° @ 16 knots	Heavy rain	¾ mile

The NWS Aviation Weather Center in Kansas City, Missouri, issued several significant meteorological information advisories (SIGMETs)[24] for turbulence in strong winds and possible low level windshear, which were applicable for LaGuardia at the time of the accident. Additionally, the NWS Aviation Weather Center in Kansas City, Missouri, issued several airman's meteorological information advisories (AIRMETs)[25] for strong winds and occasional IFR conditions, which were applicable for LaGuardia about the time of the accident. Further, Delta's meteorological staff issued an Airport Alert for moderate-to-severe turbulence, strong, gusty surface winds, and possible low level windshear at LaGuardia around the time of the accident. The SIGMETs, AIRMETs, and additional weather information are included in appendix E.

1.7.1 Weather Information Provided to the Flightcrew by Delta

The pilots of flight 554 received a complete preflight weather briefing (prepared by Delta's meteorologists) with their flight release before departing from Atlanta. A review of the weather information in the flight release paperwork revealed that it included terminal forecasts, surface weather observations, and notices to airmen (NOTAMs) for the departure, en

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[24] According to the Weather Service Operations Manual, a SIGMET advises of weather, other than convective activity, potentially hazardous to all aircraft.

[25] According to the Weather Service Operations Manual, an AIRMET advises of weather, other than convective activity, that might be hazardous to single-engine and other light aircraft, and VFR pilots. However, operators of large aircraft might also be concerned with these phenomena.

route, destination, and alternate airports, as well as pertinent weather alerts for those regions. The flight release paperwork also included SIGMET Uniform 2 and Delta's meteorological staff's Airport Alert (both for moderate-to-severe turbulence in strong winds), and the following 1251 LaGuardia hourly weather observation:

> sky -- broken ceiling at 1,200 feet, broken cloud layer at 1,800 feet, overcast at 2,200 feet; visibility -- 2 miles, in moderate rain, mist; temperature -- 16° C; dew point -- 14° C; winds -- 080° at 23 knots, with gusts to 38 knots; and altimeter setting -- 29.54 inches Hg. Remarks: peak wind -- 070° at 38 knots occurred at 1247; tower visibility 2 ½ miles; pressure falling rapidly.

The pilots also obtained an updated preflight weather briefing about 10 minutes before they departed Atlanta. The briefing included the LaGuardia hourly weather observation from 1351, which indicated winds out of the east, with wind speeds more moderate than the previous hour's observation. Records indicate that at 1511 and 1618, during the flight to LaGuardia, the pilots requested and received updated weather information via their onboard automatic communication and reporting system (ACARS).

1.7.2 Runway Visual Range (RVR)[26] Values

Investigation revealed that the RVR was taken out of service sometime after the accident because of a problem with the line that ran between the receiver and the computer, where the RVR values were recorded.[27] According to FAA airways facilities (AF) personnel, this anomaly might have resulted in slight inaccuracies in the recorded RVR values.

The minimum RVR value estimated about 1637 was 2,800 feet. ATC records indicate that at 1636, LaGuardia ATC advised traffic that runway 13 RVR at touchdown was 3,000 feet, while RVR during landing rollout was 2,200 feet.

Postaccident interviews with air traffic controllers revealed that they first observed Delta flight 554 as it neared the runway threshold; the distance between the ATC tower cab and the approach end of runway 13 is approximately 2,800 feet. According to the ILS DME runway 13 instrument approach plate, the minimum RVR required for the approach is 2,400 feet.

1.7.3 Windshear Information/Low Level Windshear Alert System (LLWAS)

Examination of the ATC transcripts for the local control frequency revealed that between 1525 and 1545, about an hour before the accident, there were numerous pilot reports of

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[26] According to the Aeronautical Information Manual, RVR is the "range over which the pilot of an aircraft on the [centerline] of a runway can see the runway surface markings or the lights delineating the runway or identifying its [centerline]."

[27] The method for determining RVR for runway 13 is discussed in section 1.10.1.2, "Runway 13 RVR Information."

windshear, and the flightcrews of four flights executed missed approaches while attempting to land on runway 13. The ATC transcripts revealed that these missed approaches were attributed to wind conditions. Examination of the LLWAS recorded data and ATC records indicated that no LLWAS system alarms occurred between 1525 and 1545; however, wind gusts were recorded during that time (peak gusts to 28 knots). Review of the ATC tapes did not reveal any pilot comments regarding windshear between 1545 and the time of the accident.

Weather Surveillance Radar-88 Doppler (WSR-88D) is installed at the NWS Forecast Office in Upton, New York, approximately 46 nautical miles east-southeast of LaGuardia. The 1640 winds aloft estimates obtained from the WSR-88D velocity azimuth display vertical wind profile revealed the following:

Height (agl)	Wind Information
1,000 feet	083° @ 60 knots
2,000 feet	090° @ 65 knots
3,000 feet	105° @ 70 knots
4,000 feet	108° @ 70 knots
5,000 feet	109° @ 65 knots

A tape containing Doppler weather radar data from the Upton, New York, WSR-88D around the time of the accident was obtained from the National Climatic Data Center. A review of these data showed the presence of weather echoes along Delta flight 554's approach to runway 13. The weather echoes varied from moderate to very strong.[28]

A Phase II LLWAS was installed and operational at LaGuardia at the time of the accident. The LLWAS system consisted of six wind sensors; one sensor was positioned near the center of the airport, and the five remaining sensors were placed in locations surrounding the airport. Information obtained from the LLWAS northwest wind sensor (sensor 6) data[29] and center field average (CFA [sensor 1]) wind data for 40 seconds about the time of the accident indicated the following surface wind conditions:

Time	Northwest Wind Sensor	CFA Wind
1638:26	080° @ 14 knots	090° @ 13 knots
1638:36	080° @ 13 knots	090° @ 14 knots
1638:46	080° @ 14 knots	090° @ 14 knots
1638:56	080° @ 14 knots	090° @ 14 knots
1639:06	080° @ 15 knots	090° @ 14 knots

[28] For details of the review of the WSR-88D data, see appendix E.

[29] The northwest wind sensor is located about 5,468 feet northwest of the approach end of runway 13.

Examination of the LLWAS recorded data indicated that no LLWAS system alarms occurred between 1600:06 and 1649:56. Additionally, no wind gusts were recorded from 1600:06 through 1649:56.

After the accident, the FAA performed a site performance evaluation system of the LLWAS archived data. The examination revealed that three of the six sensors (sensors 3, 4, and 5) appeared to have problems. According to the FAA, the sensor problems might have resulted in the system's failure to detect existing windshears, or the system producing false windshear warnings.

Postaccident discussions with FAA personnel revealed that they are "improving and expanding" the existing LLWAS system at LaGuardia. They reported that the improved LLWAS system will consist of eight new sensor sites replacing the present LLWAS sites, which should be commissioned by November 1997.

1.8 Aids to Navigation

There were no known malfunctions with the aids to navigation involved in this accident.

1.9 Communications

There were no known difficulties with internal or external communications.

1.10 Airport Information

LaGuardia Airport is located in Flushing, New York, and has an airport elevation of 22 feet.[30] The airport is served by runway 4/22, which is oriented north-northeast/south-southwest and runway 13/31, which is oriented northwest/southeast. The runways are 7,000 feet long and 150 feet wide, grooved paved surfaces, and constructed of asphalt and concrete. The approach ends of runway 22 and runway 13 extend on an elevated deck above the Rikers Channel portion of Flushing Bay. The extended portion of the runways is constructed of asphalt and concrete laid out on steel piers, the approach end of which is covered by orange and white plywood panels that extend vertically toward the water. Runways 22 and 13 are equipped with approach lighting systems built on stanchions and accessible by catwalks, which extend farther into the bay from the end of the runway deck. During postaccident interviews, the LaGuardia airport manager stated that the airport "[does] a lot in a small area,[31] [but we] feel the physical constraints of its size." Refer to figure 3, "Diagram of LaGuardia Airport."

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[30] The published touchdown zone elevation for runway 13 is 13 feet.

[31] Airport records indicate that there are 337,087 flight operations at LaGuardia per year, of which 316,287 are commercial flight operations.

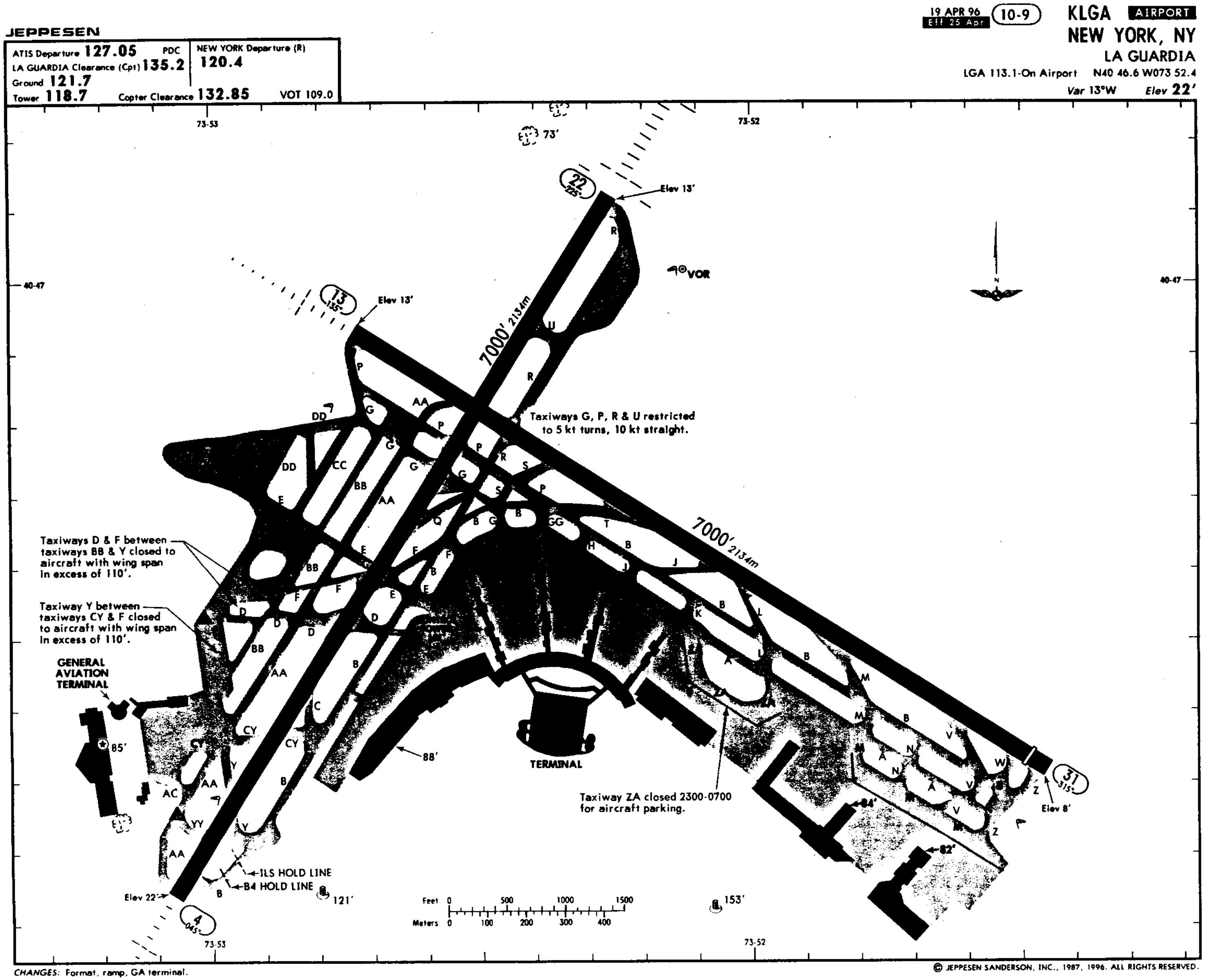

Figure 3—Diagram of LaGuardia Aiport
(Reproduced with permission of Jeppeson Sanderson, Inc.)

LaGuardia is fully certificated under 14 CFR Part 139. According to the FAA airports inspector with oversight responsibility for LaGuardia, the airport was in compliance with FAA standards, and all past deficiencies had been corrected in a timely manner.

1.10.1 Runway 13 Information

According to ATC operational records, the average prevailing winds at LaGuardia are northwesterly. Because the winds are generally out of the northwest, and because of other operational considerations, runway 13 (the landing runway for Delta flight 554) is used less frequently than the other runways. Runway 13 was equipped with high intensity runway lights (HIRL), centerline lighting, REIL, medium intensity approach light system, runway alignment indicator lights, and visual approach slope indicator (VASI) lights.

Runway 13 was serviced by an ILS DME instrument approach made up of six components: glideslope, localizer, DME, approach lighting system, marker beacons, and compass locators. The electronic glideslope is not usable below 200 feet agl because of signal irregularities.[32] According to FAA personnel, the ILS DME runway 13 DH, which is 250 feet agl (263 feet msl), is 50 feet higher than the standard DH because the localizer course is offset from the runway heading.

On the day after the accident, the FAA conducted an airborne operational check of the ILS DME approach to runway 13. All components of the instrument approach and landing system were determined to be capable of normal operation, with the electronic glideslope restriction (unusable below 200 feet) in effect. As mentioned previously, a new localizer for runway 13 should be commissioned by October 1997. The new localizer will not have an offset course.

1.10.1.1 Runway 13 Runway Lights/Spacing

According to FAA Advisory Circular (AC) 150/5340-24, "Runway and Taxiway Edge Lighting System," a runway edge lighting system is a configuration of lights that defines the lateral and longitudinal limits of the usable landing area. With regard to location and spacing of runway lights, the AC states the following:

> The longitudinal spacing of the lights should not exceed 200 feet (61 m) and be located such that a line between light units on opposite sides of the runway is perpendicular to the runway centerline. The lights should be spaced as uniformly as possible with the threshold/runway end lights used as the starting reference points. Where a runway is intersected by other runways or taxiways, a semiflush light...should be installed to maintain the uniform

[32] According to the FAA, the signal irregularities are the result of the runway pier's location over the water, tidal changes/influences, and the metal content of the water.

> spacing for HIRLs. For MIRLs [medium intensity runway lights] and LIRLs [low intensity runway lights] a single elevated edge light should be installed on the runway side opposite the intersection to avoid gaps in excess of 400 feet (122 m) where the matching of lights on opposite sides of the runway cannot be maintained... .

Postaccident measurement of the runway light spacing on runway 13 revealed that the runway lights were installed at irregular intervals, even where no other ground utilization considerations (crossing runways, taxiways, etc.) existed. The runway light spacing distances varied, with the most common distances between lights falling between 120 feet and 170 feet.[33]

1.10.1.2 Runway 13 RVR Information

Although LaGuardia has four runways that are usable for landing, the airport only uses three RVR transmissometers (visibility sensors). The transmissometers are located at three positions on the airport:

- The approach end of runway 04, aligned with runway 04.
- The approach end of runway 31, aligned with runway 31.
- The intersection of runway 13 and runway 22, aligned with runway 22.

According to the LaGuardia Tower standard operating procedures (SOPs), because the runway 13 and runway 22 touchdown areas are close to each other, a common RVR transmissometer services both runways. The shared RVR transmissometer is located about 1,500 feet from the approach end of runway 13. FAA AF personnel stated that the equipment is correctly situated to record valid touchdown RVR readings for both runways. The LaGuardia Tower SOP states, "To obtain an accurate RVR reading, the Runway 4-22 edge lights MUST BE AT A STEP THREE SETTING OR GREATER. If the Runway 13-31 HIRLs are [at a setting] equal [to] or greater than the Runway 4-22 HIRLs, then the Runway 13 RVR will display an accurate reading."

According to FAA Order 7110.65, "Air Traffic Control," at the time of the accident, the HIRLs for runways 13 and 22 should have been set on step 5, the runway 13 REILs should have been set on step 3, and the runway 13 VASI lights should have been set on high brightness. During postaccident interviews, the LaGuardia air traffic controllers stated that they did not recall what light settings were in use at the time of the accident. However, according to AF personnel, the LaGuardia HIRLs are connected to, and monitored by, a warning system. If the runway 13 and runway 22 HIRLs are not on the same setting, a "fail" light and an aural warning alarm will activate. The controllers did not indicate that an alarm had activated.

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[33] Most airports have runway edge lights generally positioned at, or near, the maximum 200-foot intervals.

1.10.1.3 Runway 13 VASI Information

The VASI light system for runway 13 is a two-bar VASI system, which may be used by pilots as a visual aid for maintaining an approximate 3° glidepath to the touchdown point on the runway. The two-bar VASI system consists of two light boxes located on the left side of the runway; the boxes are positioned on either side (downwind and upwind) of the touchdown point.[34] According to the pilots of flight 554, when the airplane descended below 200 feet agl and the electronic glideslope was considered unusable, they were in visual conditions; however, they did not observe either bar of the VASI lights during their descent to the runway. Postaccident interviews with the pilots of the four airplanes that landed on runway 13 just before flight 554 revealed that none of them recalled observing the VASI lights during their approach/landing. However, none of the pilots interviewed (including the flightcrew of flight 554) recalled specifically seeking VASI light guidance during their approach to land.

According to LaGuardia facility records and interviews with ATC personnel, there was no tower cab indication that the VASI lights were not operating normally at the time of the accident. However, a note in the "Daily Record of Facility Operation," FAA Form 7230-4, indicated at 1730 (52 minutes after the accident), a "Power surge in the [tower, runway] 13 MALSR (medium intensity approach lighting system with runway alignment indicator lights) and VASI [out of service]."[35] The runway 13 VASI light system was inspected by AF personnel on October 20, 1996. The inspection revealed that the VASI light bar angles and high brightness

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[34] The electronic glideslope touchdown point is located about 985 feet from the approach end of the runway deck. The downwind light box (closest to the landing airplane) and the upwind light box are positioned about 650 feet and 1,550 feet from the approach end of the runway deck, respectively. Each light box contains a set of white lights and a set of red lights, with the set of white lights over the set of red lights. The visual glideslope guidance is indicated by the color of the lights in the two boxes that is visible to a pilot on final approach for the runway, as follows:

- Red lights visible in both downwind and upwind light boxes = glideslope lower than 3°.
- White lights visible in both downwind and upwind light boxes = glideslope higher than 3°.
- White lights visible in downwind box, red lights visible in upwind box = glideslope equals 3°.

The Safety Board's calculations based on the positions of the light boxes revealed that an airplane on the ILS course at DH (250 feet agl) would be positioned 4,442 feet from the downwind light box and 5,342 feet from the upwind light box; an airplane on the ILS course at 200 feet agl would be positioned 3,486 feet from the downwind light box and 4,386 feet from the upwind light box.

[35] Postaccident interviews with AF personnel revealed that the log indication of "power surge" at 1730 was incorrect; a power "outage" occurred at 1730 because the "gear switch took on water." The gear switch is an electro-mechanical mechanism that monitors and controls the main airport power supply; if one power source loses power, the gear switch selects an alternate airport power source. According to a Daily Record of Facility Operation entry at 1831, "[AF personnel advised] that we were on generator from [1730-1745] when we came back to normal power, also AF [advised] that extensive damage was done to [runway 13 approach lights.]"

output current level were normal; however, the medium and low brightness output current levels were below tolerance. According to FAA Order 7110.65, "Air Traffic Control," VASI light intensity is required to be set to high brightness during the hours of "daylight - sunrise to sunset." As noted previously, ATC personnel did not recall what light settings were in use when the accident occurred.

1.11 Flight Recorders

A digital FDR and a CVR were installed in the airplane. The FDR was a Lockheed Aircraft Service Company Model 209F, SN 4548, recorder, which recorded 68 parameters of airplane flight information in a digital format on ¼-inch magnetic tape. The CVR was a Fairchild Model A100, SN 2698. Both recorders were removed from the airplane and sent to the Safety Board's laboratory in Washington, D.C., for readout. The cases of both recorders were intact and exhibited no evidence of damage or excessive wear.

1.11.1 CVR

The CVR recording consisted of four channels of audio information: the cockpit area microphone (CAM), the captain's position, the first officer's position, and the flight attendant intercom/public address (PA) system. Although the overall quality of the recording was good, the CAM and crewmember channels, from which all crewmember conversation was transcribed, were of excellent quality. A transcript was prepared of the final 30 minutes, 9 seconds of the recording. The transcript started approximately 27 minutes, 49 seconds before the first sounds of impact occurred on the CVR. The recording ended after APU shutdown, with the airplane stopped on runway 13.

1.11.2 FDR

Although the quality of the FDR data was good, the FDR experienced data loss coincident with the highest recorded vertical acceleration forces (Gs) that occurred during the airplane's impact with the approach lights and runway pier. The Safety Board's laboratory retrieved portions of the lost data and developed a composite data set of the accident approach and landing. A copy of the FDR data plot, with CVR excerpts overwritten, is included in appendix C.

The FDR data indicated that as the airplane descended on the ILS DME approach to runway 13, it was established on the electronic glideslope and localizer until it reached about 400 feet msl. As the airplane continued the approach from that point, it began to deviate above the electronic glideslope and right of the localizer. FDR data indicated that between 1637:33 and 1638:11, the airplane went from .09 dots high on the glideslope to 1.3 dots high on the glideslope. At 1638:20, the airplane was 1.43 dots high on the glideslope, and at 1638:28, when the airplane descended through 200 feet agl, the airplane was about 1.66 dots above the electronic glideslope. As discussed in section 1.10.1, from this point to the surface, the electronic glideslope information was considered unusable. Excerpted FDR data from the last 63 seconds of the approach is included in Table 1.

CVR Excerpt	Local Time hmm:ss	MSL Alt Feet	Radio Altitude feet	IAS knots	G/S Dev. dots	LOC Dev. dots	EPR Eng. 1 ratio	EPR Eng. 2 ratio	Elevator Position deg.
A/P OFF	1637:33	730	895	131	0.09 fly dwn	0.03 fly right	1.26	1.26	6.4 TEU
200 above	1637:57	468	603	129	0.06 fly up	0.04 fly right	1.27	1.27	7.5 TEU
100 above	1638:10	377	465	131	1.18 fly dwn	0.26 fly left	1.30	1.28	7.0 TEU
approach lites in sight	1638:11	376	453	131	1.30 fly dwn	0.32 fly left	1.33	1.32	5.2 TEU
little bit high	1638:13	341	435	130	1.39 fly dwn	0.39 fly left	1.37	1.35	7.0 TEU
Minimums	1638:20	265	319	133	1.43 fly dwn	0.67 fly left	1.19	1.21	9.3 TEU
speed's good	1638:25	213	259	129	2.40 fly dwn	0.87 fly left	1.16	1.19	4.8 TEU
sink's 700	1638:26	202	239/189	126	2.32 fly dwn	0.91 fly left	1.13	1.15	9.5 TEU
I'll get over there	1638:30	151	143	127	0.89 fly dwn	0.84 fly left	1.09	1.09	4.3 TEU
a little bit slow...	1638:31	133	118	126	0.27 fly dwn	0.79 fly left	1.08	1.08	8.8 TEU
Nose up	1638:33	68	59	124	2.08 fly up	0.71 fly left	1.23	1.11	20.3 TEU
Nose up/"sink rate"	1638:34	39	30	124	3.16 fly up	0.65 fly left	1.48	1.18	24.9 TEU
GPWS "sink rate"	1638:35	23	10	126	4.03 fly up	0.55 fly left	1.65	1.43	26.0 TEU

Table 1—Excerpted FDR data from the last 63 seconds of the approach

According to FDR data and CVR information, between 1638:24 and 1638:28, the engine pressure ratio (EPR) reduced from about 1.2 EPR to about 1.15 EPR as the first officer stated, "speed's good." At 1638:26, when the first officer called a 700 feet per minute descent rate, the airplane's actual rate of descent, calculated from FDR data,[36] was about 1,200 feet per minute. At 1638:30.1 (when the captain stated, "I'll get over there"), the FDR data indicated that the airplane was descending through about 110 feet agl at a rate of descent of about 1,500 feet per minute. The FDR data indicated that between 1638:24 and 1638:32, the elevator position oscillated between about 2° nose up and 8° nose up, and the airspeed decreased from 131 knots to about 126 knots. (About 1638:31, the first officer stated, "a little bit slow, a little slow.")

The FDR data indicated that an increase in EPR and nose-up elevator position began to occur about 1638:32; about 1638:33, as the engine power and pitch increased, the CVR recorded the first officer stating "Nose up...nose up." By 1638:33, the FDR data indicated that the airplane was descending through about 75 feet agl at 1,800 feet per minute. At 1638:34, the rate of descent began to decrease. At 1638:34.2 and 1638:35.7, the CVR recorded the sound of the GPWS "sink rate" warning, followed by loss of FDR data at 1638:36.5, the moment of impact.

1.11.2.1 FDR Information on Windshear

The horizontal wind encountered by Delta flight 554 during the approach to runway 13 and estimated from FDR data indicated no sudden changes associated with windshear. Postaccident examination of the windshear computer (WSC) from the accident airplane revealed that the WSC was capable of detecting and annunciating windshear alerts. No commands were recorded on the CVR regarding windshear during the final 1,000 feet of flight 554's descent.

The Safety Board requested and received FDR data from three of the four flights that preceded Delta flight 554 on the approach, and from the airplane that followed flight 554 on the approach to runway 13. FDR data was received from Delta Air Lines flight 1215, a Boeing 727, which landed at LGA about 1630; Continental flight 1614, a Boeing 727, which landed at LGA about 1633:07; USAir flight 212, a Boeing 737-300, which landed at LGA about 1634:53, and United flight 1576, a Boeing 737-300 (this flight was at an altitude of about 1,780 feet when—at 1639:08—ATC instructed the pilots to execute a missed approach after the accident). Examination of the FDR data and pilot reports from these four flights revealed no evidence of windshear encounters during the approach to runway 13.

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[36] The FDR system installed on the accident airplane did not directly record the airplane's inertial vertical speed; however, the Safety Board calculated the airplane's descent rate based on the FDR data. References to the airplane's actual rate of descent are based on these calculations.

1.12 Wreckage and Impact Information

Postaccident examination revealed damage to the approach light bars located 203 and 100 feet short of the approach end of the runway deck, the access catwalk structure, the edge of the runway deck, the runway deck support structure, and six runway threshold lights. The plywood on the vertical portion of the runway deck exhibited two main areas of impact damage; both areas of damage extended from the upper surface to a point approximately 3 feet 9 inches below the upper surface of the deck and were approximately 4 feet wide. The approximate midpoints of the damaged areas were located 11 feet and 27½ feet left of the extended runway centerline.[37] In addition, debris from the approach light structure and the access catwalk was found embedded in the plywood at the end of the runway deck.

Witness and flightcrew statements indicated that the airplane touched down on its nose landing gear and lower fuselage, slightly left of the extended runway centerline, and skidded down the runway pavement. Postaccident examination revealed that both main landing gear had separated from the airplane; although one main landing gear tire was located on airport property, the remainder of the main landing gear was not recovered during the investigation.

Examination of runway 13 revealed faint scrape marks[38] that started at the approach end of the runway deck, left of the runway centerline. The scrape marks veered farther left as they continued down the runway, to the point where the airplane came to rest, approximately 2,700 feet from the approach end of the runway. The airplane came to a stop facing north-northwest on runway 13, with the nosewheel about 99 feet left of the runway 13 centerline, and the right wing extended over the grass next to the runway. Airplane and approach light structure debris was scattered along the wreckage path.

The right wing exhibited extensive damage to the leading edge, leading edge slats, fuel tank, trailing edge flaps, wing-to-fuselage fairing, and landing and position lights. The damage consisted of crush, dents, tears, and one puncture. Wood and fiberglass objects were implanted in the leading edge of the wing structure, and stones were wedged in the trailing edge flap components. Fuel leakage was noted and traced to a right wing fuel tank puncture; an estimated 600 gallons of fuel leaked from the airplane's right wing as a result of the accident. The left wing exhibited less extensive damage to the trailing edge flaps, wing-to-fuselage fairing, and one leading edge slat.

Examination of the fuselage revealed extensive damage to underside antennae, skin, stringers, frames, and longerons, increasing in severity in the aft direction. Landing gear doors, the APU doors, and the lower surface of the tailcone were scraped and torn. Examination of what remained of the main landing gear assemblies revealed that the main landing gear

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[37] According to the Delta Air Lines MD-88 maintenance manual, section 06-10-00, pages 2 and 3, the distance between the midpoints of the main landing gear is 16.7 feet.

[38] Scrapes/damage to the runway were minimal; according to airport personnel, the runway was very wet, with areas of standing water when the accident occurred.

cylinders were fractured approximately 12 to 13 inches below the bottom surface of the wing. Although both engines exhibited foreign object damage, damage to the right engine was more severe. A diagonal buckle was located above the aft portion of the right engine pylon, the exhaust case was fractured at the forward joint, and the right engine thrust reverser had separated and was not recovered.

1.13 Medical and Pathological Information

Three passengers reported that they received minor injuries during the accident and evacuation. Two passengers reported that they bumped their heads during the landing touchdown and deceleration on the runway, and one passenger sustained a minor neck injury during the emergency evacuation; the passenger with the neck injury was transported to a local hospital, where she was treated and released the same day.

In accordance with 14 CFR Part 121 requirements, the flightcrew provided postaccident toxicological samples for analysis. The samples were analyzed[39] and found to be negative for ethanol and other drugs of abuse. Toxicological samples were not requested or received from the flight attendants or air traffic controllers.

1.14 Fire

No fire was associated with this accident.

1.15 Survival Aspects

Although no serious or fatal injuries occurred in this accident, the Safety Board examined the flight and cabin crew decisions and procedures during the emergency evacuation. The airplane was configured with 142 passenger seats, 58 of which were occupied on the accident flight. Two floor-level exits were located in the forward cabin; four overwing exits were located at seat rows 20 and 21; one floor-level exit was located in the aft galley, on the left side of the cabin; and a tailcone exit was located at the rear of the cabin. According to the flight attendants and dispatch documentation, most of the passengers were seated forward of the overwing exits. All airplane occupants were evacuated safely through the forward left (L-1) door. See figure 4 for an airplane diagram and seating chart.

[39] Toxicological analysis of the samples was conducted on October 22, 1996, at MedExpress—National Laboratory Center, per Dr. William H. Whaley, Delta Air Lines, Atlanta, Georgia.

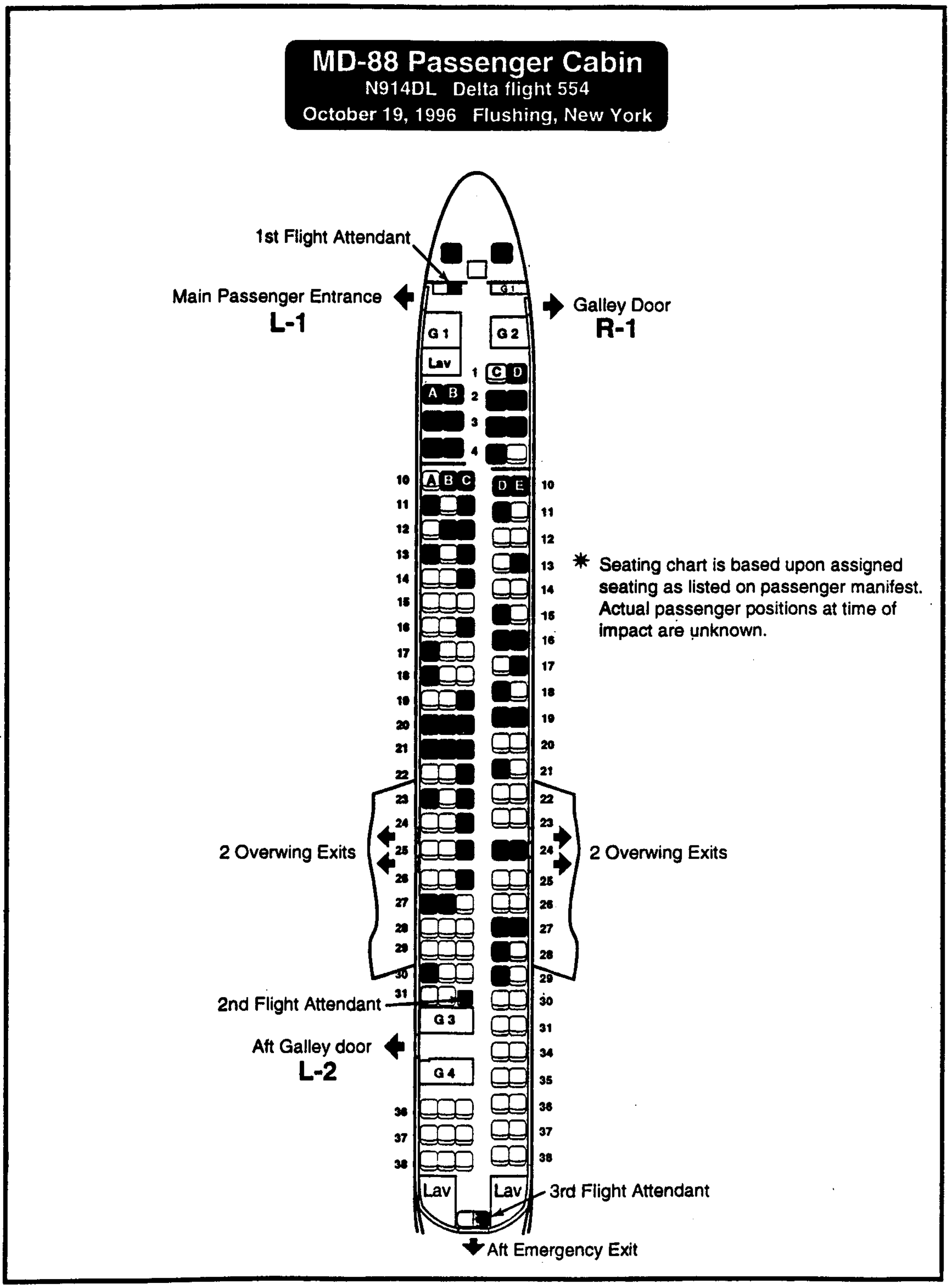

Figure 4—Airplane diagram and seating chart

1.15.1 Evacuation-related Information From CVR Transcript

According to CVR information, the airplane came to a stop on the runway about 1638:56, about 20 seconds after the first sounds of impact were heard. The CVR recorded, in part, the following comments pertaining to the emergency evacuation:

> 1639:06 (PA announcements attributed to the captain)—"Ladies and gentlemen please remain seated at this time...please remain seated with your seatbelts securely fastened please."
>
> 1639:17 (Comment attributed to the first officer--CAM)—"We need to get out of the airplane I think."
>
> 1639:29 (Comments attributed to the captain--CAM)—"Let's evacuate...well hold, hold on a minute."
>
> 1639:34 (Comment attributed to the FAIC--interphone)—"Stay away from the back."
>
> 1639:52 (Comment attributed to FO-ATC communications)—"Yes, we're gonna evacuate the airplane and...we'll try and get everyone off the front of the airplane on the...runway."
>
> (1640:01-1640:06—Unattributed comments--CAM—including "...smelling fuel..." "we need to get out," and "evacuate the airplane.")
>
> 1640:10 (PA announcement attributed to captain)—"Ladies and gentlemen we're going to evacuate the airplane...please follow the flight attendants instructions right now."
>
> 1640:12 (Evacuation instructions attributed to FAIC)—"Release your seatbelts, get up, get out...release your seatbelts, get up, get out...release your seatbelts, get up, get out."
>
> 1640:15 (Interphone comment attributed to a flight attendant in the aft cabin)—"Do you want to go forward or backwards?"
>
> 1640:19 (Sound similar to door opening and slide inflating)
>
> 1640:39 (Interphone comment attributed to a flight attendant in the aft cabin)—"Are we going out the back?"
>
> 1640:43 (Interphone comment attributed to a flight attendant in the aft cabin)—"I'm wanting to know which way out."

> 1640:48 (Interphone comment attributed to a flight attendant in the aft cabin)—"Do you want to go forward?"
>
> 1640:50 (Interphone comment attributed to the first officer)—"Lets come forward, yes come forward."

During postaccident interviews, the FAIC stated that she did not recall making the statement "Stay away from the back," which was attributed to her in the CVR transcript. Statements obtained from the FAIC and the first officer indicated that after the first officer left his seat in the cockpit to assist with the evacuation, he instructed the FAIC to use the L-1 door for the evacuation. That instruction was not audible to the aft flight attendants and was not recorded on the CVR.

1.15.2 Crewmember Responsibilities During an Emergency Evacuation

1.15.2.1 Flightcrew Duties During an Emergency Evacuation

Emergency evacuation procedures for flightcrews, in Delta's flight operations manual (FOM),[40] chapter 10, "Abnormal Operations," page 10-14.2, state the following:

> After a thorough evaluation, if an emergency evacuation is required, complete the evacuation checklist and make the evacuation announcement:
>
> "*This is the Captain, Evacuate, Evacuate.*"
>
> - If an engine fire or other conditions make certain exits unusable, state the direction of egress (i.e., Use the left side exits only).
> - Some aircraft are equipped with an evacuation signal or horn which can be used to give the evacuation command.
>
> Remove all passengers to a point well clear of the aircraft, out of range of possible fire or explosion.
> Do not allow passengers to return to the aircraft until danger no longer exists.

On page 8, Delta's MD-88/90 pilots operating manual (POM),[41] under the heading "Ditching/Evacuation," outlines the following flightcrew duties and responsibilities during an emergency evacuation:

---

[40] The FOM provides the policies, procedures, practices, instructions, and guidance for Delta flight operations personnel to follow. It is supplemented by other Delta manuals and documents.

[41] Each Delta pilot is issued a set of pilot's manuals (the POM and the pilot's reference manual [PRM]). The POM contains procedures, techniques, and operations that establish the standard to which pilots will be trained and by which the airplane should be operated. The PRM is designed as a

CAPTAIN
- Order evacuation.
- Proceed to **forward cabin area.**
- Assist in evacuating passengers as conditions dictate.
- Check that all persons have been evacuated, if possible.
- After exiting, assemble passengers away from the aircraft.

FIRST OFFICER
- Remove and carry ELT from crew closet.
- Assist in opening forward cabin door and assist in evacuation until able to proceed to **mid cabin.**
- Proceed to **mid cabin area.**
- Assist in evacuating passengers as conditions dictate.
- Assist in assembling passengers away from the aircraft.

Examination and documentation of the cockpit switch positions was accomplished on October 20, 1996; a review of the documentation revealed that all passenger evacuation checklist items had been completed, except that the emergency light switch was located in the "off" position.

1.15.2.2 Flight Attendant Duties During an Emergency Evacuation

Chapter 5, "Emergency Procedures," of Delta Air Lines' in-flight service on board manual addresses flight attendant procedures during emergency evacuations on land and water. The following excerpts from chapter 5 of the in-flight service on board manual, pages 5-20 to 5-24, address flight attendant procedures during evacuations on land:

> The type of emergency dictates the means of communication to determine if evacuation is necessary. Once determination is made to evacuate begin evacuation commands. ...
>
> **Unanticipated Emergency**
> - Call the cockpit crew to coordinate evacuation (be prepared to provide information such as structural damage, fire, etc.)
>
>   **NOTE: Upon hearing an evacuation horn [or command]..., evacuate without further communication from [the] cockpit.** (Emphasis added.)
> - Give motivational **commands**
>
>   On land --

training manual, and an in-depth reference manual, and contains specific airplane information. The information in both manuals complies with the FAA-approved airplane flight manual.

"Release seat belts! Get up! Get out!"

- Release seat belt, grab flashlight and proceed to nearest or designated exit.

Assess conditions

- Look for structural damage, fire or if exit is underwater or obstructed.
- Assess type of emergency.

Activate exit

- Quickly confirm *armed* status of exit.
- Open exit.

If exit or slide is not usable REDIRECT passengers to an alternate exit:

- Consider **T**ime, **A**vailability and **D**istance to redirect to a usable exit.

Evacuate—*LAND*
At a door

- **Command** first 2 passengers:
  "You two, stay at the bottom! Help people off!"
- **Command** passengers: "Arms straight ahead" (*all types of slides*)
  "Sit and slide!" (*slides*)
  "Move away"

Continually assess conditions—*LAND*

- If passengers are waiting in line at any exit, consider redirecting to less crowded exits.
- If passengers are piling at bottom of slide, temporarily halt evacuation.

The in-flight service on board manual also states that if a main landing gear collapse/nose high situation occurs, the most desirable exits are low door and low window exits.

1.15.3 Flight Attendant Actions/Decisionmaking During the Evacuation

During postaccident interviews, the flight attendants were asked to describe their actions, communications, and decisionmaking process during the evacuation procedure.

1.15.3.1 Flight Attendant in Charge

The FAIC, who was positioned in the forward cabin, stated that when the airplane came to a stop on the runway, she picked up her interphone handset and waited for instructions. She stated that moments later the flightcrew opened the cockpit door, and thereafter she communicated with the pilots without using the interphone. The FAIC indicated that when she heard the evacuation command, she opened the L-1 exit, pulled the manual slide inflation handle, and began the evacuation. She stated that she recalled receiving verbal guidance from one or both of the pilots to use only the L-1 door, but she did not recall specifically when or by whom that guidance was given.

The FAIC indicated that the first officer stood near the cockpit door and assisted her by attempting to calm the passengers during the evacuation. She stated that she instructed two passengers to remain at the bottom of the slide to help, but they did not do so. She stated that after four or five passengers "piled up" at the bottom of the slide, she slowed the pace of the evacuation; shortly thereafter, firefighters and police officers began to assist at the bottom of the slide, and there were no further problems with the evacuation. The FAIC indicated that when all the passengers but one had been evacuated, she exited the airplane at a firefighter's request; the flightcrew remained behind to assist the remaining passenger out of the airplane.

1.15.3.2 Second Flight Attendant

The second flight attendant indicated that from the jumpseat she occupied (forward of the aft galley, on the left side of the airplane), she was able to see outside during the accident sequence by looking out a passenger window on the left side of the cabin. She reported that she saw debris and heard "slushing sounds" during the impact sequence; then when the airplane came to a stop, she picked up the interphone handset and waited for instructions. She stated that she heard two PA announcements from the cockpit: the first was made seconds after the airplane came to a stop and instructed passengers to remain seated, and the second PA announcement, which was made about a minute after the first, ordered the evacuation. She stated that sometime between the two announcements, she began to smell fumes, which she described as a combination of burned motor oil and fuel fumes.

The second flight attendant stated that after she heard the captain's evacuation command she replaced the interphone handset, got up, and began to instruct passengers to move forward to evacuate. During the evacuation process, the second flight attendant also obtained ice from the aft galley for a passenger who had bumped her head. The second flight attendant reported that she based her decision not to use the aft exits on the following information:

- Passenger seating positions—no passengers were seated behind her in the cabin, about four passengers were located between her jumpseat and the overwing exits, and the rest of the passengers were seated forward of the overwing exits. She stated that "based on time and distance," she believed that it was "one third" faster to direct passengers to evacuate through the forward exit.
- The debris and "slushing sounds" she observed during the accident sequence led her to determine that the L-2 exit might be unsuitable for safe egress.
- A woman seated near the jumpseat occupied by the second flight attendant had bumped her head as she stood up from her seat and was slow to move/evacuate. The second flight attendant stated that she was concerned that the woman might have been trampled if they had attempted to use the aft exits.

1.15.3.3 Third Flight Attendant

According to the third flight attendant, she believed that she was somewhat "displaced" during the accident sequence and evacuation because she was seated on the aft cabin (tailcone) jumpseat and no passengers were seated in the rear of the cabin. She indicated that when the airplane came to a stop, she picked up the interphone to listen for instructions. She reported that when the captain commanded the evacuation the engines were no longer operating, and she had no difficulty hearing the announcement over the PA system. She stated that as she prepared to open the tailcone exit, the second flight attendant stopped her and indicated that they were evacuating through the L-1 door only.

The third flight attendant left her position in the rear of the airplane and proceeded forward to help the remaining passengers. She stated that as she moved forward in the airplane, she began to smell fuel fumes. By the time she reached the middle of the coach section of the cabin, most of the passengers had moved forward into the first-class section of the airplane, toward the L-1 door. However, two passengers who were standing near the midsection of the airplane appeared disoriented and were not moving forward toward the exit. The third flight attendant indicated that she tried get the two remaining passengers to move forward quickly, but the passengers did not respond. She reported that the first officer "was telling me to hurry because there was extensive aircraft damage and potential for explosion." When the first officer moved aft to carry one of the passengers out of the airplane, the third flight attendant exited through the L-1 door.

1.15.4 Delta Flight Attendant Training

According to Delta's Flight Attendant Training Manager, Delta's flight attendants are instructed that every emergency situation is different and that flight attendants should follow the evacuation guidelines outlined in the in-flight service on board manual, make an individual assessment of the conditions, and use appropriate exits.

1.15.5 Previous Safety Board Recommendation—Flight Attendants' Actions

A review of the Safety Board's previous recommendations concerning flight attendants' actions during emergency evacuation procedures revealed that as a result of information gathered in several accident investigations, on August 12, 1992, the Safety Board issued Safety Recommendation A-92-077, which recommended the following to the FAA:

> Require that flight attendants receive crew resource management training that includes group exercises in order to improve crewmember coordination and communication.

In response, the FAA revised AC 120-51B, "Crew Resource Management Training," to provide information concerning training that includes combined flight and cabin crewmember exercises, and it published its final rule, "Air Carrier and Commercial Operator

Training Programs," which requires that air carriers include CRM training for flight attendants in their FAA-approved training program.

On July 15, 1996, based on the FAA's actions, the Safety Board responded, in part:

> Because of the FAA's...adequate general definition of a comprehensive CRM program, the [Safety] Board classifies...A-92-077... "Closed—Acceptable Action." However, based on safety issues previously identified by the [Safety] Board in its accident investigations, the [Safety] Board encourages the FAA to provide additional guidance to air carriers about the importance of group exercises involving both cockpit-cabin coordination and coordination among the individual members of a flight attendant crew.

At the time of the accident, Delta pilots received 3 hours of CRM training during the 2-day ground school portion of their annual recurrent training; the 3 hours consisted of a 2-hour segment of joint flight and cabin crew CRM training and an additional 1-hour segment for flightcrew members only.

1.16 Tests and Research

No additional tests and research were conducted in this accident.

1.17 Company/Flight Operations Information

At the time of the accident, Delta had approximately 68,000 employees and operated 536 aircraft with more than 2,700 flights each day to 153 domestic and 51 foreign destinations. Delta's fleet included 52 Lockheed L-1011, 58 Boeing 767, 86 Boeing 757, 67 Boeing 737, 129 Boeing 727, 12 MD-11, 12 MD-90, and 120 MD-88 aircraft. Delta has operated the MD-88 aircraft since December 1987.

1.17.1 Delta's Procedures and Guidance Regarding Flightcrew Responsibilities During CAT I ILS Approach to Land

During postaccident interviews, several Delta MD-88 check airmen/flight instructors and the pilots of Delta flight 554 stated that Delta's manuals did not contain detailed guidance for pilot not flying (PNF) duties after visual contact with the runway environment is established during a Category (CAT) I ILS approach. A review of Delta's manuals supported that comment; excerpts from Delta Air Lines' FOM and the POM/PRM will be discussed in this section.

Delta's FOM, chapter 7, "Normal Operations," addresses flightcrew duties and responsibilities during normal flight operations, including instrument approaches. On page 7-46 (dated November 30, 1995), under the heading "Instrument Approach Procedures—General," the FOM states the following:

> Approach and landing should be planned to maintain minimum drag configurations as long as possible, safety and conditions permitting, while still meeting the stabilized approach requirements.
>
> The aircraft should be stabilized on final approach in the landing configuration at least 1,000 feet AFE [above field elevation] except where this conflicts with nonprecision approach procedures.
>
> Any abnormal condition, such as tail wind as evidenced by higher than normal sink rate while maintaining glide slope and airspeed, should be verbalized.
>
> If operable, both the Autopilot and Flight Director will be utilized for all ILS approaches when the reported visibility is below RVR 4000 or ¾ mile.

On page 7-48 (dated August 31, 1995), under the heading "Decision to Land," the FOM states the following, in part:

> During all instrument approaches, regardless of who is flying, the Captain shall announce his decision to allow the aircraft to continue to a landing or to execute a missed approach. This decision must be made no later than:
>
> - CAT I Approaches—[Decision Altitude or Height/Missed Approach Point] DA(H)/MAP
> - CAT II ILS Approaches—DA(H)/RA
> - CAT III ILS Approaches—AH/DH
>
> The Captain will state, and the F/O will acknowledge (when operating to an MDA or DH):
>
> If and when visual reference is established with the runway
> - "Approach lights in sight" or
> - "Runway in sight"
>
> Note: The "runway in sight" callout does not relieve the PF from the responsibility to execute a missed approach if it would be unsafe to continue to a landing.
> If either visual reference is not established or a safe landing cannot be accomplished in the touchdown zone
> - "Missed approach"

Also, on page 7-48, under the heading "Descent Below DH/MDA," the FOM states the following:

> Upon reaching the DH/MDA, and at any time before the missed approach point, the pilot may continue the approach below the DH or MDA and touch down if meeting the conditions listed in the Airway Manual—Procedures (Ops. Specs.).

On page 7-49 (dated June 30, 1996), under the heading "Crew Duties," the FOM states the following, in part:

> On each instrument approach the Captain shall ensure all requirements for the approach are met. The duties below are the normal duties for all pilots, however, the Captain may assign additional duties as required.
>
> **Pilot Flying (PF) Duties**
>
> - **All Approaches**
>   - Fly the aircraft.
>   - Conduct a suitable approach briefing.
>   - Conduct the approach as outlined in the POM.
>   - Crosscheck all instruments.
>   - After passing the final approach fix using the autopilot, the pilot flying should follow through on the controls and be prepared to immediately disengage the autopilot and autothrottles if performance is not satisfactory.
>
> - **CAT I and CAT II**
>   - Adjust scan pattern approaching MDA or DA(H)/RA to include outside references.
>   - Primary duty continues to be accurate aircraft control approaching DA(H) or MDA and maintaining MDA as required.
>   - Either pilot may initially call "Runway in sight" (except CAT II).
>   - Autopilot may be disconnected when "runway in sight" is established.
>   - The Captain must make the decision to continue or to execute a missed approach.
>   - The PF will continue the approach or execute the missed approach.
>   - Refer to Airway Manual—Procedures (Ops. Specs.) section for description of visual cues that allow operation below MDA or DA(H)/RA.

Pilot Not Flying (PNF) Duties

- **All Approaches**
    - ♦ Positively make all Standard Callouts.
    - ♦ Crosscheck all instruments, both primary and raw data.
        - ♦ Closely monitor flight instruments.
            - ♦ Call attention to any flight path deviations, flags or malfunctions. Any deviation from the published approach should immediately be brought to the attention of the PF.
            - ♦ After establishing visual contact, the PNF must continue to monitor the flight instruments through the flare. Call out any significant deviation to minimize the effects of possible visual illusions for the PF.
            - ♦ Monitor airspeed and sink rate through touchdown.
    - ♦ After landing, F/O assists in runway and taxiway identification.
    - ♦ If the approach cannot be continued, assist in execution of missed approach.
    - ♦ Pay particular attention to rotation, thrust, positive rate of climb, airspeed, gear/flap retraction, and the missed approach procedure.

- **CAT I**
    - ♦ Approaching DA(H), or MDA,
        - ♦ Closely monitor flight instruments.
        - ♦ Adjust scan to include outside references and verbalize those observed.

Delta's MD-88/90 POM, on pages 10-12 of the section entitled "Normal Procedures," states that during all CAT I ILS approaches, the PNF will make the following callouts:

- First positive movement of localizer—"localizer alive"
- First positive movement of glide slope bar—"glide slope alive"
- At approximately 1000 feet above DH—"1,000 above, cleared to land," or "1,000 above, no landing clearance"
- Approaching DH—"200 above" and "100 above"
- At DH—"minimums"

At the time of the accident, the POM stated that at or before the DH, the PF will call "Approach lights in sight," "runway in sight," or "missed approach," and the PNF will acknowledge that callout.

1.17.1.1 First Officer's Actions During Approach to Land

During postaccident interviews, the first officer stated that from the time he made the "one thousand above minimums" callout during the approach, he looked almost exclusively at the instruments until the captain called out "approach lights in sight"; after which point the first officer "glanced out a few times." The first officer indicated that when he stated, "a little bit high" and "above the glide slope" he was looking at the glideslope indicator on the instrument panel; however, he believed that when he said "approach lights, we're left of course," he had glanced outside. The first officer reported that he believed that the approach was a good, stable approach—not rushed—until a few seconds before impact. However, about 3 seconds before impact, he had the sensation that they would touch down short of the runway. He stated that at that point, he looked outside the cockpit and saw the approach end of the runway. Information obtained from the FDR, CVR, and flight and cabin crew statements indicate that the captain applied power about the same time (1638:33) as the first officer called out "nose up."

The first officer stated that because the guidance contained in Delta's manuals concerning the duties of the PNF during a CAT I ILS approach were "not real specific as [to] what [the PNF] should be monitoring," he followed his own personal procedures. He reported that his personal practice after the PF established ground contact was to monitor the cockpit instrumentation, provide the captain with information, and be ready to take over control of the airplane if necessary. He indicated that he did not believe that he needed to take over control of the airplane at any time during flight 554's approach to runway 13; he stated, "as I said or thought to do something, [the captain] was doing it. I don't think I could have done much more."

1.17.1.2 Delta's Postaccident Actions Regarding PF/PNF Duties

As a result of this accident, Delta's program managers discussed PNF duties and landing callout requirements in several Joint Standards Meetings. The minutes from the February 1997 meeting indicated that the program managers discussed the non-flying pilot's callout requirements in effect at other air carriers, which included the following:

- 1,000 feet agl
- 500 feet agl
- every 100 feet thereafter to 100 feet agl, then
- 50 feet agl
- 40 feet agl
- 30 feet agl
- 20 feet agl
- 10 feet agl

According to the minutes from that meeting, Delta's program managers concluded that their "...scan policy is adequately explained in [the proposed revision pages of the FOM which do not contain such callout requirements]...we wanted the PNF to be aware of the outside environment in the final phase of an approach/landing." The minutes further indicated, "A methodical approach to teaching our scan policy is needed."

According to the minutes from the March 1997 Joint Standards Meeting, the program managers agreed to revise the Maneuvers section of the FOM to reflect increased details concerning PF and PNF scanning responsibilities during instrument approaches. The following procedures are expected to be included in the revision, which is still in draft form:

Scan Policy:
- Approach scan policy is set to ensure someone is **always** focused on airspeed, altitude and profile.
- Approach scan responsibilities for the PF and PNF are listed below.
- **IN** means primary responsibility is inside the aircraft.
- **OUT** means primary responsibility is outside the aircraft.
- The item inside the parenthesis ( ) means secondary responsibility.

	PF	PNF
Runway Environment NOT in Sight	IN (out)	IN (out*)
Runway Environment in Sight	OUT (in)	IN (out)

- Except for CAT II and CAT III approaches.

1.17.2 Stabilized Approach Criteria

As mentioned previously, several Delta MD-88 check airmen/flight instructors and the pilots of Delta flight 554 stated that Delta's manuals did not contain a formal definition of a stabilized approach, and that the only specific guidance concerning pilot actions during an unstabilized approach was located in the windshear guidance section. A review of Delta's flight and pilot manuals supported their statement; although the word "stabilized" and the terms "stabilized approach" and "unstabilized flightpath" appear several times, the manuals did not define these terms, nor did they prescribe stabilized approach criteria. Excerpts from Delta's FOM, POM/PRM, and airway manual regarding stabilized approaches will be discussed in this section.

The FOM did address basic aircraft operation parameters in various phases of flight. In chapter 21, "Training," under the heading "Pilot Qualification Standards," aircraft operation parameters during the approach to land are outlined in part as follows:

Note: The tolerances described below, and throughout this document, represent the performance expected in good flying conditions.

Aircraft Control

Maintains within the following parameters unless otherwise stated:

- Airspeed within +/- 10 knots, except for target airspeed
- Heading within +/- 10 [degrees]
- Altitude within +/- 100 feet

Approach

The pilot will maintain aircraft performance within the following tolerances for the approach being flown.

CAT I Precision Approach Tolerances are listed as follows:

Final approach segment	-- Localizer and glide path	-- +/- 1 Dot
At DA	-- Localizer	-- +/- ½ Dot
	-- Glide path	-- +/- 1 Dot

The FOM did not contain specific procedural guidance with regard to pilot actions if approach tolerances were exceeded. Delta's MD-88/90 POM guidance concerning flightcrew procedures in the event of an unstabilized condition is contained in the Supplemental Information section, under the heading "Wind shear Guidance." On pages 32-33 of the POM's "Supplemental Information" section, it states the following, in part:

The following criteria for indications of an unstabilized flight path are published only as a guideline.

CRITERIA FOR RECOGNIZING AN UNSTABILIZED FLIGHT PATH

- +/- 15 KIAS
- +/- 500 fpm vertical speed
- +/- 5° pitch attitude
- 1 dot from glide slope
- Unusual throttle position for an extended period of time
- Wind shear system advisory (caution or warning)

When to Initiate a Recovery

Initiate the standard recovery technique when an unstabilized flight path or marginal aircraft performance is indicated by:

- Wind shear below 1,000 feet [above field elevation] AFE:
    - ♦ Criteria exceeded for an unstabilized flight path or
    - ♦ Wind shear caution or warning annunciated by the wind shear detection system.
- Severe or extreme turbulence encountered below 1,000 AFE.
- Stall warning encountered:

- Buffet, stick shaker or stall warning horn.

The Delta airway manual contained similar discussions of stabilized and unstabilized conditions in chapter 4 (Weather), in the section entitled "Hazardous Weather." On page 4-7, under the heading "Wind shear—Decision Tree," the Delta airway manual outlined the criteria for unstabilized flightpath, consistent with pages 32-33 of the POM Supplemental Information listed earlier in this section, and provided an outline for standard recovery technique. On page 4-11, the Delta airway manual states the following, in part:

> Heavy rain may have as significant an effect on airplane performance as wind shear. Consider using the wind shear adjustment of up to 20 knots when determining Target Airspeed.
>
> If heavy rain is experienced during approach, initiate prompt attitude correction to arrest any increase in descent rate, and immediately apply adequate thrust to maintain Target Airspeed.

1.17.2.1 Previous Safety Board/FAA Actions Regarding Stabilized Approaches

As a result of an accident that occurred on September 8, 1989, involving a Boeing 737 near Kansas City, Missouri, the Safety Board issued Safety Recommendation A-90-131, which recommended the following to the FAA:

> Direct principal operations inspectors [POIs] to verify that the airlines they surveil have clearly established stabilized approach and missed approach procedures for nonprecision approaches, such as full-scale deflection of localizer needle when the airplane is inside the final approach fix.

On May 31, 1991, the FAA revised Air Carrier Operations Bulletin (ACOB) 7-76-31, directing all POIs to verify that appropriate air carriers have clearly established stabilized approach and missed approach procedures for nonprecision approaches. The Safety Board subsequently classified Safety Recommendation A-90-131 "Closed—Acceptable Action."

As a result of an accident that occurred on June 8, 1992, involving a Beech C99, near Anniston, Alabama, the Safety Board issued Safety Recommendation A-93-36, which recommended the following to the FAA:

> Require that scheduled air carriers operating under 14 CFR Part 135 develop and include in their flight operation manuals and training programs stabilized approach criteria. The criteria should include specific limits of localizer, glideslope, and VOR needle deflections and rates of descent, etc., near the airport, beyond which initiation of an immediate missed approach would be required.

On December 29, 1994, the FAA issued Flight Standards Information Bulletin (FSIB) Air Transportation (FSAT) 94-22, "Stabilized Approaches," which states the following, in part:

> POLICY. FAA Principal Operations Inspectors (POIs) should strongly encourage operators to incorporate the stabilized approach concept [contained in FAA Order 8400.10, paragraph 511] into their approach procedures. POIs also should ensure that the IFR practices, as discussed in [FAA Order] 8400.10, paragraph 547 [generic CAT I callouts], are incorporated into the procedures used by all operators who conduct IFR operations.

Based on the FAA's action, on July 19, 1995, the Safety Board classified Safety Recommendation A-93-036 "Closed—Acceptable Alternate Action." The "stabilized approach concept" guidance referenced in FSAT 94-22, FAA Order 8400.10, paragraph 511, dated December 20, 1994, states the following, in part:

> Maintaining a stable speed, descent rate, vertical flight paths, and configuration is a procedure commonly referred to as the stabilized approach concept. Operational experience has shown that the stabilized approach concept is essential for safe operations with turbojet aircraft, and it is strongly recommended for all other aircraft.... A stabilized approach for turbojet aircraft means that the aircraft must be in an approved landing configuration...must maintain the proper approach speed with the engines spooled up, and must be established on the proper flightpath before descending below the minimum "stabilized approach height" specified for the type of operation being conducted. These conditions must be maintained throughout the rest of the approach for it to be considered a stabilized approach. Operators of turbojet aircraft must establish and use procedures which result in stabilized approaches.... A stabilized approach must be established before descending below...1,000 feet above the airport or touchdown zone elevation during any straight-in instrument approach in instrument flight conditions.

On June 26, 1995, the FAA issued FSAT 95-10A, "Instrument Approach Procedures and Training," which contains guidance that "reflects FAA analysis and the latest information and recommendations [from the NTSB] regarding instrument approach procedures." The guidance addresses the "stabilized approach concept," and states the following, in part:

> The "stabilized approach concept" of 8400.10, [paragraph] 511, will be considered essential for safe operations for "**all**" (emphasis added) aircraft in air carrier operations. Moreover, 1,000 feet per minute will normally be considered the maximum allowable for a stabilized approach inside the final approach fix. Descent rates in excess of 1,000 feet per minute will be cause for consideration to abandon the approach.

1.17.2.2 Delta's Actions Regarding Stabilized Approaches

A review of the minutes from Delta's Joint Standards Meetings and flight instructor standards meetings that took place between January 1996 and September 1996 indicated that stabilized approach definition, criteria, and guidance had been a topic of discussion. The minutes from the April 16, 1996, Joint Standards Meeting indicated that an "Old Business" item was a proposal to further define "stabilized approach" in the FOM. The minutes indicated that action would be taken on this item before the next FOM revision.

Since the accident, Delta has issued a revision to chapter 7, "Normal Operations," of the FOM, which states the following, in part:

Stabilized Approach Requirements

Maintaining a stable speed, descent rate, and vertical/lateral flight path in landing configuration is a procedure commonly referred to as the stabilized approach concept. Chapter 21—Training (Pilot Qualification Standards)[42] contains the acceptable parameters for a stabilized approach.

Any significant deviation from planned flight path, airspeed, or descent rate must be verbalized. The decision to execute a go-around is no indication of poor performance.

WARNING

Do not attempt to land from an unstable approach.

IMC

At 1,000 feet AFE, and on final, the aircraft must be:

- Configured for landing.
- Maintaining stabilized descent rate, if descending.
- On target airspeed within tolerance, or speed being reduced toward target airspeed if higher was necessary.

At 500 feet AFE, the aircraft must be:

- Maintaining stabilized descent rate not to exceed 1,000 FPM, if descending.
- On target airspeed within tolerance.
- Established on course.

[42] The guidance and parameters contained in Chapter 21 were previously discussed in section 1.17.2, "Stabilized Approach Criteria."

CAUTION

These conditions must be maintained throughout the rest of the approach for it to be considered a stabilized approach. If the above criteria cannot be established and maintained, at and below 500 feet AFE, initiate a go-around.

VMC....

Crossing the Runway Threshold

As the aircraft crosses the runway threshold it must be:

- Stabilized within tolerance on target airspeed until arresting descent rate at flare.
- On a stabilized flight path using normal maneuvering.
- Positioned to make a normal landing in the touchdown zone (i.e., first 3,000 feet or first third of the runway, whichever is less).

CAUTION

Initiate a go-around if the above criteria cannot be maintained.

Instrument Approach Procedures
General

Use all suitable electronic and visual systems. If an ILS Glideslope or VASI is available, do not descend below the ILS Glideslope prior to the Middle Marker or below the VASI Glideslope until a lower altitude is necessary for a safe landing.

1.17.3 Crew Resource Management (CRM) Training

Safety Board personnel examined Delta's Human Factors/CRM training program and syllabus. According to Delta's training syllabus, the Human Factors/CRM training includes an overview of the background of Human Factors/CRM training followed by discussion of CRM skills and flightcrew roles in areas such as communications, coordination, planning, workload management, situational awareness management, and decisionmaking. Delta's CRM training then focuses on the following seven areas of awareness:

- Crew Specific Behaviors
- Stress
- Fatigue
- Leadership/Followership
- Personality
- Effective Assertion
- Automation Pitfalls

Chapter 23 in Delta's FOM, "Human Factors," states, "CRM develops the skills, techniques, attitudes, and behaviors air crews use to direct, control, and coordinate all available resources towards the safe and effective operation of their aircraft. These skills enhance the safety and effectiveness of your crew (pilots and flight attendants) as well as the expanded team (dispatch, line maintenance, ramp service, etc.)." The FOM further states that the captain's command authority is not lessened by CRM; however, "inquiry, advocacy, and assertion by crew/team members allows for better informed decisions." Delta's FOM indicates that first and second officers should "offer or assert [their] perspective when safety and/or efficiency would be enhanced."

According to Delta's training program development program manager, at the time of the accident, Delta Air Lines provided initial CRM training to newly hired pilots as part of its initial training program. Additionally, pilots received 3 hours of CRM training during the 2-day ground school portion of their annual recurrent training, and CRM issues were emphasized during Delta's captain and first officer upgrade training.

1.18 Additional Information

1.18.1 FAA Oversight of Airman Medical Certification (Vision)

According to the June 1995 FAA Aeronautical Information Manual (AIM), chapter 8, "Medical Facts for Pilots":

> All pilots except those flying gliders and free air balloons must possess valid medical certificates in order to exercise the privileges of their airman certificates. The periodic medical examinations required for medical certification are conducted by designated Aviation Medical Examiners [AMEs], who are physicians with a special interest in aviation safety and training in aviation medicine.
>
> Pilots who do not meet medical standards may still be qualified under special issuance provisions or the exemption process. This may require that either additional medical information be provided or practical flight tests be conducted.
>
> Title 14 CFR 67.19 discusses the special issue of medical certificates as follows:
>
> At the discretion of the Federal Air Surgeon, a medical certificate may be issued to an applicant who does not meet the applicable provisions...if the applicant shows to the satisfaction of the Federal Air Surgeon that the duties authorized by the class of medical certificate applied for can be performed without endangering air commerce during the period in which the certificate would be in force.

1.18.1.1 Vision Requirements for Certification

The standards for pilot medical certification are described in 14 CFR Part 67, which was most recently updated in September 1994. According to Part 67.13, to be eligible for a first-class medical certificate, an applicant must meet the following vision requirements:

1.) Distant visual acuity of 20/20 or better in each eye separately, without correction; or of at least 20/100 in each eye separately corrected to 20/20 or better with corrective lenses (glasses or contact lenses) in which case the applicant may be qualified only on the condition that he wears those corrective lenses while exercising the privileges of his airman certificate.
2.) Near vision of at least v=1.00 at 18 inches with each eye separately, with or without corrective glasses.
3.) Normal color vision.
4.) Normal fields of vision.
5.) No acute or chronic pathological condition of either eye or adenexae that might interfere with its proper function, might progress to that degree, or might be aggravated by flying.
6.) Bifocal fixation and vergencephoria relationship sufficient to prevent a break in fusion under conditions that may reasonably occur in performing airman duties.

According to current FAA medical certification regulations, the FAA may grant any class medical certificate to monocular applicants (applicants with only one usable eye), as long as the applicant demonstrates the required near visual acuity with the usable eye and demonstrates to the satisfaction of the Federal Air Surgeon that the applicant can perform the duties authorized by the class of medical certificate applied for without jeopardizing the public's safety. In response to the Safety Board's request for additional information on medical certification of pilots with one usable eye, the acting manager of the aeromedical certification division of the FAA's Civil Aeromedical Institute (CAMI) submitted the following explanation of FAA policy:

> An airman with one eye, or with effective visual acuity equivalent to monocular (i.e. best corrected distant visual acuity in the poorer eye is no better than 20/200), may be considered for medical certification, any class, through the special issuance procedures of Part 67...if:
>
> I) A 6-month period has elapsed to allow for adaptation to monocularity,
> II) A complete evaluation by an eye specialist, as reported on FAA Form 8500-7, Report of Eye Evaluation, reveals no pathology of either eye which could affect the stability of the findings,
> III) Uncorrected distant visual acuity in the better eye is 20/200 or better and is corrected to 20/20 or better by lenses of no greater power than plus or minus 3.5 diopters spherical equivalent, and
> IV) The applicant passes an FAA medical flight test.

He further stated, "For a binocular applicant, contact lenses that correct near visual acuity only or that are bifocal are not considered acceptable for aviation duties; the first for obvious reasons, the latter because of our concerns for their effectiveness. The use of a contact lens in one eye for distant visual acuity and a lens in the other eye for near visual acuity is not acceptable because this procedure makes the pilot an effective 'alternator,' i.e. a person who uses one eye at a time, suppressing the other. Stereopsis[43] [binocular vision] is lost. Since this is not a permanent condition for either eye in such persons, there is no adaptation such as occurs with permanent monocularity." A copy of the statement is included in appendix D.

In 1968-1969, a U.S. Air Force (USAF) flight research program[44] performed a series of accuracy landing experiments that documented USAF pilots' performance with and without one eye patched, in an attempt to determine the degree of impairment experienced by pilots as a result of loss of binocular vision. The USAF report stated that in general, the pilots who participated in the experiments experienced a sense of diminished brightness, a marked lack of confidence in their ability to accurately judge height, and a significant increase in workload during monocular landings. The USAF analysis of the data gathered resulted in the following conclusions:

1. Spot landing performance in jet aircraft is not adversely affected by the sudden total loss of vision in either eye. This observation has important implications with regard to aeromedical standards.
2. Significantly steeper approaches are observed during monocular landings than those observed during approaches made with normal vision. It is suggested that the pilots' lack of confidence in their ability to accurately judge height during monocular approaches was responsible for the steeper approaches reported.
3. Eye dominance is shown not to affect monocular landing performance (95% level of confidence).
4. Noticeable increases in pilot workload are subjectively reported during monocular landings.
5. It is suggested that monocular pilots may not experience significant losses in their "functional" visual field; a definitive study is indicated.

The USAF report recognized that the experiments did not address the "problem of restricted peripheral vision" on the blinded side, and indicated that future studies should address that issue. A copy of the USAF results is included in appendix D.

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[43] According to T. J. Tredici, stereopsis "...is the visual appreciation of three dimensions during binocular vision, occurring during fusional signals from slightly disparate retinal points, which cause different retinal images in each eye... ." For the remainder of the report, the term "binocular vision" will be used to indicate stereopsis.

[44] Lewis, C.E. Jr., Krier, G.E. Flight Research Program XIV: Landing performance in jet aircraft after the loss of binocular vision. Aerospace Medicine, September 1969.

1.18.1.2 Information/Guidance Available to AMEs and Optometrists

According to the FAA's September 1996[45] Guide for Aviation Medical Examiners, the Federal Air Surgeon has determined that applicants for a first- and/or second-class medical certificate must demonstrate at least 20/20 distant visual acuity and 20/40 near visual acuity with each eye separately, with or without correction. Applicants for a third-class medical certificate must demonstrate a near visual acuity of at least 20/60 in each eye separately, with or without correction. The Guide contains the following guidance for AMEs with reference to an applicant's need for corrective glasses/lenses and the resultant flight limitations:

> When correcting glasses are required to meet the near vision standards, an appropriate limitation will be placed on the medical certificate. Contact lenses that correct only for near visual acuity are not considered acceptable for aviation duties.
>
> If the applicant meets the uncorrected near vision standard of 20/40, but already uses spectacles that correct the vision better than 20/40, it is recommended that the Examiner enter the limitation for near vision corrective glasses on the certificate.
>
> **The use of a contact lens in one eye for distant visual acuity and another in the other eye for near visual acuity [monovision contact lenses] is not acceptable** (emphasis added).
>
> For all classes, the appropriate wording for the near vision limitation is "Holder shall possess corrective glasses for near vision." Possession only is required, **because it may be hazardous to have distant vision obscured by the continuous wearing of reading glasses** (emphasis added).
>
> For combined defective distant and near visual acuity when unifocal glasses or contact lenses are used and correct both, the appropriate limitation is: "Holder shall wear corrective lenses."

The September 1996 Guide for Aviation Medical Examiners also contained the following information concerning contact lens use:

> Experience has indicated no significant risk to aviation safety in the use of contact lenses for **distant** vision correction. As a consequence, no special evaluation is routinely required before the use of contact lenses is authorized, and no [Statement of Demonstrated Ability] SODA is required or issued to a

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[45] The information contained in the September 1996 Guide for Aviation Medical Examiners is consistent with the information available to the AME who issued the captain's most recent medical certificate.

> *contact lens wearer who meets the standards and has no complications.* **Contact lenses that correct near visual acuity only or that are bifocal are not considered acceptable for aviation duties. Similarly, the use of a contact lens in one eye for distant visual acuity and a lens in the other eye for near visual acuity is not acceptable.** (Emphasis added.)

The AME who had examined the captain for airman medical certification indicated that although he was not specifically aware that MV contact lenses were not approved for use while flying, if the issue had come up with airman medical certificate applicants, he would have advised them not to use MV correction when flying. He did not recall discussing MV correction with the captain; further, he indicated that it was unlikely that such a discussion took place, because he did not know that the captain possessed contact lenses.

Although corrected and uncorrected vision testing is included in the airman medical certificate examination, AMEs are not required to ask pilots whether they possess/wear contact lenses; pilots who require vision correction are required to bring contact lenses **or** glasses to the examination. Additionally, although the airman medical certificate application, FAA Form 8500-8, contains numerous questions concerning the applicant's medical history, the application does not ask whether the applicant uses contact lenses. The AME who examined the captain reported that if he was aware that a pilot wore contact lenses, he would ask that pilot to bring the contact lenses to his or her examination; otherwise (as occurred when the captain was examined), the pilots generally brought their glasses.

According to several optometrists interviewed during this investigation, no published information tells optometrists that the use of MV contact lenses by pilots while flying is prohibited. The literature on MV contact lenses provided to optometrists by one manufacturer (for distribution to patients) indicated, "Monovision is a contact lens fitting technique that lets you see clearly both near and far...without the bother of bifocals," and did not refer to any hazards or contraindications. A copy of the literature on MV contact lenses is included in appendix D.

1.18.2 Information on Monovision (MV) Contact Lenses

Optometrists indicated that traditionally, bifocal, and even trifocal, spectacles have been prescribed for individuals who need both distant and near vision correction. However, they indicated that with increasing frequency, optometrists are prescribing MV contact lenses in place of bifocal spectacles for these individuals.

According to USAF medical personnel,[46] when an individual has symmetrical binocular vision, the brain fuses the two images presented by the eyes into a single image,

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[46] Brooks Air Force Base personnel, including Jose L. Perez-Becerra, Lt. Col., USAF, FS (Staff Ophthalmologist); Thomas J. Tredici, M.D. (Senior Scientist); and Douglas J. Ivan, Col., USAF, MC, CFS (Chief, Ophthalmology Branch).

resulting in three-dimensional vision, which aids in the determination of distance from objects in the environment (depth perception). USAF medical personnel also reported that although the brain is able to fuse the images presented through bifocal spectacles normally, it is unable to fuse the disparate images presented through MV contact lenses normally, which can result in monocular vision in individuals wearing MV contact lenses. Additionally, the USAF medical personnel indicated that the eye wearing MV contact lens correction for near vision will present a blurred image to the brain when used for distance vision; although the brain will try to accommodate by "suppressing" the blurred image, that accommodation is rarely complete.

USAF research personnel indicated that stereoscopic vision is normally most critical in determining the distance from objects close to an individual, although stereoscopic vision is generally accurate to distances of up to 600 feet. They stated that beyond about 20 to 25 feet, monocular cues,[47] such as comparative size, motion parallax, interposition, texture, convergence, and perspective, usually assume an increasing role in the judgment of distance. Because the use of MV contact lenses results in degraded depth perception and occasional blurred images, an individual wearing MV contact lenses will rely more heavily on monocular cues under all circumstances to judge distance than an individual wearing binocular vision correction.

1.18.2.1 The Captain's Use of Monovision Contact Lenses

According to the AME who had routinely examined the captain for airman medical certification since 1984, the captain had 20/20 vision in both eyes until 1989. Records indicate that since 1989, the captain's distance vision remained 20/20 without correction, but his near vision worsened. The AME stated that before the accident occurred, he believed that the captain corrected his near vision with glasses.

According to the captain's optometrist, the captain became a client in February 1990 and first obtained MV contact lenses in 1991. The optometrist indicated that a lot of his patients were airline pilots, and he knew that the captain was an airline pilot before the accident occurred. He further stated that he was unaware that the use of MV contact lenses while flying was not approved. The optometrist told investigators that in general, he felt "someone in a position of public safety" should use bifocal correction (spectacles) rather than MV contact lenses. He further stated that binocular vision correction would be preferable for pilots while performing flying duties, because there is a need for stable near and distant vision in cockpit situations. He reported that a pilot's use of MV contact lenses could impair sink rate perception, depth perception at some distances, and scanning vision, especially on the side with near vision correction. The captain of Delta flight 554 had near vision correction in the left lens.

The optometrist stated that MV contact lenses can impair depth perception, especially at distances of less than 20 to 25 feet. He further indicated that the impairment resulting from using MV contact lenses could make it more difficult to land a small airplane or

[47] Monocular cues are depth cues that do not require binocular vision.

parallel park a car; in his opinion, the use of MV contact lenses should not adversely affect depth perception at distances greater than 25 feet. The optometrist did not perform a depth perception test on the captain.[48] The optometrist did not specifically recall discussing the limitations of MV contact lenses with the captain when he first prescribed the lenses, and his medical notes did not indicate that he discussed the issue with the captain.

According to the captain, he began using MV contact lenses several months after he began using glasses. He indicated that he had been using either bifocal spectacles or MV contact lenses with distance and near vision correction since 1990. He stated that he became accustomed to the MV contact lenses easily, and that he had not perceived any deficiency in vision or depth perception when wearing the MV contact lenses. The captain reported that he used the MV contact lenses interchangeably with the glasses for general use, and that he used MV contact lenses for vision correction approximately 75 percent of the time that he flew. The captain indicated that he had not noted any problems wearing the contact lenses while driving or flying. He stated that because he had flown with FAA medically certificated pilots who operated with what he considered to be a worse deficiency (pilots with only one usable eye), he had believed that MV contact lenses would be acceptable for use by pilots while flying. He stated that he was unaware that MV contact lenses were not approved for use by pilots while flying.

1.18.2.2 Captain's Postaccident Vision Test Results

In an attempt to determine whether the captain's use of MV contact lenses was an issue in the accident, the Safety Board requested a complete ophthalmological evaluation of the captain's vision and depth perception. The captain's vision, fusion, and binocular vision were tested and documented under the following conditions: uncorrected, corrected with bifocal spectacles, and corrected with MV contact lenses.

According to the results of the examination, the captain's uncorrected distance vision in both eyes was 20/20 and his uncorrected near vision in both eyes was 20/70. He had fusion of binocular images at all distances;[49] however, his uncorrected near binocular vision (200 seconds/15° of arc) was below the norm,[50] and his uncorrected distance binocular (120 seconds) was only one increment better than the worst measurement unit.[51]

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[48] For details on the captain's postaccident vision test results, including depth perception, see section 1.18.2.2.

[49] The Worth 4 dot method was used to evaluate fusion.

[50] The Titmus method measurements are as follows: best = 40 seconds/15° of arc, norm = 40 seconds/15° of arc, and worst = 800 seconds/15° of arc.

[51] Binocular vision was measured by the Titmus (near) and BVAT (distant) methods. According to the ophthalmologist who examined the captain, although the Titmus method has a well-established and accepted norm, the norm for the BVAT method is not as well standardized. However, BVAT units of measurement double in incremental increase; the best and worst measurements are 15 seconds and 240 seconds, respectively.

Additionally, the examination revealed that the captain's corrected vision using bifocal spectacles was 20/20 in both eyes for both near and distant vision; he had fusion of binocular images at all distances; his near binocular vision (40 seconds/15° of arc) was documented at the best increment; and his distance binocular vision (120 seconds) was one increment better than the worst measurement unit.

Finally, the ophthalmologist evaluated the captain's vision corrected by MV contact lenses, with the right eye contact lens correcting for distance vision and the left eye contact lens correcting for near vision. The results indicated that the captain's distance vision was 20/20 +2 in the right eye and 20/30 in the left eye, and his near vision was 20/50 in the right eye and 20/20 in the left. The captain had normal fusion at 3 feet; however, at 20 feet he exhibited suppression of the left eye. The captain's near and distant binocular vision using MV contact lenses was one increment worse than it was using bifocal spectacles.

1.18.2.3 General Aviation Accident Involving Monovision Contact Lenses

During the investigation, the Safety Board became aware of a general aviation accident previously investigated by the Safety Board that occurred on February 15, 1996. The general aviation accident involved a private pilot operating a Cessna 210 in degraded day VMC (low clouds and light snow) near Shelbyville, Illinois.[52] The private pilot told the Safety Board that he "didn't pull the nose up" during the landing; the airplane bounced, and then touched down on and blew the nose landing gear tire. The Safety Board determined that the probable cause of the accident was "the pilot's misjudged flare and improper recovery from a bounced landing. Factors relating to the accident were: the pilot's improper use of procedure by wearing unapproved correcting lenses, and his resultant decreased depth perception."

According to a flight instructor who was hired by the private pilot to help him prepare for a postaccident FAA flight evaluation, the private pilot exhibited a consistent tendency to begin the landing flare too close to the ground and had difficulty landing with crosswinds. On July 16, 1996, when the private pilot returned to his AME to renew his medical certificate, the AME noticed the pilot's use of MV contact lenses. The AME informed the private pilot that MV contact lenses were not approved for use by pilots while flying; the pilot returned with his eyeglasses, and the medical examination was successfully completed. The flight instructor stated that the pilot's landings "improved suddenly and dramatically upon switching back to glasses." The private pilot indicated that he had been wearing MV contact lenses when the accident occurred.

Postaccident interviews with the private pilot's optometrist revealed that he had prescribed MV contact lenses for the pilot in March 1995. Both the private pilot and the optometrist indicated that they were unaware of the prohibition against the use of MV contact lenses by pilots while flying until the pilot visited the AME after the accident.

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[52] For more detailed information, see Brief of Accident CHI96LA089.

1.18.2.4 Postaccident Delta Air Lines Actions Regarding MV Contact Lenses

Delta records indicate that after this accident occurred, the company issued a mandatory electronic flight operations bulletin alerting its pilots and medical personnel about the hazards of MV contact lens use by flightcrew members. The mandatory electronic flight operations bulletin will show up when a pilot checks in on the computer before the next flight; the pilot must indicate that he/she has read the bulletin before he/she can continue to check in for the flight.

1.18.3 Information on Visual Cues/Illusions

According to the FAA AIM, many different visual illusions experienced in flight can lead to spatial disorientation, landing errors, and even accidents. Section 8-1-5 of the AIM, dated July 20, 1995, states the following:

> Various surface features and atmospheric conditions encountered in landing can create illusions of incorrect height above and distance from the runway threshold. Landing errors from these illusions can be prevented by anticipating them during approaches, aerial visual inspection of unfamiliar airports before landing, using electronic glide slope or VASI systems when available, and maintaining optimum proficiency in landing procedures.

Section 8-1-5 describes several specific types of illusions, including featureless terrain illusion, atmospheric illusions, and ground lighting illusions. These illusions are described as follows:

> (d) ***Featureless terrain illusion:*** An absence of ground features, as when landing over water, darkened areas, and terrain made featureless by snow, can create the illusion that the aircraft is at a higher altitude than it actually is. The pilot who does not recognize this illusion will fly a lower approach.
>
> (e) ***Atmospheric illusions:*** Rain on the windscreen can create the illusion of greater height, and atmospheric haze the illusion of being at a greater distance from the runway. The pilot who does not recognize these illusions will fly a lower approach. Penetration of fog can create the illusion of pitching up. The pilot who does not recognize this illusion will steepen the approach, often quite abruptly.
>
> (f) ***Ground lighting illusions:*** Lights along a straight path, such as a road, and even lights on moving trains can be mistaken for runway and approach lights. Bright runway and approach lighting systems, especially where few lights illuminate the surrounding terrain, may create the illusion of less distance to the runway. The pilot who does not recognize this illusion will fly a higher approach. **Conversely, the pilot overflying terrain**

which has few lights to provide height cues may make a lower than normal approach. (Emphasis added.)

As the pilots descended out of the clouds during their approach to land on runway 13, they were in heavy rain conditions, with the windshield wipers operating at the highest setting. The captain reported that visibility through the windscreen was limited to the arc of the windshield wipers, with rain obscuring the side windows. The estimated RVR for runway 13 was 3,000 feet, with limited visibility because of fog. According to *Fundamentals of Aerospace Medicine*,[53] a perception of a shortened runway, with part of the length obscured by fog and/or rain, might result in an illusion of "size constancy," in which a pilot perceives the runway as more distant than it is.

1.18.4 Information Regarding Special Airports

1.18.4.1 FAA Information Regarding Special Airports

According to 14 CFR 121.445, "Pilot in command [PIC] airport qualification: Special areas and airports," the FAA Administrator "may determine that certain airports (due to items such as surrounding terrain, obstructions, or complex approach or departure procedures) are special airports requiring special airport [airman] qualifications... ." The regulation further states,

> no certificate holder may use any person, nor may any person serve, as pilot in command to or from an airport determined to require special airport [airman] qualifications unless, within the preceding 12 calendar months:
>
> (1) The pilot in command or second in command has made an entry to that airport (including a takeoff and landing) while serving as a pilot flight crewmember; or
> (2) The pilot in command has qualified by using pictorial means acceptable to the Administrator for that airport.
>
> ...this section does not apply when an entry to that airport (including a takeoff or a landing) is being made if the ceiling at that airport is at least 1,000 feet above the lowest MEA [minimum en route altitude] or MOCA [minimum obstruction clearance altitude], or initial approach altitude prescribed for the instrument approach procedure for that airport, and the visibility at that airport is at least 3 miles.

On June 20, 1990, the FAA published AC 121.445-1D, which provides information concerning the routes and airports where the FAA has determined that pilots require

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[53] DeHart, R. L. *Fundamentals of Aerospace Medicine*. Baltimore: Williams & Wilkins, 1996.

special qualifications to operate as pilot in command. Page 2 of AC 121.445-1D, under the heading "Special Airports," states the following:

> Appendix 1 contains a listing of airports, by regions, where it has been determined that pilots require special airport qualifications. FAR Section 121.443 ["PIC qualification: Route and airports"] requires, in part, for each certificate holder to provide a system acceptable to the Administrator for disseminating the information required therein to ensure that the pilots have adequate knowledge concerning the areas, and each airport and terminal area into which the pilot is to serve. Therefore, airports with congested areas and physical layouts such as John F. Kennedy in New York and O'Hare Field in Chicago, which do not have terrain problems, are not included.

Page 3 of AC 121.445-1D states the following, in part:

> Air carriers are encouraged to recommend additions or deletions to these listings. Recommendations, along with an explanation of the need for the addition or deletion, should be submitted to the assigned Principal Operations Inspector. The Principal Operations Inspector will forward the recommendation with his/her comments to his/her regional Flight Standards Division. The regional Flight Standards Division will provide updated information on these listings, as changes occur, to the Air Transportation Division, AFS-200, who will make appropriate changes periodically.

During postaccident interviews, the first officer indicated that he believed that LaGuardia should be classified as a special airport because a pilot landing at the airport for the first time might have difficulty with the nature of the approaches and the traffic density. He pointed out, "the visual approach to Runway 31 requires maneuvering the airplane at high bank angles close to the ground [and] the approach to Runway 13 requires landing over water, a 250 foot DH, and an offset localizer." LaGuardia was not designated a special airport in appendix 1 of the AC. Airports listed in appendix 1 of the AC were considered to be special airports for a variety of reasons, including the following:

- <u>Terrain issues</u>—"Mountainous terrain;" "mountainous terrain in immediate vicinity of airport, all quadrants;" "mountainous terrain on both sides of final approach;" "airport is surrounded by mountainous terrain. Any go-around beyond ILS...MAP will not provide obstruction clearance;" "runway located on mountain slope with high gradient factor;" "special conditions due to precipitous terrain;" "high terrain;" "high field elevation;" "high altitude requires special performance;" "lake effect upon thermals on short final [approach];" "mountainous to 2,300 feet within 3 miles of the localizer."
- <u>ATC/Approach/Departure issues</u>—"Special arrival/departure procedures;" "unique arrival/departure procedures;" "unique approach;" "complex ATC procedures;" "limited approach facilities;" "complex departure procedures;"

"all nonprecision approaches;" "no [air traffic control] tower;" "no approach control;" "traffic complexity;" "traffic density;" "no radar environment."

- Other issues—"Political sensitivity of corridor adherence;" "limited information."

The FAA's special assistant for air carrier operations indicated that at the time of the accident, no criteria were published designating special airports, and he did not believe that such criteria had ever existed. He stated that in October 1996, the FAA met with industry representatives and developed a list of criteria based on factors such as accident histories, human performance concerns, and runway anomalies that the FAA could use to develop objective criteria for designating special airports. He stated that he hoped the FAA would develop a procedure to add or remove airports from the special airport list and publish criteria for special airport designation.

1.18.4.2 Delta's Information Regarding Special Airports

According to Delta's FOM, the following airport destinations are FAA-designated Class I special airports:

> Asheville, North Carolina; Wilkes Barre/Scranton, Pennsylvania; Birmingham, Alabama; Burlington, Vermont; Burbank, California; Washington, D.C. (National Airport); Guadalajara, Mexico; Hilo, Hawaii; Ketchikan, Alaska; Harrisburg, Pennsylvania; Kahului, Hawaii; Ontario, California; Palm Springs, California; Reno, Nevada; San Diego, California; Sondre Stromfjord, Greenland; San Francisco, California; Sitka, Alaska; Stuttgart, Germany; St. Thomas, Virgin Islands; and airports in the Peoples Republic of China.

The following Class II special airports (FAA designated, with additional Delta requirements) are listed in Delta's FOM:

> Eagle, Colorado; Gunnison, Colorado; Jackson Hole, Wyoming; and Missoula, Montana.

Juneau, Alaska, was listed in the Delta FOM as a Class III special airport (FAA designated, with lower-than-published minimums authorized), and the Class IV special airports (Delta designated) were Kalispell, Montana; Helena, Montana; and Mexico City, Mexico. According to Delta's FOM, Class II and Class III special airports and Mexico City, Mexico, have more rigorous flightcrew member initial qualification and currency requirements, which include a review of pictorial, video, or Qualification Manual information concerning the specific airport and an initial special airport entry flight under the observation of a company line check airman. In addition, Class II and Class III special airport qualifications are aircraft specific.

2. ANALYSIS

2.1 General

The pilots held appropriate flight and medical certificates; they were trained and qualified for the flight and were in compliance with the Federal regulations on flight and duty time. However, the captain was using monovision (MV) contact lenses, which were not approved by the FAA for use by pilots while flying. The captain indicated in postaccident interviews that he was not aware that MV contact lenses were not approved for use while flying.

The flight attendants had completed Delta's FAA-approved flight attendant training program.

The airplane was properly certificated, and there was no evidence that airplane maintenance was a factor in the accident.

A review of ATC procedures revealed that the controllers followed proper air traffic separation rules, and air traffic separation was assured during flight 554's approach to the runway. In addition, ATC provided the pilots with timely weather (rain and visibility) information during their approach to runway 13. No ATC factors contributed to the cause of the accident.

Although the pilots did not receive several pieces of weather information, Delta Air Lines provided the pilots with sufficient preflight, en route, and arrival weather information to allow them to conduct the flight safely; however, because of rapidly changing surface conditions, the conditions they encountered differed from what was forecast.

Although the pilots encountered a low cloud ceiling and degraded visibility, the ceiling and visibility were still above the minimums required for the ILS approach. The Safety Board concludes that although the weather conditions encountered by the pilots during the approach differed from the forecast conditions, these conditions should not have affected the pilots' ability to conduct a safe approach and landing.

The pilots reported that they did not encounter much turbulence after they descended through 3,000 feet on the approach, and the recorded wind speeds were less than expected. FDR data from flight 554 and four other airplanes that made the approach to runway 13 between 9 minutes before and 1 minute after the accident disclosed no evidence of significant windshear. Additionally, no pilot reports of windshear, LLWAS windshear alerts, or wind gusts were recorded during the 50 minutes preceding the accident. Therefore, the Safety Board concludes that Delta flight 554 did not encounter windshear during its approach to runway 13 at LaGuardia.

The pilots performed the instrument approach to runway 13 in low clouds, moderate-to-heavy rain, fog, and in limited light conditions.

Although the pilots did not observe the VASI lights during the approach to runway 13, postaccident examination revealed that the VASI light system was capable of normal operation at the time of the accident. Although it is likely that the runway 13 VASI light system was operating normally when the accident occurred, with the reduced visibility that existed at the time of the accident, the pilots would not have been able to utilize descent path guidance from the VASI light system until late in the visual phase of the approach, and then only if they sought such guidance.

2.2 The Accident Scenario

2.2.1 The Approach and Descent

The pilots reported that the departure, en route, and initial approach portions of the flight were routine. The CVR transcript indicated that after Delta flight 554 had been cleared to land on runway 13, the flightcrew of TWA 8630, which was departing from runway 13, advised ATC that it was aborting its takeoff roll on the runway. ATC asked the TWA pilots to expedite their turn off the runway, so that Delta flight 554 would not have to execute a missed approach.

About 20 seconds after their decision to abort the takeoff, the pilots of TWA 8630 reported that they were "turning off," and LaGuardia ATCT responded, thanking them. About 5 seconds later, TWA 8630 was off of runway 13 and was taxiing southwest on runway 22 towards taxiway Golf; however, during postaccident interviews, the captain of Delta flight 554 stated that he was uncertain if the TWA airplane had yet cleared runway 13.

During the seconds after TWA 8630 had aborted its takeoff roll, the CVR recorded an expletive on the Delta flight 554 captain's channel. The captain stated that he made the expletive comment because he believed he might have to perform a missed approach because of the airplane on the runway; he reported that he was not certain that he would be landing until he established visual contact with the approach lights.

Based on the FDR data and calculated descent rate information, the airplane was established in the landing configuration (flaps and landing gear extended), on target airspeed (+/- 4 knots), with an average rate of descent of about 750 feet per minute, and was established on the localizer and electronic glideslope (+/- 1/10 of a dot) from the time it descended through about 1,000 feet agl (at 1637:05) until it reached an altitude of 431 feet agl (approximately 1638:02). Between 1638:02 and 1638:08, the airplane's rate of descent decreased, and the airplane began to deviate above the glideslope; however, at 1638:09 (just before the airplane exceeded 1 dot deviation above the electronic glideslope), the captain applied nose-down elevator, and the airplane began to pitch down. The momentary reduction in descent rate occurred when the captain later stated that he had been uncertain if TWA 8630 would clear runway 13 in time for flight 554 to land, and it may have been the result of the captain's anticipation of (and preparation for) a missed approach.

Regardless of the reason for the reduction in the descent rate, by the time the airplane began to deviate more than 1 dot above the electronic glideslope (at 1638:10), it appears that the captain had recognized the deviation and had applied correction in an attempt to reestablish the airplane on the glideslope. According to the FDR data, about 1638:14, the engine thrust reduced and the descent rate increased slightly; however, the airplane did not reintercept the electronic glideslope. FDR data indicated that from 1638:14 until 1638:26, the airplane's airspeed and descent were generally steady and on target, and the airplane was in a position from which a successful landing could be made. At 1638:21, as the airplane descended through 200 feet agl, the pilots were in (degraded) visual conditions; they were aware that guidance from the electronic glideslope was unusable below 200 feet agl; and they were using other cockpit instrumentation and outside visual references for glidepath information. The Safety Board concludes that because the airplane was in stable flight and the captain had taken actions to correct for a glideslope deviation, the captain's continuation of the approach after he established visual contact with the approach lights was not inappropriate.

About 10 seconds before impact, just after the first officer called "sink's seven hundred," the airplane's rate of descent began to increase. According to FDR data, the airplane's calculated sink rate at that time was actually about 1,200 feet per minute. The difference between the 700 feet per minute rate of descent reported (and presumably observed on the VSI) by the first officer, and the 1,200 feet per minute rate of descent indicated by the FDR data was probably the result of the lag time in the non-instantaneous vertical speed information displayed on the VSI. (This issue is discussed in greater detail in section 2.5.)

FDR data indicated that about 10 seconds before impact, the engine power was reduced gradually (from 1.2 EPRs at 1638:22, to 1.15 EPRs at 1638:28, to 1.09 EPRs at 1638:31). During this period, the elevator position oscillated, averaging between 2° nose up to about 8° nose up. The Safety Board concludes that the captain gradually reduced the engine power because he perceived a need to slightly increase the airplane's rate of descent; however, the descent rate increased beyond what the captain likely intended to command. At 1638:30, the airplane's descent rate was about 1,500 feet per minute. By 1638:32, the captain had recognized that corrective action was required and was increasing the nose-up elevator deflection and increasing the engine power.[54] About 2 to 3 seconds before the initial impact, the airplane was descending about 1,800 feet per minute; however, the trend in vertical velocity started to reverse.

According to the first officer, several seconds before impact he glanced outside and realized that the airplane was descending short of the runway, and at 1638:33.7, he stated, "Nose up...nose up." The first officer stated that the captain had already added power and the nose of the airplane pitched up; however, it was too late to avoid the accident.

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[54] At 1638:32, the EPRs began to increase rapidly (from 1.10 EPRs at 1638:32, to 1.15 EPRs at 1638:33, to 1.25 EPRs at 1638:34, and to 1.55 EPRs at 1638:35).

2.2.2 The Landing

The Safety Board sought to determine why the descent rate of flight 554 continued to increase until a safe landing could no longer be achieved. The Safety Board analyzed the visual cues in the airport environment, including the airport lighting system and the effect of the weather at the time of the accident, the effect of the captain's vision limitations, and the first officer's actions and input to the captain during the last 10 seconds of the flight.

The pilots performed the instrument approach and landing in low clouds, moderate-to-heavy rain and fog (which obscured the VASI lights and the runway environment), and in limited light conditions. In addition, the pilots indicated that when they descended out of the clouds, the airplane was positioned over the waters of Flushing Bay (which appeared gray), with no visible structures to aid in visually judging distance and/or altitude. Although the weather conditions were sufficient for the approach to be made safely, the low overcast cloud layer and heavy rain and fog encountered by flight 554 during its approach to runway 13 degraded visual cues that the captain might otherwise have used to gauge the airplane's rate of descent/descent path during the visual portion of the approach.

As discussed in section 1.18.3, according to the FAA AIM, visual illusions that might lead a pilot to perceive that the airplane is higher or more distant from the runway than it is during an approach can result from the following conditions:

- an absence of ground features [as when landing over water]
- rain on the windscreen
- atmospheric haze/fog
- terrain with few lights to provide height cues

The Safety Board notes that all of these conditions were present when the pilots of Delta flight 554 descended out of the overcast cloud layer and the captain transitioned to visual conditions. According to FAA and medical publications[55] on the subject of visual illusions, these conditions could result in improper perception of altitude and descent path; specifically, a pilot might perceive the altitude to be higher than the airplane's actual altitude, especially during periods of reduced visibility, when other visual cues are not available.

Further, the runway 13 edge lights were spaced irregularly—most of the lights were spaced at intervals less than the maximum interval of 200 feet set forth in AC 150/5340-24—and the departure end of runway 13 was obscured by rain and fog, so the pilots were visually presented with a foreshortened runway. Pilots who are accustomed to operating into airports at which runway lights are spaced at consistent 200-foot intervals might perceive their distance and angle to the runway differently when presented with runway lights spaced at shorter, irregular intervals.

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[55] FAA AIM and *Fundamentals of Aviation Medicine*.

The Safety Board concludes that the irregular and shortened runway edge light spacing and degraded weather conditions can result in a pilot making an unnecessarily rapid descent and possibly descending too soon, especially in the absence of other visual references or cues. Therefore, the Safety Board believes that the FAA should identify Part 139 airports that have irregular runway light spacing, evaluate the potential hazards of such irregular spacing, and determine if standardizing runway light spacing is warranted.

Although the airport and weather conditions that existed at the time of the accident combined with the irregular (and shortened) spacing of the runway lights presented a potential challenge for any pilot landing on runway 13, other airplanes used the ILS DME approach to runway 13 around the time of the accident and landed without incident. In an effort to understand why the captain of Delta flight 554 was unable to land safely, the Safety Board analyzed the effect that his use of MV contact lenses had on his vision under those conditions.

Individuals with normal binocular vision use both binocular and monocular cues for depth perception. Although binocular vision is generally accurate to distances of up to 600 feet, binocular cues are most critical in determining the distance from objects close to an individual, while monocular cues assume an increased role in the perception of distances from objects farther away. The Safety Board concludes that the captain's use of MV contact lenses resulted in his (unrecognized) degraded depth perception, and thus increased his dependence on monocular cues (instead of normal three-dimensional vision) to perceive distance. However, because of the degraded conditions encountered by flight 554, the captain was not presented with adequate monocular cues to enable him to accurately perceive the airplane's altitude and distance from the runway during the visual portion of the approach and landing. This resulted in the captain's failure (during the last 10 seconds of the approach) to either properly adjust the airplane's glidepath or to determine that the approach was unstable and execute a missed approach.

The unnecessary increase in descent rate 10 seconds before impact is consistent with the captain's degraded binocular vision, because it suggests that he had the impression that the airplane was slightly higher than it actually was. A flying pilot with normal depth perception might have perceived the airplane's increasingly excessive sink rate earlier and either slowed the rate of descent to make a normal landing possible or performed a missed approach. However, the captain did not have normal depth perception and did not recognize that anything was wrong with the approach until about 4 seconds before the accident, when the "aim point shifted down into the lights." The captain applied engine power and pitched up and the airplane's rate of descent began to decrease; about 2 seconds later, the airplane struck the approach lights and then the runway deck, where the main landing gear separated from the airplane.

The Safety Board concludes that because of the captain's use of MV contact lenses, he was unable to overcome the visual illusions resulting from the approach over water in limited light conditions (absence of visible ground features), the irregular spacing of the runway edge lights at shorter-than-usual intervals, the rain, and the fog, and that these illusions led the captain to perceive that the airplane was higher than it was during the visual portion of the approach, and thus, to his unnecessarily steepening the approach during the final 10 seconds before impact.

The first officer stated that during the visual portion of the descent and landing he primarily monitored the cockpit instrumentation, provided the captain with feedback based on that information, and glanced outside occasionally to monitor the approach visually, while the captain flew the approach primarily using outside visual references. As stated earlier, at 1638:26, when the first officer advised the captain "sink's seven hundred," the airplane was actually descending about 1,200 feet per minute. The first officer stated that he never observed a descent rate indication on the VSI of more than 1,000 feet per minute during the approach descent. Had the first officer called out information from the airplane's radar altimeter,[56] it would have helped one or both of the pilots perceive the airplane's actual descent rate; however, the first officer did not (and was not required by Delta to) call out radar altimeter information (because he either did not look at it, or did not perceive the importance of that information) during the approach.

The first officer told Safety Board investigators that he believed that Delta's manuals did not contain clearly defined guidance regarding PNF duties during a CAT I ILS approach once the PF established ground contact. The first officer indicated that during the approach to runway 13, he followed his own "unofficial" procedures; he primarily monitored the cockpit instrumentation, provided the captain with feedback based on that information, and glanced outside occasionally to monitor the approach visually while the captain flew the approach primarily using outside visual references. The Safety Board notes that after the captain (PF) reported that he had the approach lights in sight, there were several occasions when the first officer (PNF) attempted to provide the captain with useful feedback (i.e., speed's good, sink's 700, a little slow, nose up), which was not specifically required by Delta's manuals, before the airplane struck the runway deck. The Safety Board concludes that during the visual portion of the approach, when the captain was primarily relying on visual cues, the first officer, who was primarily monitoring cockpit instrumentation to gauge the airplane's position with regard to the runway, provided input to the captain that surpassed what was set forth in the guidance available to the pilots at that time.

2.3 Delta's Flightcrew Procedures

When the first officer observed "sink's seven hundred" in an attempt to provide the captain with useful vertical speed information during the approach, he unintentionally provided the captain with misleading vertical speed information because of the 4-second lag time inherent in the VSI as it was installed in the airplane. Use of radar altitude would have been more useful, and more correct. If Delta's manuals had contained either specific PNF callout instructions using radar altimeter information (i.e., altitudes of 300, 200, 100, 50, 40, 30, 20,

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[56] The altitude information displayed on the radar altimeter would represent the airplane's radar altitude above the water (not the runway) until the airplane crossed the edge of the runway deck. However, because the runway 13 touchdown zone elevation is only 13 feet above the water level, it is likely radar altimeter information would have helped the pilots perceive the airplane's actual descent rate.

10...), or a specific scan policy to ensure that someone was focused on airspeed, altitude and approach profile, the first officer probably would have provided the captain with information that would have been useful in determining the airplane's position (and rate of change of position) relative to the runway. Therefore, the Safety Board concludes that the Delta manuals were not sufficiently specific regarding PNF duties during CAT I ILS approaches after the PF establishes visual contact with the ground. (The Safety Board recognizes that Delta is revising PF/PNF CAT I ILS duties listed in its manuals and related pilot training to include specific scan policy guidance.)

In addition, Delta's manuals did not specify operational criteria for a stabilized approach, nor did they contain procedural guidance for pilots to follow if an approach became unstabilized. The guidance and definitions that did exist regarding stabilized approach criteria and procedures were either unclear or difficult to locate (the only guidance pertaining to "unstabilized approaches" was located in the Supplemental Information section, under "Wind shear Guidance"). Further, the manuals did not contain specific, accessible procedural guidance about what action a pilot should take if an unstabilized condition developed during an otherwise stabilized approach. However, as previously noted, the captain flew a stabilized approach until about 1 second before he reported that he had the approach lights in sight (by which time the airplane had deviated more than 1 dot above the electronic glideslope), and then he promptly began to take corrective action. Therefore, the Safety Board concludes that although Delta's manuals did not adequately specify operational criteria for a stabilized approach, the lack of guidance in this area did not contribute to the accident.

The Safety Board notes that Delta personnel had discussed the lack of adequate information concerning stabilized approaches before the accident, and revisions to the manuals were being prepared when the accident occurred. Delta's revised manuals now contain more thorough information and criteria concerning stabilized approaches. However, the Safety Board is concerned that if Delta's manuals contained inadequacies in these "safety of flight" areas other air carriers' manuals might also be inadequate. Therefore, the Safety Board believes that the FAA should require all 14 CFR Part 121 and 135 operators to review and revise their company operations manuals to more clearly delineate flightcrew member (pilot flying/pilot not flying) duties and responsibilities for various phases of flight, and to more clearly define terms that are critical for safety of flight decisionmaking, such as "stabilized approach."

2.4 Availability of Information About the Hazards of Monovision Contact Lenses

The AME who examined the captain reported that he was unaware that the captain used MV contact lenses; he indicated that it would never have occurred to him that the captain might use MV contact lenses, because the captain's vision did not indicate the need for MV contact lens correction. The Safety Board concludes that AMEs need to know if pilot examinees are using contact lenses, and currently no process is in place to ensure that AMEs are provided with that information. The Safety Board believes that the FAA should revise FAA Form 8500-8, "Application for Airman Medical Certificate," to elicit information regarding contact lens use by the pilot/applicant.

Additionally, the captain and the optometrist who prescribed the MV contact lenses for the captain were not aware that the use of MV contact lenses by pilots performing flying duties was not approved by the FAA. This is consistent with the information obtained during the previously mentioned Safety Board investigation into the general aviation accident that involved MV contact lens use.[57] The Safety Board concludes that information concerning the possible hazards of MV contact lens use is not well disseminated among optometrists and the pilot population.

Because the information available to optometrists and pilots is insufficient, the Safety Board believes that the optometric associations should issue a briefing bulletin to member optometrists, informing them of the potential hazards of and prohibition against MV contact lens use by pilots while performing flying duties, and urging them to advise pilot-rated patients of those potential hazards (MV contact lens' effect on distance judgments/perceptions). In addition, the Safety Board believes that the FAA Civil Aeromedical Institute should publish and disseminate a brochure containing information about vision correction options, to include information about the potential hazards of MV contact lens use by pilots while performing flying duties and to emphasize that MV contact lenses are not approved for use while flying.

The Safety Board is aware that since this accident, Delta Air Lines has alerted its pilots and medical personnel to the hazards of MV contact lens use by flightcrew members. The Safety Board believes that the FAA should require all 14 CFR Part 121 and 135 operators to notify their pilots and medical personnel of the circumstances of this accident, and to alert them to the hazards of MV contact lens use by flightcrew members. Additionally, the Safety Board believes that the FAA should require all flight standards district office air safety inspectors and accident prevention specialists to inform general aviation pilots of the circumstances of this accident and to alert them to the hazards of MV contact lens use by pilots while flying.

2.5 Non-Instantaneous Vertical Speed Indicator (VSI)

As pointed out earlier, during the final 12 seconds before impact, the airplane's rate of descent, which had been averaging about 700 feet per minute, began to increase. At 1638:26, as the first officer called out a sink rate of 700 feet per minute (based on VSI information), the airplane was actually descending about 1,200 feet per minute. Had the first officer seen a descent rate of 1,200 feet per minute, he would likely have been alarmed and immediately indicated that to the captain. However, by 1638:33, when the first officer stated, "nose up," he had undoubtedly transferred his focus to external cues; thus, the first officer never saw cockpit instrumentation indicate an excessive rate of descent. (This is consistent with the first officer's postaccident statement.) The Safety Board concludes that the lag time in the display of vertical speed information in the VSI installed in the accident airplane limited the first

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[57] For additional information on the general aviation accident, see section 1.18.2.3 or the Safety Board's report, CHI96LA089.

officer's ability to provide the captain with precise vertical speed information during the critical final seconds of the approach, and therefore contributed to the accident.

The Safety Board notes that several Delta check airmen and flight instructors interviewed during the investigation stated that they believed that most Delta line pilots were unaware that the vertical speed information presented by the VSIs in the MD-88 was not instantaneous. If Delta's MD-88 pilots were unaware that the VSIs in the MD-88 presented them with non-instantaneous vertical speed information, the Safety Board considers it likely that pilots with other air carriers/flying other aircraft might also be unaware of the nature of the information (instantaneous or non-instantaneous) provided by the VSIs in their airplanes. The Safety Board is concerned that a pilot who is unaware that the VSI in his/her airplane does not provide instantaneous vertical speed information might be misled into believing that the airplane's sink rate is appropriate when it is not (as occurred with the first officer in the accident airplane). Therefore, the Safety Board concludes that pilots need to be aware of the type of vertical speed information provided by the VSI installed in their airplane, and to understand the possible ramifications of that information. Therefore, the Safety Board believes that the FAA should require all 14 CFR Part 121 and 135 air carriers to make their pilots aware (through specific training, placards, or other means) of the type of vertical speed information (instantaneous/non-instantaneous) provided by the VSIs installed in their airplanes, and to make them aware of the ramifications that type of information could have on their perception of their flight situation.

VSIs can be rewired to provide instantaneous vertical speed information in airplanes that are equipped with an inertial reference unit (IRU). Again, the Safety Board notes that Delta is replacing the attitude/heading reference system (AHRS) units installed in the MD-88 fleet with IRUs, and will have the capability of upgrading the timeliness of the vertical speed information displayed on airplanes equipped with IRUs. The Safety Board believes that the FAA should require all 14 CFR Part 121 and 135 operators to convert, where practical, the non-instantaneous vertical speed instrumentation on airplanes that have IRUs installed to provide flightcrews with instantaneous vertical speed information.

2.6 Special Airport Designation

The first officer told Safety Board investigators that he believed that LaGuardia should be designated an FAA special airport; he specifically cited the approaches to runway 31—which require maneuvering the airplane at high bank angles close to the ground—and runway 13—which require landing over water, a 250-foot DH, and an offset localizer—as being worthy of special pilot qualification requirements; the Safety Board also received other anecdotal comments concerning designating LaGuardia a special airport. Because of the northwesterly prevailing winds and other operational considerations, runway 13 is used less frequently than the other runways at LaGuardia; the pilots of Delta flight 554 had not performed the approach to runway 13 in inclement weather conditions, and the first officer indicated that he was not aware that the runway extended on a pier over the water.

Although 14 CFR 121.445 contains a description of the special pilot qualifications necessary for special airport operations, and AC 121.445-1D contains a description of the special pilot qualifications required for operating in and out of special airports, a list of designated special airports, and brief remarks to describe the "special" feature(s) of each designated special airport, there are no published criteria or procedures for special airport designation. In addition, the information provided in AC 121.445-1D's remarks section is general, and does not provide operators with detailed information as to the justification for special airport designation, nor does it describe specific approaches, runways, hazards, or obstacles. The Safety Board concludes that the FAA's current guidance on special airports contained in AC 121.445-1D is not sufficiently specific about criteria and procedures for designation of special airports; therefore, the FAA's current guidance might not always be useful to air carriers operating in and out of (existing or potential) special airports.

The Safety Board is aware that the FAA met with industry representatives in October 1996 to develop a list of factors—based on accident histories, human performance concerns, runway anomalies, etc.—to use in determining criteria for classification of special airports. However, the Safety Board is concerned that the FAA has apparently not made any progress in developing such criteria since that meeting. Therefore, the Safety Board believes that the FAA should expedite the development and publication of specific criteria and conditions for the classification of special airports; the resultant publication should include specific remarks detailing the reason(s) an airport is determined to be a special airport, and procedures for adding and removing airports from special airport classification.

The Safety Board is also concerned that if an airport is designated "special" because of a specific approach or runway configuration (i.e., the ILS DME approach to runway 13 at LaGuardia) a pilot who satisfies the special pilot qualification requirements by landing and departing on a different runway at that airport might not have appropriate familiarization with the special features of that specific approach or runway configuration and therefore might not adequately satisfy the intent of the special airport regulation. The Safety Board concludes that the present requirements for special airport pilot qualifications might not be sufficient to ensure that pilots who are so qualified have been exposed to the runways and/or approaches at those airports that make the airport "special." Thus, the Safety Board believes that the FAA should develop criteria for special runways and/or special approaches giving consideration to the circumstances of this accident and any unique characteristics and special conditions at airports (such as those that exist for the approaches to runways 31 and 13 at LaGuardia) and include detailed pilot qualification requirements for designated special runways or approaches. Also, the Safety Board believes that once criteria for designating special airports and special runways and/or special approaches have been developed, the FAA should evaluate all airports against that criteria and update its special airport publications accordingly.

2.7 Flight and Cabin Crew Evacuation Actions

The Safety Board considers that in general, the crewmembers' responses after the airplane came to a stop were commensurate with the circumstances of this accident. First, the crewmembers assessed the condition of the airplane and reviewed their options; then, when the captain was informed that there was a smell of jet fuel fumes in the passenger cabin, he promptly commanded an emergency evacuation. The Safety Board concludes that the flightcrew coordination appeared adequate, and the decision to evacuate the airplane was appropriate and timely. Further, the Safety Board concludes that the FAIC, who began shouting evacuation commands within 2 seconds of the evacuation order, reacted to the evacuation command promptly and assertively, in accordance with Delta's flight attendant manuals and training. All passengers were successfully evacuated through the L-1 door, with minimal evacuation-related injuries. Although under other circumstances the decision to use only one exit may have critical consequences, in this case the decision to use only the L-1 door did not have adverse results.

The CVR transcript indicated that while the evacuation was being conducted at the front of the cabin, the two flight attendants in the aft cabin remained on the interphone trying to obtain additional evacuation instructions for at least 38 seconds after the captain issued the evacuation command. About 40 seconds after the evacuation was commanded, the first officer (who had been assisting with the evacuation at the L-1 door) responded on the interphone to the aft flight attendants' inquiry, with instructions to evacuate "forward," and the aft flight attendants began to participate in the evacuation. Because the airplane was carrying a light passenger load, with most of the passengers seated in the front half of the cabin, by the time the aft flight attendants began evacuation actions, most of the passengers had exited or moved toward the first class cabin area.

The aft flight attendants stated that they sought further instructions before taking action because they were concerned that the damage to the airplane and the possibility of spilled fuel might affect the usability of their exits. According to the guidance contained in Delta's flight attendant manual, when an evacuation is commanded, flight attendants should promptly assess the condition of their assigned exits, activate exits as appropriate, and issue guidance to passengers. The manual further states that if a flight attendant judges that his or her assigned exit is not usable, the flight attendant should redirect passengers towards an appropriate exit. The Safety Board notes that it was appropriate for the aft flight attendants to evaluate and make a decision regarding the usability of their exits; however, a 38-second delay before beginning evacuation actions may have been critical if more hazardous conditions (e.g., fire) had developed.

Delta's flight attendant manual also indicates that once an evacuation is commanded, flight attendants should begin the evacuation promptly, and "without further communication from [the] cockpit." The Safety Board concludes that the two aft flight attendants did not react promptly or demonstrate assertive leadership, as specified in Delta's flight attendant manuals and training. Therefore, the Safety Board believes that the FAA should require all 14 CFR Part 121 and 135 operators to review their flight attendant training programs and emphasize the need for flight attendants to aggressively initiate their evacuation procedures when an evacuation order has been given.

2.8 CRM Issues

The Safety Board examined the interactions between the pilots, among the cabin attendants, and between the pilots and the flight attendants, to assess the quality of the CRM before and after the accident. The evidence suggests that the quality of the interaction between the pilots was good, and that both pilots provided appropriate assistance to each other when needed, and that individually and together they performed effectively as a crew both before and after the accident.

As previously discussed, the Safety Board found some deficiencies in the actions of the aft flight attendants during the evacuation. However, the evidence overall indicates that the quality of the CRM of the flight and cabin crewmembers of Delta flight 554 was good and in accordance with Delta's training and procedures. Therefore, the Safety Board concludes that the quality of the CRM was not a factor in this accident.

2.9 Other LaGuardia Airport Issues

The Safety Board is aware that because of an anomaly in a data transmission line, the RVR values from the time of the accident (3,000 feet) might be slightly incorrect. However, postaccident pilot and air traffic controller statements indicate that the actual visibility at the time of the accident was at least 3,000 feet. The flight visibility experienced by the pilots was at least 3,000 feet, which is consistent with the estimated (and ATC reported) RVR value, and which is above the 2,400-foot RVR minimum required for the approach.

In addition, the Safety Board evaluated LaGuardia's use of an RVR transmissometer aligned with runway 22 to measure touchdown RVRs for runway 13. Although the installation is not typical, the FAA has concluded that the transmissometer is situated such that it can reliably serve both runway 22 and runway 13, and the evidence gathered during this investigation suggests that the existing installation provided representative data at the time of the accident. Therefore, the Safety Board concludes that the atypical installation and use of RVR transmissometer equipment at LaGuardia did not adversely affect the validity of the RVR values reported at the time of the accident.

According to the FAA, a postaccident evaluation of the LLWAS data revealed that three of the six LLWAS sensors for LaGuardia might have been producing unreliable data during the time of the accident. It is not known what effect this might have had on the windshear detection capabilities of the system. However, surface wind speeds during Delta flight 554's approach and landing were relatively low (10 to 15 knots). Also, no wind gusts or LLWAS windshear alarms were recorded during the 50 minutes before the accident. In addition, there were no pilot reports of windshear during the 50 minutes before the accident. Therefore, the Safety Board concludes that the LLWAS equipment anomalies were not a factor in this accident.

However, the Safety Board is concerned with the performance of the LLWAS at LaGuardia. The Safety Board notes that the FAA is planning to improve and expand the existing LLWAS at LaGuardia, with commissioning of a new system scheduled for November 1997. The Safety Board agrees with these efforts by the FAA and urges the FAA to make every effort to expedite the improvements.

3. CONCLUSIONS

3.1 Findings

1. The pilots held appropriate flight and medical certificates; they were trained and qualified for the flight, and were in compliance with the Federal regulations on flight and duty time. However, the captain was using monovision contact lenses, which were not approved by the FAA for use by pilots while flying.

2. The flight attendants had completed Delta's Federal Aviation Administration-approved flight attendant training program.

3. The airplane was properly certificated, and there was no evidence that airplane maintenance was a factor in the accident.

4. No air traffic control factors contributed to the cause of the accident.

5. Although the pilots did not receive several pieces of weather information, Delta Air Lines provided the pilots with sufficient preflight, en route, and arrival weather information to allow them to conduct the flight safely; however, because of rapidly changing surface conditions, the conditions they encountered differed from what was forecast.

6. Although the weather conditions encountered by the pilots during the approach differed from the forecast conditions, these conditions should not have affected the pilots' ability to conduct a safe approach and landing.

7. Delta flight 554 did not encounter windshear during its approach to runway 13 at LaGuardia.

8. Because the airplane was in stable flight and the captain had taken actions to correct for a glideslope deviation, the captain's continuation of the approach after he established visual contact with the approach lights was not inappropriate.

9. The captain gradually reduced the engine power because he perceived a need to slightly increase the airplane's rate of descent; however, the descent rate increased beyond what the captain likely intended to command.

10. Irregular and shortened runway edge light spacing and degraded weather conditions can result in a pilot making an unnecessarily rapid descent and possibly descending too soon, especially in the absence of other visual references or cues.

11. The captain's use of monovision contact lenses resulted in his (unrecognized) degraded depth perception, and thus increased his dependence on monocular cues (instead of normal three-dimensional vision) to perceive distance.

12. Because of the captain's use of monovision contact lenses, he was unable to overcome the visual illusions resulting from the approach over water in limited light conditions (absence of visible ground features), the irregular spacing of the runway edge lights at shorter-than-usual intervals, the rain, and the fog, and that these illusions led the captain to perceive that the airplane was higher than it was during the visual portion of the approach, and thus, to his unnecessarily steepening the approach during the final 10 seconds before impact.

13. During the visual portion of the approach, when the captain was primarily relying on visual cues, the first officer, who was primarily monitoring cockpit instrumentation to gauge the airplane's position with regard to the runway, provided input to the captain that surpassed what was set forth in the guidance available to the pilots at that time.

14. The Delta manuals were not sufficiently specific regarding pilot-not-flying duties during Category I instrument landing system approaches after the pilot flying establishes ground contact.

15. Although Delta's manuals did not adequately specify operational criteria for a stabilized approach, the lack of guidance in this area did not contribute to the accident.

16. Aviation medical examiners (AMEs) need to know if pilot examinees are using contact lenses, and currently no process is in place to ensure that AMEs are provided with that information.

17. Information concerning the possible hazards of monovision contact lens use is not well disseminated among optometrists and the pilot population.

18. The lag time in the display of vertical speed information in the vertical speed indicator installed in the accident airplane limited the first officer's ability to provide the captain with precise vertical speed information during the critical final seconds of the approach, and therefore contributed to the accident.

19. Pilots need to be aware of the type of vertical speed information provided by the vertical speed indicator installed in their airplane, and to understand the possible ramifications of that information.

20. The Federal Aviation Administration's (FAA) current guidance on special airports contained in Advisory Circular 121.445-1D is not sufficiently specific about criteria and procedures for designation of special airports; therefore, the FAA's current guidance might not always be useful to air carriers operating in and out of (existing or potential) special airports.

21. The current requirements for special airport pilot qualifications might not be sufficient to ensure that pilots who are so qualified have been exposed to the runways and/or approaches at those airports that make the airport "special."

22. The flightcrew coordination appeared adequate, and the decision to evacuate the airplane was appropriate and timely.

23. The flight attendant in charge, who began shouting evacuation commands within 2 seconds of the evacuation order, reacted to the evacuation command promptly and assertively, in accordance with Delta's flight attendant manuals and training.

24. The two aft flight attendants did not react promptly or demonstrate assertive leadership, as specified in Delta's flight attendant manuals and training.

25. The quality of the crew resource management was not a factor in this accident.

26. The atypical installation and use of runway visual range transmissometer equipment at LaGuardia did not adversely affect the validity of the runway visual range values reported at the time of the accident.

27. The low level windshear alert system equipment anomalies were not a factor in this accident.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the inability of the captain, because of his use of monovision contact lenses, to overcome his misperception of the airplane's position relative to the runway during the visual portion of the approach. This misperception occurred because of visual illusions produced by the approach over water in limited light conditions, the absence of visible ground features, the rain and fog, and the irregular spacing of the runway lights.

Contributing to the accident was the lack of instantaneous vertical speed information available to the pilot not flying, and the incomplete guidance available to optometrists, aviation medical examiners, and pilots regarding the prescription of unapproved monovision contact lenses for use by pilots.

4. RECOMMENDATIONS

As a result of the investigation of this accident, the National Transportation Safety Board makes the following recommendations:

—to the Federal Aviation Administration:

Identify Part 139 airports that have irregular runway light spacing, evaluate the potential hazards of such irregular spacing, and determine if standardizing runway light spacing is warranted. (A-97-84)

Require all 14 CFR Part 121 and 135 operators to review and revise their company operations manuals to more clearly delineate flightcrew member (pilot flying/pilot not flying) duties and responsibilities for various phases of flight, and to more clearly define terms that are critical for safety of flight decisionmaking, such as "stabilized approach." (A-97-85)

Revise FAA Form 8500-8, "Application for Airman Medical Certificate," to elicit information regarding contact lens use by the pilot/applicant. (A-97-86)

Require the Civil Aeromedical Institute to publish and disseminate a brochure containing information about vision correction options, to include information about the potential hazards of monovision (MV) contact lens use by pilots while performing flying duties and to emphasize that MV contact lenses are not approved for use while flying. (A-97-87)

Require all 14 CFR Part 121 and 135 operators to notify their pilots and medical personnel of the circumstances of this accident, and to alert them to the hazards of monovision contact lens use by flightcrew members. (A-97-88)

Require all flight standards district office air safety inspectors and accident prevention specialists to inform general aviation pilots of the circumstances of this accident and to alert them to the hazards of monovision contact lens use by pilots while flying. (A-97-89)

Require all 14 CFR Part 121 and 135 air carriers to make their pilots aware (through specific training, placards, or other means) of the type of vertical speed information (instantaneous/non-instantaneous) provided by the vertical speed indicators installed in their airplanes, and to make them aware of the ramifications that type of information could have on their perception of their flight situation. (A-97-90)

Require all 14 CFR Part 121 and 135 operators to convert, where practical, the non-instantaneous vertical speed instrumentation on airplanes that have inertial reference units installed to provide flightcrews with instantaneous vertical speed information. (A-97-91)

Expedite the development and publication of specific criteria and conditions for the classification of special airports; the resultant publication should include specific remarks detailing the reason(s) an airport is determined to be a special airport, and procedures for adding and removing airports from special airport classification. (A-97-92)

Develop criteria for special runways and/or special approaches giving consideration to the circumstances of this accident and any unique characteristics and special conditions at airports (such as those that exist for the approaches to runways 31 and 13 at LaGuardia Airport) and include detailed pilot qualification requirements for designated special runways or approaches. (A-97-93)

Once criteria for designating special airports and special runways and/or special approaches have been developed as recommended in Safety Recommendations A-97-92 and -93, evaluate all airports against that criteria and update special airport publications accordingly. (A-97-94)

Require all 14 CFR Part 121 and 135 operators to review their flight attendant training programs and emphasize the need for flight attendants to aggressively initiate their evacuation procedures when an evacuation order has been given. (A-97-95)

—to optometric associations:

Issue a briefing bulletin to member optometrists, informing them of the potential hazards of and prohibition against monovision (MV) contact lens use by pilots while performing flying duties, and urging them to advise pilot-rated patients of those potential hazards (MV contact lens' effect on distance judgments/perceptions). (A-97-96)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

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Member

August 25, 1997

5. APPENDIXES

APPENDIX A—INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was initially notified of this accident about 1710 eastern standard time on October 19, 1996, by the FAA's Eastern Region Communication Center. One investigator from the Safety Board's Northeast Regional Office was immediately dispatched to the scene as investigator-in-charge. In addition, a partial team of group chairmen/specialists was dispatched from the Safety Board's headquarters in Washington, D.C. The partial team comprised the following group specialists: Operations, Air Traffic Control, and Meteorology. CVR, FDR/Aircraft Performance, Survival Factors, Airports, and Human Performance specialists also assisted in the investigation.

Parties to the investigation were the FAA, Delta, McDonnell Douglas, and the Air Line Pilots Association.

2. Public Hearing

No public hearing was held in connection with this accident.

APPENDIX B—COCKPIT VOICE RECORDER TRANSCRIPT

NATIONAL TRANSPORTATION SAFETY BOARD
Engineering & Computer Services Division
Washington, D.C. 20594

SPECIALIST'S FACTUAL REPORT OF INVESTIGATION

Cockpit Voice Recorder

NYC97MA005

by

Vincent M. Giuliana
Electronics Engineer/CVR

Warning

The reader of this report is cautioned that the transcription of a CVR tape is not a precise science but is the best product possible from an NTSB group investigative effort. The transcript, or parts thereof, if taken out of context, could be misleading. The attached CVR transcript should be viewed as an accident investigation tool to be used in conjunction with other evidence gathered during the investigation. Conclusions or interpretations should not be made using the transcript as the sole source of information.

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

December 16, 1996

Cockpit Voice Recorder

Group Chairman's Factual Report
by Vincent M. Giuliana

A. ACCIDENT

Location:	LaGuardia Airport Flushing, NY
Date:	October 19, 1996
Time:	0438 eastern daylight time (EDT)
Aircraft:	Delta Airlines Flight 554 MD-88, N914DL
NTSB Number:	NYC97MA005

B. GROUP

Chairman:	Vincent M. Giuliana Electronics Engineer/CVR National Transportation Safety Board
Member:	Martin H. Potter Federal Aviation Administration
Member:	Greg Saylor Air Line Pilots Association
Member:	Don Alexander McDonnell Douglas Corporation
Member:	Bill Watts Delta Air Lines Flight Operations

C. SUMMARY

This transcript was derived from a Fairchild Cockpit Voice Recorder (CVR) (Model A100, S/N 2698) removed from the accident aircraft and delivered to the audio laboratory of the National Transportation Safety Board.

The playback time of the recording was approximately thirty-one minutes and forty seconds (31:40). Per approval by the Office of Aviation Safety and the Office of Research and Engineering directors, and the investigator-in-charge, the final thirty minutes and nine seconds (30:09) were transcribed. All times incorporated into the transcript are in eastern daylight times, correlated with a copy of the LaGuardia Air Traffic Control Tower tape, Local Control position.

D. DETAILS OF INVESTIGATION

Three of the four channels of the CVR contained audio information from the cockpit area microphone (CAM), the captain's position and the first officer's position. The fourth channel combined audio information from the passenger cabin public address system and the flight attendant intercom system. The crewmember channels were of excellent quality, enhanced by the use of the hot microphone system. There was no structural damage evident on the CVR unit.

Mr. Greg Saylor, representative for the Air Line Pilots Association, believed an excessive amount of extraneous background (tower) conversation could be heard during several of the local controller's transmissions.

On January 7, 1997, both the captain and first officer (accompanied by Mr. Greg Saylor) reviewed the CVR recording and transcript at the NTSB headquarters in Washington, DC. Their comments are attached as an appendix to this report.

The transcript begins at 0410:47 as Delta flight five fifty-four is in contact with the New York Air Route Traffic Control Center. According to a subsequent radio call at 0412:52, the aircraft is at an altitude of approximately eleven thousand feet.

Vincent M. Giuliana
Electronic Engineer/CVR

Transcript of a Fairchild cockpit voice recorder (Model A100, S/N 2698) installed on a MD-88, N914DL, which was involved in an accident at LaGuardia Airport in Flushing, NY on October 19, 1996.

LEGEND

CAM	Cockpit area microphone
HOT	Crewmember hot microphones
RDO	Radio transmission from accident aircraft
-1	Voice (or position) identified as Captain
-2	Voice (or position) identified as First Officer
-3,-4,-5	Voice identified as Flight Attendant
-?	Unidentifiable voice
NYCNTR	New York Air Route Traffic Control Center
NYAPP	New York TRACON
RAMP	Delta ramp operations
COM	Unknown radio information
NAV	Radio Navigation information
917W	Flight nine seventeen whiskey
DAL1215	Delta flight twelve fifteen
BR960	Blue Ridge flight nine sixty
LGATWR	LaGuardia Local Tower Control
TWA8630	TWA flight eighty-six thirty
UAL1576	United Air Lines flight fifteen seventy-six
INT/PA	Flight Attendant intercom and/or passenger public address system

*	Unintelligible word
#	Expletive deleted
@	Nonpertinent word (or name)
...	Pause
( )	Questionable text
[ ]	Editorial insertion
-	Break in continuity

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0409:16 [Start of Recording]			
0410:47 [Start of Transcript]			
0410:47 HOT-1	lots of fuel.		
0410:56 HOT-2	one to go.		
0410:59 CAM	[sound similar to that of altitude alert tone]		
0411:02 HOT-1	did you tell the people to hang onto their hats?		
0411:04 HOT-2	no I didn't .. I probably should have ... I just said cloudy, windy and rainy.		
0411:12 HOT-1	that's okay.		
0411:14 HOT-2	[sound of chuckle]		
0411:20 HOT-1	coming up on eleven.		
0411:31 HOT-1	anyway one three at LaGuardia.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0411:33 HOT-2	okay.		
		0411:40 NYCNTR	delta five fifty-four fly heading of zero three zero short vector in trail.
		0411:44 RDO-2	delta five fifty-four heading zero three zero.
		0411:46 NYCNTR	affirmative thanks.
0411:48 HOT-2	you're welcome.		
0411:51 HOT-1	she's awfully thankful today for us.		
0411:57 HOT-1	it's ah not straight in by any stretch .. three degree off.		
0412:07 HOT-2	okay .. yeah.		
0412:11 HOT-1	one thirty-two is degrees .. it's ah one oh eight five .. glide slope at Garde is seventeen forty ... set two-sixty three and two fifty.		
		0412:14 NYCNTR	delta eleven-sixty affirmative sir .. they still do have high winds at LaGuardia.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0412:24 HOT-2	two-fifty two sixty-three alright.		
0412:29 HOT-1	radar's required .. glide slope unusable below two hundred feet.		
		0412:31 NYCNTR	delta five fifty-four turn right fly heading of zero nine zero .. rejoin the Minks one arrival.
0412:35 HOT-1	zero nine zero -		
		0412:36 RDO-2	delta five fifty-four heading zero nine zero join the arrival.
		0412:39 NYCNTR	delta five fifty-four thanks .. contact new york approach on one two five point eight five, bye bye.
		0412:45 RDO-2	delta five fifty-four twenty-five eighty-five good day.
		0412:52 RDO-2	approach delta five fifty-four eleven thousand feet turning to zero nine zero with delta.
0412:53 CAM	[sound similar to that of trim alert tone]		
		0413:00 NYAPP	delta five seventy-four new york altimeter two niner five two.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0413:04 RDO-2	delta five fifty-four two nine five two.
0413:09 HOT-2	two nine five two.		
0413:11 HOT-1	tell 'em that zero nine zero isn't gonna get it with the winds.		
		0413:15 RDO-2	delta five fifty-four was given zero nine zero to intercept the arrival .. with the winds like this do you want us to turn further right or just go maybe direct Minks?
		0413:23 NYAPP	ah just fly that heading for now is fine .. vector final.
		0413:27 RDO-2	okay zero nine zero thank you delta five fifty-four.
0413:30 HOT-1	okay radar's required, glide slope's unusable below two hundred feet .. final approach course crosses runway center line and twenty-seven hundred and fifty-four feet from threshold .. who cares .. yeah okay so we get .. (slight right hand) missed approach climb to eight hundred feet then a left turn to two thousand feet direct to UR which is Orchy which is three eighty-five which is the outer marker for ... the other side for two two.		
0414:00 HOT-2	okay.		
0414:04 HOT-1	and that would be a right-hand teardrop ..... entry.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0414:15 HOT-1	forty flaps manual brakes and a short runway seven thousand feet I believe .... if we turn off at the end it will be a short taxi in.		
0414:26 HOT-2	that's right.		
0414:36 HOT-2	let me make one more PA and I'll scare 'em to death.		
0414:43 PA-2	ladies and gentlemen one more update from the flight deck .. right now we are about fifteen miles from the airport at LaGuardia and we expect to start our approach pretty shortly here .. right now they have us on an extended vector just fitting us into the traffic arriving into the new york area .. the latest weather reports are it's still raining at the airport and the winds are out of the southeast .. the velocity's decreased somewhat it's now fifteen to twenty miles an hour instead of the thirty to thirty-five they had before .. as we go through the clouds and the rain we will get a few bumps as we make our approach and it's probably gonna be a little bit bumpy all the way until landing .. and as you get out of the airport and walk to your cars or whatever it will still be windy and bumpy so it's just one of those days up here ... we still estimate that we will be to the gate at about four thirty-five or close to that .. I'd like to thank you again for flying with us on delta and we hope to see you again soon .. thank you.		
		0414:56 NYAPP	delta five seventy-four turn right heading one one zero for sequence.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0415:01 RDO-1	was that for delta five fifty-four?
		0415:21 RDO-1	center did you have a heading for delta five fifty-four?
		0415:27 NYAPP	delta five seventy-four that was for heading one one zero.
		0415:38 NYAPP	is that delta five seventy-four or five fifty-four?
		0415:43 RDO-1	delta five fifty-four is just north of Luize.
		0415:47 NYAPP	alright, that was for you sir .. a one one zero heading.
		0415:51 RDO-1	delta five fifty-four heading one one zero.
0415:54 HOT-1	okay you can have it back.		
0415:55 HOT-2	alright.		
0416:12 HOT-2	man it's just sitting over new york .. I mean it's sunny and I mean it's pretty calm back this way.		
0416:15 CAM	[sound of four chimes similar to that of no smoking chime]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0416:17 HOT-1	let's sit 'em down.		
0416:18 HOT-2	alright.		
0416:22 PA-3	ladies and gentlemen to prepare for landing please bring all seatbacks and tray tables to their original and locked position .. all remaining cups and glasses will be picked up at this time .. we'll be arriving shortly.		
0416:32 HOT-1	hang on to your hats folks .. ladies and anybody else.		
0416:34 HOT-2	ah still got some spoilers out.		
0416:35 HOT-1	oh shoot.		
0416:37 HOT-2	I didn't even notice it.		
0416:38 HOT-1	I didn't either .... obviously.		
0416:39 HOT-2	let's see airspeed -		
		0416:39 NYAPP	delta five fifty-four descend and maintain niner thousand.
		0416:42 RDO-2	delta five fifty-four nine thousand feet.

INTRA-COCKPIT COMMUNICATION | **AIR-GROUND COMMUNICATION**

TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0416:45 HOT-2	let's see two eighteen, seventy-three, forty-seven, thirty-five, and flaps forty one twenty-three plus the additive so -		
0416:57 HOT-1	there's some rain.		
0416:59 CAM	[sound similar to that of trim alert tone]		
0416:59 HOT-1	okay we'll use two eighteen, one seventy-three, one forty-seven and one thirty-five and the additive's going to be quite stout I gotta feeling .. one twenty-three plus -		
0417:11 HOT-2	right now it's just sixteen knots so it'd be plus eight but -		
0417:13 HOT-1	I'd say it'd be one thirty-one.		
0417:15 HOT-2	alright.		
0417:16 HOT-1	I don't want to use much more then I have to .. let's see what it's .. let's play it by ear but I might add a couple to that if it's gusty.		
0417:21 HOT-2	okay .. sure .. alright altimeter's two nine five two.		
0417:26 HOT-1	two nine five two set and cross check.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0417:27 HOT-2	set and cross checked .. airspeed bugs we just talked about set cross checked.		
0417:32 HOT-1	set cross checked ... and approach check too.		
0417:35 HOT-2	alright.		
		0417:39 NYAPP	delta five fifty-four turn left heading zero niner zero maintain seven thousand.
		0417:43 RDO-2	delta five fifty-four zero nine zero seven thousand feet.
0417:48 HOT-1	zero nine zero seven thousand.		
0417:50 HOT-2	seatbelt light is on .. approach briefing complete .. flight and nav instruments?		
0417:55 HOT-1	flight and nav instruments are set to one thirty-two and one oh eight two ah for right now .. I'll get ah let's see eleven fifteen they got DME on it ..... ah ah eleven ah one oh eight five excuse me.		
0418:08 HOT-2	one oh eight five okay .. one thirty-two.		

INTRA-COCKPIT COMMUNICATION | **AIR-GROUND COMMUNICATION**

TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0418:12 HOT-1	one oh eight five one thirty-two set on my side, your side on LaGuardia for now.		
0418:15 HOT-2	alright.		
0418:15 HOT-1	that's good -		
0418:16 HOT-2	set cross checked -		
0418:17 HOT-1	temperature ten degrees.		
0418:19 HOT-2	okay .. radio baro altimeter bugs?		
0418:21 HOT-1	radio and baro bugs are set at ah let's see we got ah two sixty-three and two fifty set cross check.		
0418:32 HOT-2	alright .. two sixty-three baro two fifty radio set cross checked .. altimeters again two nine five two.		
0418:39 HOT-1	two nine five two set and cross checked.		
0418:42 HOT-2	no smoking chime switch cycled and on .. nav setup to go.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0418:44 NYAPP	nine seventeen whiskey just verify you're going to LaGuardia and you have ATIS delta for LaGuardia.
		0418:48 917W	affirmative .. we have delta and we are going to LaGuardia.
		0418:50 NYAPP	thank you .. altimeter two nine five zero
0419:03 HOT-1	* *.		
0419:13 HOT-1	eight for seven.		
0419:16 HOT-2	one to go .... let me give ramp a call ... I'll be off a second.		
0419:21 HOT-1	okay .. I don't see anything on the radar that looks like we have to go around it yet, do you?		
0419:27 CAM	[sound similar to that of an altitude alert tone]		
0419:27 HOT-2	it looks pretty good .. I'll ask -		
0419:29 HOT-1	just rain.		
		0419:30 RDO-2	ramp five fifty-four we should be there on time at thirty-five.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0419:35 RAMP	roger five fifty-four you'll be parking gate number six sir gate number six .. electric and air is available .. I'd appreciate a call on the ground.
		0419:42 RDO-2	alright .. we'll call you on the ground, thank you.
0419:46 HOT-2	gate six .. as published they got power and air at the gate.		
0419:50 HOT-1	super, thank you.		
0419:51 HOT-2	they want us to call them on the ground.		
0419:53 HOT-1	coming up on seven thousand ... I gotta go potty.		
0419:59 HOT-2	boston's got east winds twenty-three gusts thirty ten miles visibility.		
0420:05 HOT-1	good the weather, other than that?		
0420:09 HOT-2	still, still let's see.		
0420:11 HOT-1	that's a pretty stout low pressure.		
0420:12 HOT-2	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0420:13 HOT-1	twenty-nine fifty.		
0420:16 HOT-2	zero eight zero at twenty-five gusts thirty ten miles .. twenty-nine ninety three .. peak winds zero eight zero at thirty-three .. so it's windy up there so -		
0420:24 HOT-1	not gonna be a fun day to go out and play.		
0420:45 HOT-1	okay what we got for traffic here .. we got one eight coming down.		
		0420:53 NYAPP	american three seventy new york ATIS delta altimeter two niner five zero.
0421:00 HOT-2	they're calling it twenty-nine fifty now.		
0421:02 HOT-1	five zero.		
		0421:02 NYAPP	delta five fifty-four turn left heading zero five zero descend and maintain four thousand.
		0421:06 RDO-2	delta five fifty-four heading zero five zero down to four thousand feet and is it two nine five zero now?
		0421:12 NYAPP	twenty-nine fifty yes.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0421:14 RDO-2	thank you.
0421:15 HOT-1	four thousand feet, fifty degrees.		
0421:16 HOT-2	four thousand .... down to four .. getting ready to fly up the river, huh.		
0421:23 CAM	[sound similar to that of trim alert tone]		
0421:25 HOT-1	short turn on.		
0421:31 HOT-1	fourteen degrees ... good shape for the shape we're in.		
0421:36 HOT-2	alright.		
0421:38 HOT-1	a little bit of red up there but a short range red .. I don't know but we probably won't fly through it anyway ... it's between us and the field ... somebody in it right now at four thousand feet.		
0421:52 HOT-2	yup.		
0421:58 HOT-1	okay let's see ... got everything done I think we need for now .... is this the downwind leg or ah ... crosswind leg for the turn to the downwind?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0422:12 HOT-2	yeah, crosswind to downwind ... daisy chain.		
0422:35 HOT-1	(is this called) a minimum fuel approach?		
0422:38 HOT-2	yeah.		
0422:52 HOT-1	it's about L over D max isn't it ... clean speed plus ten?		
0422:55 HOT-2	is that right?		
		0422:55 NYAPP	usair one eighty-four contact new york on one two zero point eight.
0422:57 HOT-1	huh?		
		0422:58 RDO-2	delta five fifty-four one twenty point eight, good day.
		0423:01 NYAPP	no delta five fifty-four you stay with me ... usair one eighty-four contact one two zero point eight.
0423:05 HOT-2	alright.		
0423:07 HOT-1	(us) next.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0423:11 HOT-2	one twenty point eight I think.		
0423:16 CAM	[sound similar to that of altitude alert tone]		
0423:17 HOT-1	five for four.		
0423:17 HOT-2	seven hundred feet to go.		
0423:28 HOT-1	do da do do ... fifteen miles the field the way the crow flies .... looks like there's some heavy # right over there right over the airport.		
0423:42 HOT-2	ah huh.		
0423:44 HOT-1	be long gone by the time we get there as fast as it's moving though.		
0424:03 HOT-1	turn final we'll stop.		
0424:06 HOT-2	what's that?		
0424:07 HOT-1	when we turn final we'll 'bout stop.		
0424:09 HOT-2	yeah that's right .. no more ground speed.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0424:24 HOT-1	[sound of yawn]		
		0424:26 NYAPP	delta five fifty-four reduce speed to one eight zero.
		0424:28 RDO-2	delta five fifty-four slow to one eighty.
0424:30 HOT-1	slats please.		
		0424:30 NYAPP	delta five fifty-four contact one two zero point eight.
0424:32 CAM	[sound similar to that of slat/flap handle actuation]		
		0424:33 RDO-2	delta five fifty-four good day.
0424:37 CAM	[sound similar to that of trim alert tone]		
		0424:39 RDO-2	approach delta five fifty-four is with you four thousand feet we're slowing to a hundred eighty knots.
		0424:43 NYAPP	delta five fifty-four new york thank you.
0424:44 HOT-1	flaps eleven.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0425:00 HOT-2	okay you've got flaps eleven.		
0425:01 HOT-1	this thing actually sped up .. did you see that .. we're at two forty instead of two thirty.		
0425:06 HOT-2	hum.		
0425:15 HOT-1	a little rain right here.		
0425:20 CAM	[sound similar to that of trim alert tone]		
0425:30 HOT-2	want any ignition on?		
0425:32 HOT-1	good idea.		
0425:33 HOT-2	yeah it's heavy rain .. is that one on the list?		
0425:37 HOT-1	that's one of them.		
0425:38 HOT-2	yeah ..... I'll do a clock in case we spend a lot of time -		
0425:46 CAM	[sound similar to that of trim alert tone]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0425:54 HOT-1	with the flaps that'll give us a little extra .. cushion.		
0425:59 HOT-2	yeah.		
0426:17 HOT-1	could be fun all the way in man.		
0426:19 HOT-2	[sound of chuckle]		
0426:21 HOT-1	gonna be fun all the way to the ramp.		
0426:25 HOT-2	I laugh now but ... I get to do the walk-around.		
0426:30 HOT-1	you laugh now?		
0426:32 HOT-2	gate two is bad .. it's got a ... it was raining up here last time .. it doesn't drain well out there.		
0426:40 HOT-1	what's that?		
0426:41 HOT-2	it doesn't .... the ramp area doesn't drain, it's -		
		0426:45 DAL1215	okay you were blocked but if that was twelve fifteen eighteen seven is that correct?

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0426:48 NYAPP	that's correct delta .. good day.
0426:51 HOT-2	eighteen seven.		
0426:59 HOT-1	got us pretty close to this course here ..... maybe they're gonna take us to the other side.		
0427:10 HOT-1	I bet he's gonna take us across the top.		
0427:12 HOT-2	and then come back a left turn in.		
0427:13 HOT-1	yup.		
0427:13 HOT-2	yeah.		
0427:25 HOT-1	well if we'd have come straight in like we normally do we'd have been there by now .. or on time.		
0427:29 HOT-2	yeah.		
0427:30 HOT-1	just about.		
0427:44 HOT-2	now wouldn't you rather be here doing this than being at home in sunny georgia?		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME and SOURCE	CONTENT
0427:47 HOT-1	yup .. much rather ... pay's the *same* ..... I'm making a buck sixty an hour .. what do you care .. what are you talking about.
0428:04 HOT-2	yeah yeah.
0428:06 HOT-1	no way I'm gonna (fill) up.
0428:10 HOT-2	yeah.
0428:20 HOT-1	bouncing around on a sunday afternoon .. saturday afternoon.
0428:46 HOT-1	I hope that's what he's got in store for us.
0429:06 HOT-2	huh .. I guess our heading and track are off that much.
0429:09 HOT-1	yup .. ah probably not ... that's ten thousand foot winds still computed .. ah it says a hundred and twelve at sixty-one it's increased .. it was one forty-five ... or forty-five knots before.
0429:20 HOT-2	yeah ... I was just looking at this funny return on the radar .. on the map page .. the map.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0429:25 HOT-1	oh yeah .. that's probably why .. yeah see the sweep only goes over that far.		
0423:26 HOT-2	yeah.		
0429:31 HOT-1	the sweep is off the heading not the course, obviously.		
0429:35 HOT-2	yeah.		
0429:42 HOT-1	I never knew that .. you learn something new every day.		
0429:44 HOT-2	I never saw it do that.		
0429:52 HOT-1	you'd think the sweep would be off the course cause that's pointed off the nose of the airplane.		
		0429:56 NYAPP	delta five fifty-four turn left heading three six zero descend and maintain three thousand.
		0430:01 RDO-2	delta five fifty-four heading three sixty three thousand feet.
0430:05 HOT-1	three sixty three thousand feet.		
0430:08 HOT-2	this should be a good altitude on this side.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0430:16 HOT-1	intercept at twenty-eight hundred at Lymps, so.		
0430:17 HOT-2	yeah.		
0430:18 CAM	[sound similar to that of altitude alert tone]		
		0430:25 NYAPP	delta five fifty-four turn left heading three two zero.
		0430:28 RDO-2	delta five fifty-four heading three three zero.
0430:30 HOT-1	three two .. three two zero.		
0430:32 HOT-2	was it.		
0430:34 HOT-1	well we'll check it .. split the difference.		
0430:36 HOT-2	alright.		
0430:40 CAM	[sound similar to that of trim alert tone]		
		0430:41 RDO-2	could you say the heading again for delta five fifty-four please.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0430:44 NYAPP	yeah I said three twenty .. you said three thirty but that'll work .. I'll be turning you again in about three miles delta five fifty-four ... maintain the heading three two zero three thousand.
		0430:51 RDO-2	delta five fifty-four three twenty thank you.
0430:54 HOT-2	three thousand three twenty.		
0430:59 HOT-1	let's go flaps fifteen.		
0431:00 HOT-2	flaps fifteen.		
0431:02 HOT-1	a little more cushion.		
0431:03 HOT-2	alright.		
0431:06 HOT-2	alright you've got flaps fifteen.		
0431:09 HOT 1	that's as good as it gets.		
0431:13 HOT-1	just gained ten knots like a shot.		
0431:15 HOT-2	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0431:16 CAM	[sound similar to that of trim alert tone]		
		0431:19 NYAPP	delta five fifty-four turn left heading two three zero.
		0431:22 RDO-2	delta five fifty-four two three zero.
0431:27 HOT-1	two three zero.		
0431:28 HOT-2	I'm gonna come over with you showing the ... (one oh eight) five.		
0431:31 HOT-1	how many people are puking in the back?		
0431:33 HOT-2	[sound of chuckle] let's make it good and hot back there.		
0431:36 HOT-1	yeah.		
0431:42 HOT-1	I'm gonna leave it at one eighty for a little bit just unless he gives us something slower to keep a little cushion.		
0431:43 CAM	[sound similar to that of trim alert tone]		
		0431:44 NAV	[sound of morse code ident for IGDI ILS runway one three]

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INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0431:47 HOT-1	speed is life .. someone told me that once.		
0431:50 HOT-2	[sound of chuckle] alright ... yeah.		
0431:51 HOT-1	speed is life right.		
0431:52 HOT-2	yeah.		
		0431:53 NYAPP	delta five fifty-four turn left heading one eight zero.
0431:56 HOT-1	one eight zero.		
		0431:56 RDO-2	delta five fifty-four heading one eighty.
		0431:59 NAV	[sound of morse code ident for IGDI ILS runway one three]
0432:04 HOT-2	you're identified.		
0432:06 HOT-1	one eighty okay ... thank you.		
0432:10 HOT-1	[unknown sound heard only on captain's cvr channel]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0432:11 HOT-1	approach check done?		
0432:12 HOT-2	we're both identified.		
0432:13 HOT-1	[unknown sound heard only on captain's cvr channel]		
0432:14 HOT-2	approach check's complete.		
0432:14 HOT-1	thank you.		
0432:15 HOT-2	I've got a got a palisades park tuned up on ADF too just something else -		
0432:20 HOT-1	palisades okay .. and this is the missed approach if we need it.		
0432:23 HOT-2	right.		
0432:32 CAM	[sound similar to that of alert trim tone]		
0433:04 HOT-1	thought we were going to be inside Lymps .. I guess not ... this track .... I was looking at the course or looking at the heading and said oh #.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0433:13 HOT-2	yeah .. yeah.		
		0433:14 COM	[sound of radio static on captain's and first officer's radio]
0433:28 HOT-1	still showing sixty-three knots now.		
		0433:33 NYAPP	delta five fifty-four turn left heading one three zero .. you're three miles from Lymps .. maintain three thousand until Lymps .. cleared ILS DME runway one three approach.
		0433:40 RDO-2	delta five fifty-four heading one thirty cleared ILS to one three approach.
0433:55 HOT-2	yeah I guess the wind's gonna blow us over.		
0433:58 HOT-1	I think you're right.		
0433:59 HOT-2	he's got us a half mile off course ... yeah it's gonna look funny on this -		
		0434:01 NYAPP	blue ridge nine sixty new york altimeter two nine five two ATIS echo is now current advise echo.
0434:03 HOT-1	it's gonna look real funny plus it's gonna be right behind this post is where the runway's gonna be.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0434:10 HOT-2	yeah.		
0434:13 HOT-1	I might need the windshield wipers on final.		
0434:15 HOT-2	alright.		
0434:19 HOT-2	that's been about ten minutes on the ignition .. you want to go to -		
0434:21 HOT-1	let's change it.		
0434:22 HOT-2	alright.		
0434:22 HOT-1	let's (just) put it on one.		
0434:23 HOT-2	alright.		
0434:26 HOT-1	(one of 'em's) gonna get screwed.		
0434:31 HOT-1	we've been cleared for the approach?		
0434:33 HOT-2	we have ... ah it's -		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0434:34 BR960	and negative echo .. it doesn't seem to be coming up yet blue ridge nine sixty
0434:37 HOT-1	how we doing on the -		
		0434:38 NYAPP	okay thanks blue ridge nine sixty .. I'll give the tower a call.
0434:39 HOT-2	still not getting it .. starting to move now .. course is alive.		
0434:41 HOT-1	okay .. we're good then to go down.		
		0434:48 NYAPP	delta five fifty-four contact LaGuardia tower one one eight point seven good day.
		0434:52 RDO-2	delta five fifty-four one eighteen seven good day.
0434:56 HOT-2	"loc" capture.		
0434:57 HOT-1	thank you.		
0435:00 CAM	[sound of altitude alert tone and voiced "altitude" repeats twice]		

TIME and SOURCE	INTRA-COCKPIT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
0435:15 HOT-1	okay the bank angle's fifteen and ah .... gimme flaps ah let's see -		
		0435:19 LGATWR	delta five fifty-four LaGuardia tower.
		0435:21 RDO-2	delta five fifty-four's with you for one three.
		0435:23 LGATWR	delta five five four you're number two traffic to follow seven (three) seven two mile final the wind now one zero zero at one two runway one three .. continue one departure prior to your arrival .. braking action reported good by seven three seven .. low level wind shear reported on final by seven three seven also.
0435:24 HOT-1	gear down please.		
0435:26 CAM	[sound similar to that of landing gear extension]		
		0435:36 RDO-2	delta five fifty-four roger .. and understand we're cleared to land one three.
0435:38 HOT-1	twenty -		
		0435:39 LGATWR	ah no not cleared to land .. one more departure prior to arrival .. accommodate departure please.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0435:43 RDO-2	roger.
0435:44 HOT-1	twenty-two knots .. flaps twenty-eight and forty ... before landing checklists .. we're not cleared to land yet.		
0435:51 HOT-2	okay .. I thought he said twelve knots but he said -		
0435:52 HOT-1	twelve knots?		
0435:53 HOT-2	yeah .. I'll double check that again too .. we're not cleared to land yet.		
0435:57 HOT-1	okay .. he'll give it to us again.		
0435:58 HOT-2	ignition "A" .. landing gear?		
0436:00 HOT-1	down and three green.		
0436:00 HOT-2	down and three green ... flaps slats?		
0436:03 HOT-1	we have ah forty forty land.		
0436:06 HOT-2	forty forty land ... autobrakes? ... what would you like?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0436:09 HOT-1	gimme medium.		
0436:10 HOT-2	medium ... spoilers armed.		
0436:12 CAM	[sound of click similar to that of spoiler handle arming]		
0436:13 HOT-2	annunciator panel is checked.		
0436:15 CAM	[sound similar to that of trim alert tone]		
		0436:18 LGATWR	runway one three RVR touchdown three thousand .. rollout two thousand two hundred.
0436:22 HOT-1	three thousand foot RVR.		
0436:23 CAM	[sound similar to that of trim alert tone]		
0436:23 HOT-2	okay.		
0436:24 HOT-1	must be raining hard at the airport.		
0436:25 HOT-2	before landing check is complete ... not cleared to land yet.		

INTRA-COCKPIT COMMUNICATION TIME and SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME and SOURCE	CONTENT
0436:37 HOT-1	I got one thirty-five on the speed for right now.		
		0436:41 RDO-2	say the winds please.
		0436:42 LGATWR	wind now one zero zero one two.
0436:44 HOT-1	one two.		
0436:45 HOT-2	okay.		
0436:45 HOT-1	come back a little bit.		
0436:46 HOT-2	alright .. a thousand feet above minimums.		
0436:54 CAM	[sound similar to that of trim alert tone]		
0436:55 HOT-1	don't see # yet ... what was the ceiling on the ATIS?		
0437:00 HOT-2	ah .. thirteen ah hundred.		
0437:03 HOT-1	you can forget that.		
0437:04 HOT-2	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0437:08 LGATWR	twa eighty-six thirty wind one zero zero at one two runway one three cleared for takeoff traffic three mile final runway one three.
0437:08 HOT-1	(try it).		
0437:10 CAM	[sound similar to that of windshield wipers start]		
		0437:13 TWA8630	twa eighty-six thirty's cleared for takeoff .. twa eighty-six thirty's rolling.
		0437:16 LGATWR	thank you.
0437:17 CAM	[sound similar to that of trim alert tone]		
		0437:18 LGATWR	delta five fifty-four the wind now one zero zero at one two .. runway one three cleared to land.
		0437:22 RDO-2	delta five fifty-four cleared to land one three.
0437:24 HOT-2	starting to pick up some ground contact.		
0437:27 HOT-1	one zero at one two .. okay.		

INTRA-COCKPIT COMMUNICATION

TIME and SOURCE	CONTENT
0437:31 HOT-1	I got the jet.
0437:33 HOT-2	alright.
0437:52 HOT-1	#.

AIR-GROUND COMMUNICATION

TIME and SOURCE	CONTENT
0437:29 TWA8630	twa eighty-six thirty needs to turn off.
0437:31 LGATWR	twa eighty-six thirty make the first right turn runway four two two .. can you do that for me sir?
0437:37 LGATWR	[momentary transmission interference] if you could expedite traffic on a two mile final ah prevent him from going around.
0437:41 TWA8630	twa eighty-six thirty's turning off.
0437:43 LGATWR	thank you very much .. and ah say the reason for the abort sir?
0437:48 LGATWR	twa eighty-six thirty just continue down the runway .. make the first right turn on taxiway golf right turn on golf please and ah when you get a chance let me know the reason for the abort.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0437:56 TWA8630	right turn on golf and we're ah looking at an engine.
0437:57 HOT-2	two hundred above.		
		0437:59 LGATWR	okay no problem .. turn right on golf .. hold short of taxiway bravo bravo and contact ground point seven.
0438:01 HOT-2	speed's good sink's good.		
		0438:05 TWA8630	right on golf .. hold short of bravo bravo and contact ground on point seven.
0438:07 HOT-1	no contact yet.		
		0438:09 LGATWR	[momentary transmission interference] if you can ah find out exactly what's wrong report the information to the ground controller.
0438:10 HOT-2	one hundred above.		
0438:11 HOT-1	I got the (REIL) .. approach lights in sight.		
0438:13 HOT-2	you're getting a little bit high.		

INTRA-COCKPIT COMMUNICATION TIME and SOURCE	INTRA-COCKPIT COMMUNICATION CONTENT	AIR-GROUND COMMUNICATION TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
0438:15 HOT-2	a little bit above glide slope.		
0438:17 HOT-2	approach lights we're left of course.		
		0438:18.0 LGATWR	you are cleared to land delta five fifty-four.
		0438:20.0 RDO-2	delta five fifty-four cleared to land.
0438:20.6 CAM	[sound of GPWS "minimums"]		
0438:21.8 CAM	[sound similar to that of windshield wipers increasing to full speed]		
0438:22.4 HOT-1	approach lights in sight.		
		0438:22.9 UAL1576	tower united fifteen seventy-six is with you outside of Garde.
0438:25.6 HOT-2	speed's good.		
0438:26.7 HOT-2	sink's seven hundred.		
		0438:28.2 LGATWR	united fifteen seventy-six LaGuardia tower continue the wind one zero zero at one zero runway one three braking action reported good by a seven three seven -

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0438:30.1 HOT-1	I'll get over there.		
0438:31.1 HOT-2	a little bit slow a little slow.		
0438:33.7 HOT-2	nose up.		
0438:34.2 CAM	[sound of GPWS "sink rate"]		
0438:34 .3 HOT-2	nose up.		
0438:35.7 CAM	[sound of GPWS "sink rate"]		
0438:36.5 CAM	[sound of impact]		
0438:36.9 CAM	[sound similar to that of power interrupt to CVR]		
		0438:37 LGATWR	[continued from previous LGA transmission] yo Bill Bill Bill Bill .. Bill.
0438:38 CAM	[sound of tone and aural "landing gear" from CAWS starts and repeats to the end of recording]		
0438:43 HOT-1	#.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0438:44 HOT-2	hundred knots.		
0438:48 HOT-2	sixty knots.		
0438:49 CAM	[sound similar to that of windshield wipers speed decreasing]		
0438:51 HOT-1	#.		
0438:52 HOT-2	hang on hang on.		
0438:54 CAM	[sound similar to that of windshield wipers stopping]		
0438:56 HOT-1	# # #.		
0438:57 HOT-2	okay okay settle down Joe .. it's alright it's alright.		
0438:59 HOT-1	okay .. let's see what we got here.		
0439:04 INT/PA-3	stay in your seats.		
0439:05 INT/PA-4	hello.		
0439:06 INT/PA-1	ladies and gentlemen please remain seated at this time.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0439:12 INT/PA-1	please remain seated with your seatbelts securely fastened please.		
0439:17 CAM-2	we need to get out of the airplane I think.		
0439:18 INT/PA-3	are you alright .. stay in your seats.		
0439:21 CAM-2	get * *.		
0439:22 CAM-1	yeah ... do that.		
0439:24 CAM-3	you alright?		
0439:26 INT/PA-3	I'm just waiting for someone -		
0439:26 INT/PA-1	ladies and gentlemen please abort a -		
0439:29 HOT-1	let's evacuate.		
0439:32 INT/PA-3	@.		
0439:33 HOT-1	well hold hold on a minute.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0439:33 INT/PA-4	yeah.		
0439:34 INT/PA-3	stay away from the back.		
0439:35 INT/PA-4	I'm fine I'm fine.		
		0439:35 RDO-2	tower delta five fifty-four.
0439:41 INT/PA-3	[unintelligible] stay in your seats .. stay seated.		
		0439:46 RDO-2	tower delta five fifty-four.
		0439:48 LGATWR	delta five fifty-four emergency vehicles are responding sir * * can you respond?
		0439:52 RDO-2	yes we're gonna evacuate the airplane and ah we'll try and get everyone off the front of the airplane on the ah runway.
0439:56 CAM-1	(start) the evacuation checklist.		
		0439:59 LGATWR	no problem at all evacuate your discretion sir .. the vehicles are responding on *.
0440:01 CAM-1	let's evacuate the airplane.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0440:02 CAM-?	[male and female voice simultaneously] smelling fuel.		
0440:03 INT/PA	[sound of cabin chime]		
0440:03 CAM-1	pardon?		
0440:04 CAM-?	[male and female voice simultaneously] smelling fuel.		
0440:04 INT/PA-3	[unintelligible] are you alright?		
0440:05 CAM-2	we need to get out.		
0440:05 CAM-1	evacuate the airplane.		
0440:06 CAM-2	okay.		
0440:10 INT/PA-1	ladies and gentlemen we're going to evacuate the airplane .. please follow the flight attendants instructions right now.		
0440:12 CAM-3	release your seatbelts get up get out .. release your seatbelts get up get out ... release your seatbelts get up get out.		
0440:15 INT/PA-4	do you want to go forward or backwards?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0440:18 CAM-1	evacuation checklist.		
0440:19 CAM	[sound similar to door opening and slide inflating]		
0440:20 INT/PA	[sound of cabin chime]		
0440:22 CAM-?	go go.		
0440:23 CAM-3	sit and slide [repeated several times]		
0440:29 CAM-?	why don't you go out and meet at the front of the airplane .. meet at the front of the airplane.		
0440:30 CAM	[sound similar to cockpit call chime]		
0440:35 INT/PA-5	this is @ .. do you want forward?		
0440:36 INT/PA-4	no @ I need the ba - forward.		
0440:37 CAM-1	emergency power switch *.		
0440:39 INT/PA-5	are we going out the back?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0440:40 CAM	[two sounds similar to cockpit call chimes]		
0440:43 INT/PA-4	I'm wanting to know which way out.		
0440:45 CAM-1	[mostly unintelligible words relating to emergency evacuation checklist]		
0440:46 INT/PA-?	do not open the window -		
0440:48 INT/PA-2	hello.		
0440:48 INT/PA-4	do you want to go forward?		
0440:50 INT/PA-2	let's come forward yes come forward.		
0440:56 [End of Recording and Transcript]			

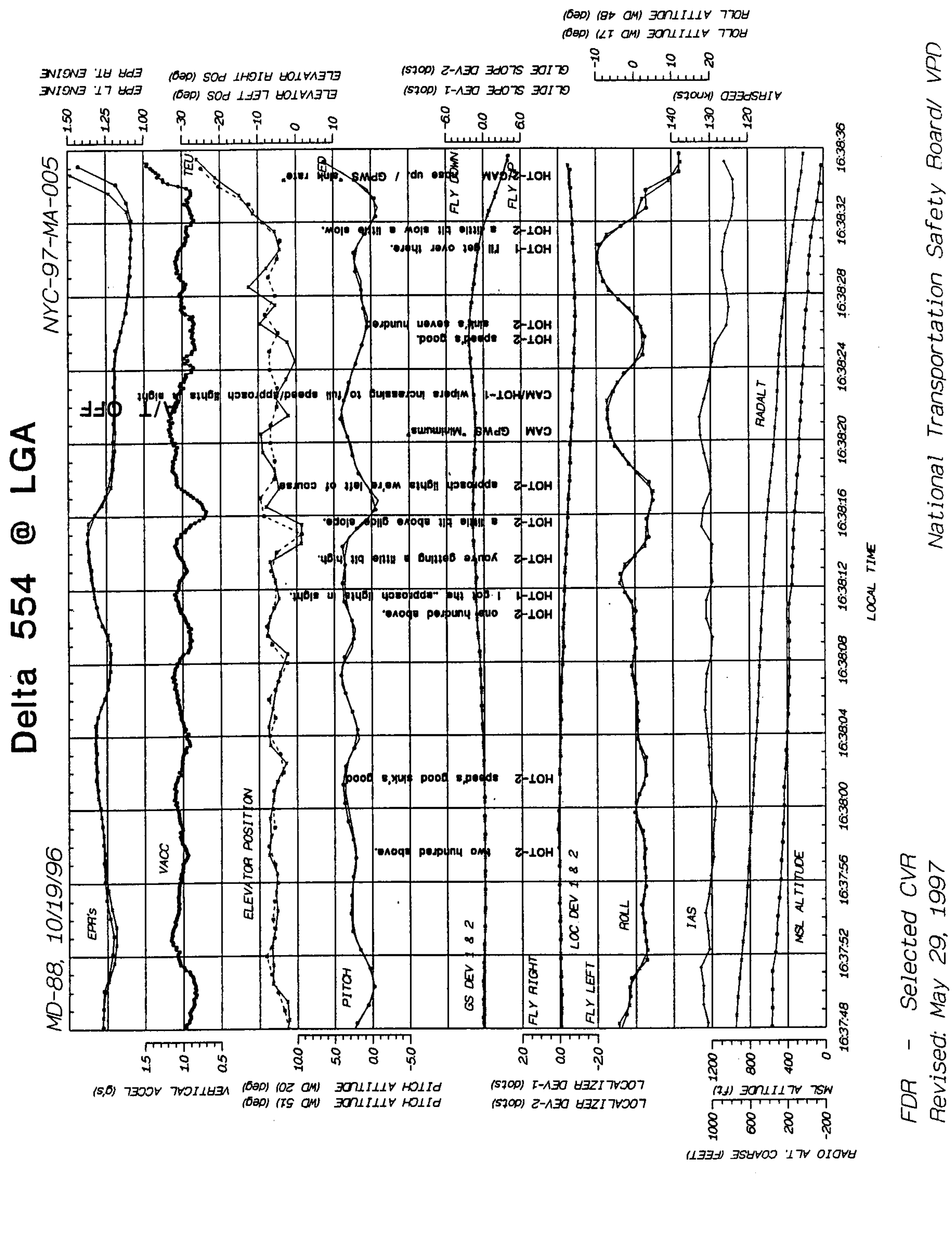
On January 7, 1997, both the captain and first officer reviewed the CVR recording and transcript at the NTSB headquarters in Washington, DC. Their comments are as follows:

- The first officer wants to convey that, "the following two excerpts from the transcript were made in a joking manner:"

  0414:36
  HOT-2 let me make one more PA and I'll scare 'em to death.

  0431:33
  HOT-2 [sound of chuckle] let's make it good and hot back there.

APPENDIX C—EXCERPT FROM FDR REPORT



APPENDIX D—MEDICAL/VISION INFORMATION

U.S. Department
of Transportation
**Federal Aviation
Administration**

Mike Monroney
Aeronautical Center

P.O. Box 25082
Oklahoma City, Oklahoma 73125

April 16, 1997

Mitchell Garber, M.D.
Medical Officer
National Transportation Safety Board
490 L'Enfant Plaza East, S.W.
Washington, D.C. 20594

Dear Dr. Garber

This is in response to our telephone conversation of April 16, 1997 concerning your question: Why does the FAA certify monocular pilots but does not certify pilots with two eyes who wear a contact lens in one eye for distant visual acuity and a lens in the other eye for near visual acuity?

An airman with one eye, or with effective visual acuity equivalent to monocular (i.e. best corrected distant visual acuity in the poorer eye is no better than 20/200), may be considered for medical certification, any class, through the special issuance procedures of Part 67 (14CFR67.401) if: I) A 6-month period has elapsed to allow for adaptation to monocularity, II) A complete evaluation by an eye specialist, as reported on FAA Form 8500-7, Report of Eye Evaluation, reveals no pathology of either eye which could affect the stability of the findings, III) Uncorrected distant visual acuity in the better eye is 20/200 or better and is corrected to 20/20 or better by lenses of no greater power than plus or minus 3.5 diopters spherical equivalent, and, IV) The applicant passes an FAA medical flight test. If the person is amblyopic rather than anatomically monocular, the criteria above are slightly different.

For a binocular applicant, contact lenses that correct near visual acuity only or that are bifocal are not considered acceptable for aviation duties; the first for obvious reasons, the latter because of our concerns for their effectiveness. The use of a contact lens in one eye for distant visual acuity and a lens in the other eye for near visual acuity is not acceptable because this procedure makes the pilot an effective "alternator," i.e. a person who uses one eye at a time, suppressing the other. Stereopsis is lost. Since this is not a permanent condition for either eye in such persons, there is no adaptation such as occurs with permanent monocularity.

Feel free to contact me if you need any additional information.

Sincerely,

Melchor J. Antuñano, M.D.
Acting Manager, Aeromedical Certification Division
FAA Civil Aeromedical Institute

Flight Research Program: XIV. Landing Performance in Jet Aircraft After the Loss of Binocular Vision

CHARLES E. LEWIS, JR., and GARY E. KRIER

NASA Flight Research Center, Edwards, California 93523

LEWIS, C. E., JR., and G. E. KRIER. *Flight research program: XIV. Landing performance in jet aircraft after the loss of binocular vision.* Aerospace Med. 40(9):957-963. 1969.

Thirteen (13) pilots were studied in a T-33A Jet Trainer during a series of touch-and-go landings. Each flight included landing approaches with full binocular vision, followed by approaches with first the left and then the right eye covered. Both lateral and longitudinal miss-distance were photo-optically measured from a specified touchdown point. Performance on final approach with respect to airspeed control, sink rate, and the approach angle, was analyzed. Landing errors were clearly shown not to increase significantly during approaches made with one (1) eye covered. The pilots were free to select any angle of descent during approach that they desired. Steeper approaches were consistently observed when vision was restricted to one eye than those flown with normal vision.

One (1) pilot was studied for three (3) consecutive weeks during which his dominant eye was patched. Landing performance was analyzed during three (3) flights including thirty-five (35) landings and compared with control data flown on the day prior to patching his dominant eye, and six (6) days after removal of the patch—this delay was necessary to allow resolution of diplopia which had developed during the patched period. Analysis of these data revealed no significant difference in landing performance with vision restricted to one (1) eye over the entire period.

These findings have important implications with regard to aeromedical certification standards.

THE SUCCESSFUL COMPLETION of many aerospace operations such as formation flying, landing maneuvers, and docking of orbital spacecraft often depends on the pilot's ability to precisely position his craft by means of visual cues alone. This implies the accurate visual estimation of distance in space; *visual depth perception.*

The exact mechanism of depth perception in humans is unclear and has long been a subject of controversy. It has been well established, however, to be a very complex function depending on both monocular and binocular cues. A number of well qualified investigators have discussed, in great detail, the many factors thought to be important.[1-10] This difficult subject will not be reviewed here; especially since the entire discussion becomes somewhat academic when one must decide whether or not an airman with impaired binocular vision is to be certified and potentially entrusted with several million dollars in flight equipment and the lives of hundreds of human beings.

In view of the responsibility involved in this decision, it is tempting to categorically disqualify all but the physically most perfect, but this policy would inevitably result in the loss of a number of talented and expensively trained aviators. Obviously, it would be desirable to certify many of these aviators if it could be done so with safety. Before this can be done, however, some method of reliably assessing the risks to be expected, if any, must be provided.

Relevant information can be found in the analysis of aircraft accident statistics. Data abstracted for us by Dr. Stanley Mohler* from the Federal Aviation Administration files indicates that during the last five years no one-eyed pilot has been involved in a flight accident related to vision and more than twenty-six hundred were flying as of 10 December 1968. These data are encouraging but are, of course, indirect and inconclusive. Well controlled objective data defining the relationship between pilot performance and binocular vision would be extremely useful. There is, however, a surprising lack of such data in the literature and the few studies reported to date are not convincing.

In 1935, Jongbloed[11] was unable to demonstrate any degradation in landing performance following blindfolding of one eye. Conversely, Pfaffmann[12] reported a tendency to flare-out high in pilots whose nasal visual fields were occluded in such a way that central binocular cues were eliminated. In his study, though, landings were made in the center of a large, open field (one mile square) which deprived the pilots of linear perspective cues and may have accounted for the differences observed.

In a previous NASA study[13] a total of 155 landings in a T-33A were successfully performed utilizing an increasingly narrow horizontal field-of-view. The narrowest of these (five degrees horizontal by thirty degrees vertical) produced a vertical slit narrower than the interpupillary distances of the pilots studied.

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Roman[14] observed that stereopsis could not have been used during these landings since the field-of-view perceived by each eye was entirely different because of the narrow slit through which the pilot viewed the approach scene. There was, however, no significant decrement in pilot performance as visual cues passed from binocular to monocular.

Guifoyle[15], reporting his experiences as a "uniocular pilot" in 1938, described a tendency to flare high initially followed by gradual improvement in his landing performance during a two-month period after the accidental loss of one eye. A similar but protracted experience was reported to the authors personally by a NASA pilot who lost vision in his right eye subsequent to a flight accident in 1967.

Finally, the accomplishments of one-eyed pilots such as Wylie Post leave little doubt that highly motivated, well qualified pilots can successfully operate aircraft after the loss of stereopsis; however, prior to the present study, the degree of handicap, if any, to be overcome by such pilots was not known, nor was the length of time required for return to acceptable performance levels well understood. Likewise, the extent of immediate impairment of function, if any, following the sudden loss of stereopsis was unknown. This experiment was undertaken, therefore, to establish, by objective means, both the acute (Phase I) and chronic (Phase II) effect on pilot landing performance in jet aircraft associated with the loss of binocular vision.

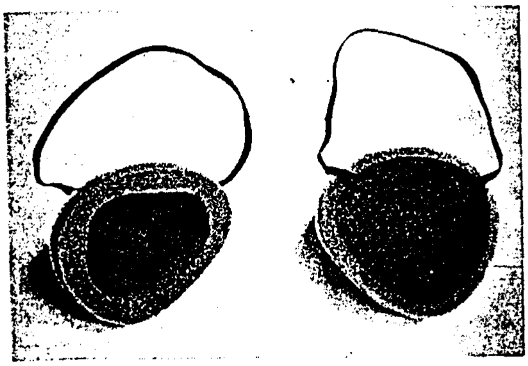

Fig. 1. The modified eye patch.

Fig. 2. A subject pilot with the eye patch in place.

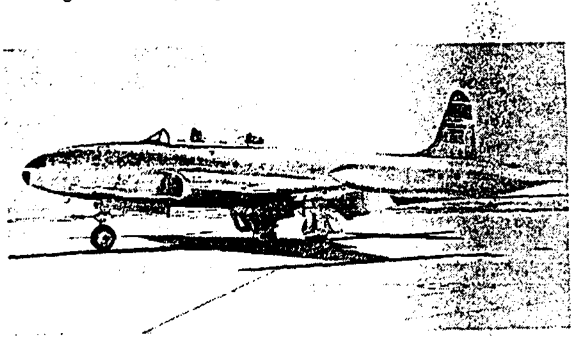

Fig. 3. The T-33A; all data reported was collected in this aircraft.

METHODS

Phase I—Thirteen pilots qualified to fly the T-33A Jet Trainer were studied during a series of thirteen touch-and-go landings each. Each flight included landings with full binocular vision, landings with the left eye covered, and landings with the right eye covered. A safety pilot was carried in the rear cockpit on all flights. A standard closed pattern with the landing gear extended was used. Patching was accomplished on the downwind leg while the safety pilot flew the airplane. A standard black clinical eye patch was used, modified slightly to provide clearance of the eyelashes, and a tight light seal (Figure 7); this was assured by entrapping the patch (Figure 2) beneath the oxygen mask nasally and the crash helmet laterally.

A prominent white line was painted across the North Edwards Air Force Base Runway eight hundred feet from the approach end and specified as the touchdown spot. The pilots were asked to fly power-on approaches to a fully flared touchdown as near the specified line as possible. They were not otherwise constrained as to the type of approach flown except that they were cautioned in advance against forcing the aircraft onto the runway without flaring in order to achieve a more precise touchdown.

All pilots studied have normal stereoscopic vision as measured by the Wertz test. All have normal distant visual acuity (20/20 or better); two wear corrective lenses because of minor presbyopic changes. Eye dominance was determined by means of a simple aiming technique.

The T-33A (Figure 3) was chosen for this experiment because of its relatively docile handling characteristics, and because it provided a flat approach profile during power-on approaches to the flare. This technique assures a sensitive indication of depth perception in that minor errors in judgment of height at the flare initiation point creates relatively large errors in longitudinal touchdown performance.

Prior to flight each pilot was carefully briefed utilizing a standardized protocol. No pilot was aware of the trend in the data prior to his participation as a subject in the experiment. In order to obtain the most uniform landing performance possible, pilots not recently proficient in the T-33A were allowed up to five periods of practice at a different airfield prior to participation in this program. After flight each pilot was carefully debriefed and asked to submit his subjective impressions for inclusion in this report.

Phase II—This phase was designed to explore changes in pilot performance, if any, over a longer period of time after the loss of binocular vision, but was discontinued when the trend of the data from Phase I was established. Consequently, only one pilot, number 128 from Phase I, was studied; however, the data are of considerable interest and are included. This pilot was studied for three consecutive weeks during which his dominant eye was patched. Landing performance was analyzed during three flights including thirty-five landings and compared with control data flown on the day prior to patching and six days after removal of the patch. This delay was necessary to allow resolution of diplopia which had developed during the experimental period.

INSTRUMENTATION

Longitudinal and lateral misses about the specified touchdown spot were photo-optically measured by means of simultaneous motion pictures taken from a point fifteen hundred feet abeam the touchdown spot and on the centerline two hundred feet beyond the departure end of the runway. Arriflex Model 16S 16mm motion picture cameras were used in both positions. The side camera was equipped with a 150-mm lens and fitted with a panning head so that the aircraft could be smoothly tracked throughout approach and touchdown. The centerline camera was equipped with a 100-mm lens, mounted on a three-foot tripod, aligned with the centerline of the runway and fixed in position. Both cameras were operated at 24-frames/sec which produced at the landing speeds observed a longitudinal resolution of ten feet and a vertical resolution of .25 feet. Longitudinal resolution was improved to less than three feet through interpolation between frames by careful examination of the smoke generated as the tire contacted the runway at touchdown. Linear scale factors were calibrated on each film by comparison of known dimensions on the aircraft. Suitable brightly colored targets were placed alongside the runway and positioned such that their image on the side camera film appeared at one hundred foot intervals relative to the runway centerline including eight stations on either side of the selected touchdown spot. The zero touchdown line was identified with a larger square target painted alternately black and white. (Figure 4).

All pilots were instrumented for electrocardiogram, respiratory rate, respiratory volume, normal acceleration and voice comments from both the subject pilot and the safety pilot. These measurments were made to estimate the cardiorespiratory stresses associated with this experiment and will be the subject of a subsequent report.

RESULTS

Data reduction of the landing films was accomplished on the Telereadex Evaluator Model 29A. Landing data thus obtained was punched on cards using the Telecordex Encoder Type 282E and the IBM Type 523 Summary Card Punch. Subsequently the data cards generated were processed on the Flight Research Center's

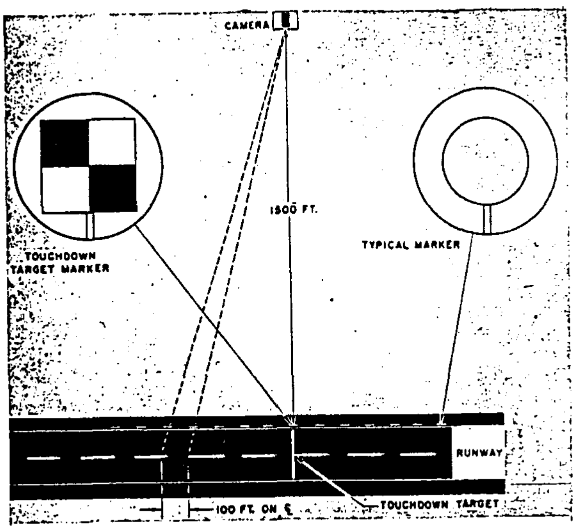

Fig. 4. The North Edwards Air Force Base Runway showing arrangement of targets and the side camera in position.

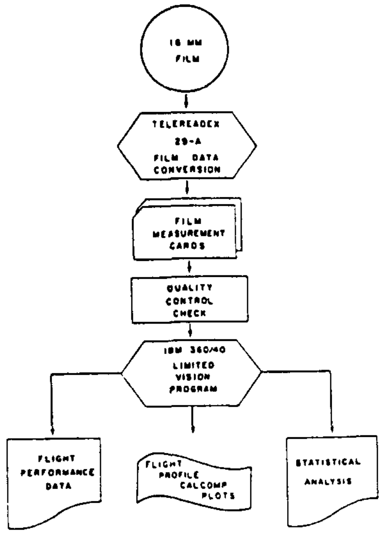

Fig. 5. Data reduction schema.

IBM 360-40 Computer using a program especially written for this project that provided automatically: (Figure 5)

1. Longitudinal and lateral miss analysis.
2. Analysis of performance on final approach with respect to airspeed control, sink rate, and the approach angle.
3. Plotting of fitted curves for the three treatments studied.
4. The necessary statistical analyses; Two-way analysis of variance, (ANOVA), "F"-Tests, and regression analysis.

Phase I—Longitudinal miss-data along with the standard errors observed are presented in Table I. Surprisingly, overall monocular performance was better than the corresponding overall binocular performance; however, the difference observed was not statistically significant. The ANOVA summary on which this conclusion was based is presented in Table II. Data relevant to lateral misses, sink rate on final approach, indicated airspeed on final approach and the approach angle flown were analyzed in exactly the same manner. The combined results from these analyses are presented in Table III at confidence levels of both 95 percent and 99 percent. Note that the pilot effects (variable 1), as expected, are significantly different; also that the effect on landing performance of restricted vision (variable 2) was not significantly different for either lateral and longitudinal misses.

Analysis of the approaches flown reveal highly significant differences in the technique chosen by the pilots during monocular approaches. Interestingly, except for one pilot whose approach performance plots almost exactly overlay, steeper approaches (Figure 6) were observed during monocular landings than those observed during corresponding binocular controls although none of the pilots was aware of this difference at the time. These steeper approaches are reflected in the differences in airspeed, sink rate, and the approach angle shown in Table III.

Data that describe the pilot population studied with

TABLE I. AVERAGE LONGITUDINAL MISS DISTANCES AND STANDARD ERRORS IN FEET

Pilot Code	Landing Vision: Left Eye	Right Eye	Combined Monocular	Binocular
143	105.3 ± 92.0	71.3 ± 61.5	88.3 ± 78.2	151.1 ± 145.4
141	139.9 ± 54.1	105.2 ± 72.4	122.5 ± 63.9	53.3 ± 47.5
142	112.8 ± 126.0	73.0 ± 59.9	92.9 ± 98.7	260.2 ± 97.5
149	68.8 ± 50.7	68.4 ± 73.9	68.6 ± 63.3	60.4 ± 41.6
120	73.8 ± 20.0	97.4 ± 143.7	85.6 ± 102.6	248.6 ± 90.3
150	374.5 ± 251.2	155.7 ± 71.7	265.1 ± 184.7	226.8 ± 152.6
146	127.4 ± 129.7	273.3 ± 242.5	200.4 ± 194.4	146.4 ± 65.4
140	79.6 ± 41.2	156.4 ± 143.0	118.0 ± 105.3	122.2 ± 107.9
128	268.3 ± 140.9	94.0 ± 73.6	181.2 ± 112.4	203.1 ± 205.6
138	83.4 ± 85.6	72.4 ± 91.0	77.9 ± 88.4	65.5 ± 91.3
207	66.1 ± 54.0	86.8 ± 81.1	76.4 ± 68.9	103.5 ± 36.4
215	160.8 ± 142.9	125.2 ± 133.5	143.0 ± 138.3	238.4 ± 227.8
214	315.3 ± 256.9	103.6 ± 76.0	209.4 ± 189.4	157.6 ± 182.5
Average	152.0 ± 17.4	114.0 ± 17.4	133.0 ± 8.7	158.1 ± 17.4

TABLE II. TWO-WAY ANALYSIS OF VARIANCE (DATA: LONGITUDINAL MISS DISTANCE IN FEET)

Source of Variation	d.f.	Sum of Squares	Mean Square	F Observation	F@ .05 Table	F@ .01 Table
Pilots	12	433547.93	36128.99	2.29*	2.05	2.34
Treatments	2	59341.48	29670.74	1.88	3.80	4.98
Interaction (PxT)	24	463044.65	19293.52	1.22	1.76	1.95
Error	117	1842983.23	15751.99			
Total	155	2798917.29				

S.E. = 125.51

*Significant at 5 percent level

TABLE III. EFFECT OF PILOT DIFFERENCES AND LOSS OF BINOCULAR VISION ON LANDING PERFORMANCE

Landing Performance Variable	$\alpha = 0.05$ Variable 1 Signif.	$\alpha = 0.05$ Variable 2 Signif.	$\alpha = 0.01$ Variable 1 Signif.	$\alpha = 0.01$ Variable 2 Signif.
Long. Misses	yes	no	no	no
Lat. Misses	yes	no	yes	no
Sink Rate	yes	yes	yes	yes
Indicated Airspeed	yes	yes	yes	yes
Approach Angle	yes	yes	yes	yes

Variable 1: Pilot Effects, Variable 2: Effect of restricted vision
α: Confidence interval

TABLE IV. PILOT AGE, EXPERIENCE, AND EYE DOMINANCE

Pilot Code	Age (Yrs)	Experience (Hrs)	Dominant Eye
143	34	2,650	Left
141	43	10,000	Right
142	38	5,100	Right
149	33	3,100	Right
120	37	2,300	Right
150	36	3,200	Right
146	33	2,800	Right
140	40	5,000	Right
128	39	2,100	Right
207	43	4,284	Right
215	36	3,637	Right
214	30	2,222	Left
138	47	5,291	Alternator
Average	37.6	3,975.7	

TABLE V. LONGITUDINAL MISS DISTANCES AND STANDARD ERRORS IN FEET VERSUS EYE DOMINANCE
(Rearranged from Table I)

Pilot Codes	Landing Vision: Non-Dominant Patched	Dominant Patched	Binocular Vision
143	105.3 ± 92.0	71.3 ± 61.5	151.1 ± 145.4
141	105.2 ± 72.4	139.9 ± 54.1	53.3 ± 47.5
142	73.0 ± 59.9	112.8 ± 126.0	260.2 ± 97.5
149	68.4 ± 73.9	68.8 ± 50.7	60.4 ± 41.6
120	97.4 ± 143.7	73.8 ± 20.0	248.6 ± 90.3
150	155.7 ± 71.7	374.5 ± 251.2	226.8 ± 152.6
146	273.3 ± 242.5	127.4 ± 129.7	146.4 ± 65.4
140	156.4 ± 143.0	79.6 ± 41.2	122.2 ± 107.9
128	94.0 ± 73.6	268.3 ± 140.9	203.1 ± 205.6
207	86.8 ± 81.1	66.1 ± 54.0	103.5 ± 36.4
215	125.2 ± 133.5	160.8 ± 142.9	238.4 ± 227.8
214	315.3 ± 256.9	103.6 ± 76.0	157.6 ± 188.5
	137.9 ± 39.7	137.2 ± 31.6	165.8 ± 28.7

NOTE: One pilot who was an alternator has been excluded from this analysis.

respect to age, experience, and eye dominance are presented in Table IV. Longitudinal miss distances from Table I rearranged with respect to dominance are presented in Table V. The average performance with the dominant eye patched is seen to be almost identical to the average performance with the non-dominant eye patched. Again, the monocular performance appears slightly superior to the corresponding binocular control data but the difference was not statistically significant.

Phase II—Data obtained from the pilot studied in Phase II are presented in Table VI along with the standard errors observed. The average binocular performance observed is slightly better than the average monocular performance observed, however, flights number 3 and 4 were flown in the presence of a significant quartering tailwind which materially degrades pilot landing performance in the T-33A. In spite of this, statistical examination of the data (ANOVA) has shown these treatments not to be significantly different. Performance on final approach for all five flights studied is presented in Figure 7. The striking similarity to the data presented in Phase I is observed. This becomes even more impressive when it is realized that the flights were flown in markedly different wind conditions and flight number 5 was flown four weeks later than flight number 1. Finally, the data from both phases were tested for learning effect by analysis of variance and rank correlation but none could be demonstrated.

DISCUSSION

In this study, pilots' spot landing performance was measured during landings with vision restricted to monocular cues only. These data are compared with suitable controls flown during the same flight with full binocular vision. Landing performance judged on the sole criteria of misses about a predetermined spot on the runway was not significantly affected by the loss of stereopsis. Significant differences in the techniques chosen to accomplish these approaches have been observed.

With the exception of the senior author, the pilot population studied is a highly experienced group of test pilots. The results expressed herein, therefore, are not considered representative of even the jet pilot popu-

TABLE VI. AVERAGE LONGITUDINAL MISS DISTANCES IN FEET

Flight No.	Landing Vision: Monocular (Dominant Eye Patched)	Binocular
1		126.5 ± 106.7
2	126.4 ± 71.2	
3	169.1 ± 149.6	
4	166.6 ± 150.1	
5		132.6 ± 131.7
Average	152.4 ± 20.8	129.6 ± 25.2

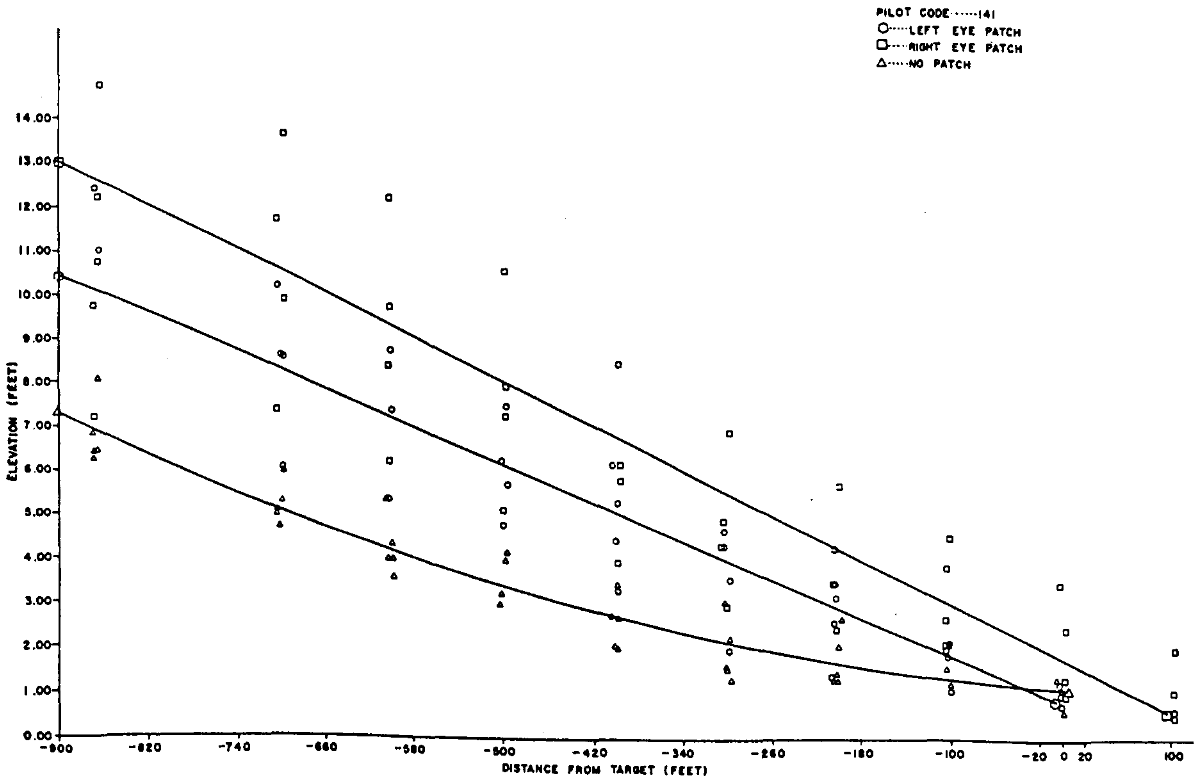

Fig. 6. Typical final approach performance, Phase I.

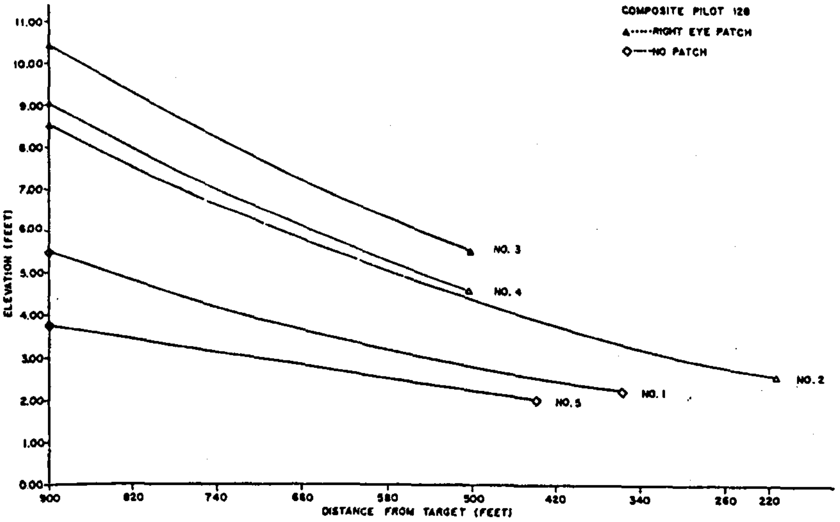

Fig. 7. Combined final approach performance, Phase II.

lation and certainly not representative of general aviation pilots. Caution must be exercised therefore in the widespread application of these data.

In the group studied, the results obtained have conclusively shown that the one-eyed pilot can precisely perform the spot landing task; indeed, it would appear that he suffers *no impairment of function whatever* even immediately following the sudden loss of stereopsis. This argues strongly in favor of granting aviators, in this experience category, full Class I flying status.

It is recognized in this regard that the experiment reported does not treat the problem of restricted peripheral vision on the blind side. The authors have observed, however, while watching the subjects in this experiment, that a different pattern of head motions was used with one eye covered than those observed while flying with normal vision. Consider also that the peripheral visual field of a single eye is very little different than that of two eyes except for the presence of the nose, the cheekbones, and the supra-orbital structures. By cocking his head slightly to favor the blind side and changing his mode of head motion, it may be that the one-eyed pilot suffers very little loss of what we have come to call the "functional" peripheral field-of-view. A formal experiment designed to explore this point will be conducted at the Flight Research Center during 1969 and reported later.

Subjective comments were solicited from each pilot following his flight and analyzed as part of this study. All pilots studied were impressed with the difference in perception after patching either eye. Many reported a sensation of diminished brightness generally; most reported a marked lack of confidence in their ability to accurately judge height. Some felt their ability to judge height was not significantly altered but were quite reluctant to depend on this information which may have been responsible for the tendency to fly the higher final approaches observed. Most pilots reported a significant increase in "workload" during monocular landings.

CONCLUSIONS

In the pilot population studied:

1. Spot landing performance in jet aircraft is not adversely affected by the sudden total loss of vision in either eye. This observation has important implications with regard to aeromedical standards.

2. Significantly steeper approaches are observed during monocular landings than those observed during approaches made with normal vision. It is suggested that the pilots' lack of confidence in their ability to accurately judge height during monocular approaches was responsible for the steeper approaches reported.

3. Eye dominance is shown not to affect monocular landing performance (95% level of confidence).

4. Noticeable increases in pilot workload are subjectively reported during monocular landings.

5. It is suggested that monocular pilots may not experience significant losses in their "functional" visual field; a definitive study is indicated.

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Summary of the results of Dr. Arlene Drack's Ophthalmology Evaluation
on Captain Joseph Broker

Uncorrected Vision:

	Distant vision	Near vision
Right eye	20/20	20/70
Left eye	20/20	20/70

Vision wearing bifocal glasses:

	Distant vision	Near vision
Right eye	20/20	20/20
Left eye	20/20	20/20

Vision wearing monovision contact lenses:

	Distant vision	Near vision
Right eye	20/20+2	20/70
Left eye	20/30	20/20
Both	20/15-2	20/20

Worth 4 dot test

Uncorrected vision:	fusion at all distances
Vision wearing bifocal glasses:	fusion at all distances
Vision wearing monovision contact lenses:	fusion at 3 feet, suppression of the left eye at distance

Titmus (near) stereopsis test

Uncorrected vision:	200 seconds/15 minutes of arc
Vision wearing bifocal glasses:	40 seconds/15 minutes of arc
Vision wearing monovision contact lenses:	80 seconds/15 minutes of arc

BVAT (distance) stereopsis test

Uncorrected vision:	120 degrees
Vision wearing bifocal glasses:	120 degrees
Vision wearing monovision contact lenses:	240 degrees

7 Mar 97

MEMORANDUM FOR THE NATIONAL TRANSPORTATION SAFETY BOARD

ATTENTION: DR. MITCH GARBER

FROM: AL/AOCO

2507 Kennedy Circle

Brooks AFB TX 78235-5117

SUBJECT: Consultation Response Case # NTSB ID: NYC97MA005

1. Thank you for the opportunity to review this case. This package is in response to your inquiry in reference to case # NTSB ID : NYC97MA005; where a 48 year-old male pilot wearing "monovision" contact lenses as his current optical correction was involved in a landing mishap, under IMC conditions.
2. We would like to begin with a brief background on "monovision". "Monovision" is an optical technique of fitting presbyopic patients (who need reading glasses) with one contact lens for distance correction, and the other lens for near correction . It is well documented in

the literature that on average "monovision" (MV) lenses produce a minor reduction in high contrast visual acuity when compared with the use of full binocular distance and near correction (BV)(1). Clinically measured near stereoacuity (fine depth perception) can be expected to diminish from 40 arc sec to 50 arc sec (BV) to 80 to 100 arc sec (MV) using a +2.00 add. Stereopsis is more sensitive to monocular blur than to similar amounts of binocular blur. Sensory functions, such as contrast sensitivity and stereoacuity, are affected most. In 1982, Larson WL, and Lachance A., published a study in reference to stereoscopic acuity with induced refractive errors. Their findings confirm and amplify those of previous reports because they demonstrated that stereopsis is scarcely affected when lenses are added symmetrically. On the other hand, lens asymmetry caused a systematic reduction in stereoacuity which was related to the amount of the imbalance(2). Clinically significant anisometropia (the difference in correction between the eyes) is known to cause amblyopia and decreased stereopsis, but the amount of anisometropia required to do this is usually on the order of 1.00 D or more. Other study results indicate that considerably smaller amounts of anisometropia may induce visual performance penalties(3). So, we can conclude that a relative visual blur in one eye induced by correction imbalances leads to a decrement greater than if both eyes are equally blurred together (4), and could be regarded as a potential problem if the anisometropia is greater than 1.00 diopter or more.

3. Answering your specific questions:

A. How would the degradation of stereopsis associate with monovision contact lenses likely affect the ability of this pilot to correctly assess his altitude, glide path, and descent rate, given the prevailing conditions ?

Given the poor weather conditions, and after reviewing the submitted package, we can summarize that all the visual cues for this landing were minimal putting them in a visually deprived environment. Stereopsis would be decreased somewhat by monovision and other gross depth perception cues would also be minimal such as perspective straight ahead (couldn't see the end of the runway). More gross peripheral or side cues such as motion parallax were also compromised being obscured by rain. Thus, they were in an extremely visually deprived environment where the loss of any critical visual performance ability, such as stereopsis (binocularity) would be more critical to bolster the sparse monocular cues. This assumes that the mishap pilot had normal stereopsis to begin with, which is an important issue in this case. In MV, there may be some residual fine stereopsis, but for the reasons stated above it will be somewhat decreased. Thus, his overall ability to judge depth based cues would be decreased over normal binocular function. Other situational factors contributed to the overall degradation of the visual scene: poor visibility, decentered approach to the runway, so that if the instrument approach was not within parameters, then the loss of stereopsis might contribute to loss of visual performance and increased reaction times at a time when it least could be afforded. In other words, others will need to judge the approach mechanics to determine if it was salvageable even with perfect capabilities, and if it was, then monovision effects certainly degraded his visual performance over a normal pilot in this case and in our opinion, further degraded the situation. Stereopsis would have been helpful under such conditions. We consulted an active duty USAF senior pilot, to help us in the interpretation of the printout from the Flight Data Recorder. In his opinion, this was a classic example of "duck under" on instrument approach. He was unable to determine the technical impact of the optical correction related to this case, but he agreed a pilot would have needed all of his normal depth perception and vision skills during this potentially unsalvageable landing scenario, regardless of vision status. He agreed that other possible contributing factors included: the weather, diminished visual cues, flying over water, sparse peripheral visual cues, visibility, etc. He also added that the approach itself would need to be questioned by competent authorities as to whether it was recoverable or not, even before the visual cues would enter into the picture, meaning that once a decision to land was made, compromised vision and stereopsis didn't help.

B. How long might it take for this pilot, wearing his contact lenses, to clearly change his focus from the instrument panel to the runway, considering visual blur and any potential deformation of the lens of the dominant eye due to prolonged accommodation while in instrument flight?

Presbyopes (1) with remaining accommodative function might be expected to experience some confusion between the accommodation system and MV conditions, particularly in the intermediate viewing range. In theory, MV patients with reading add powers less than 2 D, should be able to control accommodation to maintain clear vision in the distant eye from the nearpoint to optical infinity. In 1988 (5) Schor C. and Erickson P., studied the patterns of binocular suppression and accommodation in monovision. They found that some subjects wearing MV lenses were able to retain a clearly perceived binocular image continuously throughout both monocular ranges of clear vision. Others achieved this only when the initial object position was in the range of clear vision of the nondominant eye. These results suggest that most presbyopes are well equipped to coordinate accommodation with target distance changes under less critical but typical real viewing conditions.

As we all know, accommodation time increases with age. If he was in monovision mode (if properly fit) his accommodation / disaccommodation times would be shorter, since one eye is instantly available for near (w/o accommodating) and one is instantly available for distance.

C. Would the use of MV lenses render this pilot particularly susceptible to any common visual illusions, such as aerial perspective or size constancy?

We believe, based on AOCO experience, that monovision does not cause true visual illusions. However, it does compromise the quality of the overall visual scene and binocular function. We know that the blurred view for distance in the CL wearing "near" eye interferes with the overall perception of the distant scene in the uncorrected other eye, such that the scene becomes clearer by "shutting" the MV eye. This occurs across the entire contrast spectrum. The potential effects of MV correction during driving or flying activities are of concern. Deficits of visual acuity and contrast sensitivity during MV (especially when the conditions are near threshold) may reduce target identification. "Ghosting", which can be present in MV is attributed to incomplete suppression of the interocular blur. If this should be present, these secondary images can be distracting. The ability to suppress the blur may improve with adaptation, but performance levels equivalent to those with normal binocular vision may never be achieved. This in combination with acute disturbances in steropsis, is why the USAF does not recommend this approach to correct presbyopic aircrew.

D. How would the use of MV lenses affect the ability of this pilot to accurately see and interpret cockpit instruments?

For the same reasons expressed above, it is our believe that MV would probably <u>not</u> interfere with the perception and interpretation of the near scene (the cockpit).

E. How do you feel that the issue of differing near and distant visual acuity can be most safely handled in the pilot population?

Throughout aviation history, the near and distance visual acuity issue is not a new one and has become even more of a problem, especially in the military, as older aircrew continue to want to fly high performance aircraft. It is less of a problem in commercial aircraft. It is the position of the USAF that bifocals cheaply, safely, and easily correct the most of the functional problems associated with presbyopia up to the age of 50 years, and trifocals possibly are more helpful above that age. In some cases, an additional add on the top of the lens the so-called "double D" add, may be useful in the commercial cockpit. Furthermore, although progressives adds are not authorized in military aircraft because of blurred images inferotemporally, and nasally, coordination of eye/head movements, adaptability issues, and cost, the commercial or equivalent military cockpit is a much more friendlier environment for their use. Bifocal contacts and particularly monovision scenarios are not allowed. Obviously, all corrective lenses should be fitted to both eyes in such a way that they are not interfering with normal binocularity.

F. What is the Air Force policy on MV lenses in pilots and what is the basis for that policy?

Because of the above already expressed and other reasons, the current Air Force policy in reference to MV lenses for aircrew, mitigates strongly against monovision and bifocal contact lenses.

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Nature has her way of reminding us that time is passing. One of the most common signs of growing older is when it becomes difficult to focus clearly on objects close to you. This usually means it's time to wear bifocals or reading glasses.

When you reach the age for bifocals, you can reach for Acuvue for Monovision. Monovision is a contact lens fitting technique that lets you see clearly both near and far. Acuvue gives you the added convenience of disposable contact lenses.

Whether you've already joined the millions of adults who have trouble seeing near, or you're headed in that direction, you can look forward to the freedom of reading and other close-up activities without the bother of bifocals.

The easier way to see near and far.

Monovision is a different vision correction system than bifocal contact lenses and doctors have used it for years. With Monovision, your contact lenses let you see clearly from near and far effortlessly.

If you currently wear bifocals or reading glasses, Acuvue for Monovision frees you from the nuisances associated with them. Your field of vision is greater, because there are no eyeglass frames interrupting your peripheral vision. Acuvue also means no more glasses to put on and take off, misplace or lose. And you won't have glasses sliding down your nose. Or fogging up.

Disposable Contacts That ACUVUE® CONTACT LENSES FOR MONOVISION Can Disp

APPENDIX E—WEATHER INFORMATION

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington D.C. 20594

Meteorological Factual Report
NYC97MA005
February 13, 1997

A. ACCIDENT

Location: La Guardia Airport, Flushing, New York [KLGA]
Date: October 19, 1996
Time: 2038 UTC
Aircraft: McDonnell Douglas MD-88, N914DL, Delta Air Lines Flight 554 [DAL 554].

B. WEATHER GROUP

Chairman: Gregory D. Salottolo, National Transportation Safety Board, Washington D.C.

Member: Arlan D. Ellmaker, Manager Meteorology, Delta Air Lines, Inc., Atlanta, Georgia.

Member: James P. Johnson, Air Line Pilots Association, Glenview, Illinois.

C. DETAILS OF INVESTIGATION

Note in the report all times Coordinated Universal Time (UTC) based on the 24 hour clock unless noted. All heights above mean sea level (MSL) unless noted. Heights in surface weather observations and terminal forecast above ground level (AGL). All directions with reference to true north unless noted. Z = Coordinated Universal Time. All distances in statute miles unless noted. Eastern Daylight Time (EDT) = Z - 4 hours. McIDAS - Man computer Interactive Data Access System. McIDAS is an interactive meteorological analysis and data management computer system. McIDAS is administered by personnel at the Space Science and Engineering Center at the University of Wisconsin at Madison. Data are accessed and analyzed on an IBM PS/2 Model 77 Computer.

*Note: All referenced attachments are available in the public docket. They are not included in this Appendix

Synoptic Situation

The 2100Z National Weather Service (NWS) Surface Analysis showed a low pressure center in central New Jersey with a weak occluded front extending to the east and southeast. Strong easterly winds and rain were noted to the north and northeast of the low pressure center (See Attachment 1).

Surface Weather Observations

An Automated Surface Observing System(ASOS) was installed at KLGA. The ASOS data is edited and augmented by a certified weather observer from Weather Experts Inc. The weather office is located on the third floor of the Marine Air Terminal which is located about 3,700 feet southwest of the approach end of runway 13. The following observations are for KLGA (See Attachments 2, 3,4):

2027Z .. Special .. Winds 080 degrees at 14 knots; visibility 3/4 mile; heavy rain; mist; ceiling 800 feet broken, 1,300 feet overcast; temperature 14 degrees C; dew point 14 degrees C; altimeter setting 29.49 inches of Hg.; tower visibility 2 1/2 miles; pressure falling rapidly; runway 04 visual range 4,000 variable 4,500 feet; cumulative precipitation sensor inoperative.

2034Z .. Special .. Winds 090 degrees at 12 knots; visibility 1/2 mile; heavy rain; fog; ceiling 800 feet broken, 1,100 feet broken, 1,900 feet overcast; temperature 14 degrees C; dew point 14 degrees C; altimeter setting 29.50 inches of Hg.; tower visibility 2 1/2 miles; pressure falling rapidly; runway 04 runway visual range 4,000 to 4,500 feet; cumulative precipitation sensor inoperative.

2051Z .. Winds 070 degrees at 13 knots; visibility 1 mile; heavy rain; mist; ceiling 800 feet broken, 1,100 feet broken, 1,900 feet overcast; temperature 14 degrees C; dew point 14 degrees C; altimeter setting 29.50 inches of Hg.; tower visibility 2 1/2 miles; pressure falling rapidly; runway 04 runway visual range 4,000 to 5,000 feet; cumulative precipitation sensor inoperative.

According to the Weather Observer on duty at the time of the accident all equipment with the exception of the cumulative precipitation sensor was operating. All observations were transmitted to the tower within 30 seconds of the observation time. The Weather Observer also indicated that he called the tower to notify tower personnel of these observations.

The following wind, present weather, and visibility information is from the 5 minute ASOS data:

2025Z .. 080 degrees at 17 knots .. Heavy rain .. 1 1/4 miles
2030Z .. 090 degrees at 14 knots .. Heavy rain .. 3/4 mile
2035Z .. 090 degrees at 11 knots .. Heavy rain .. 1/2 mile
2040Z .. 060 degrees at 16 knots .. Heavy rain .. 1/2 mile
2045Z .. 060 degrees at 16 knots .. Heavy rain .. 3/4 mile

The following is from the 1 minute ASOS engineering data (See Attachments 5 and 6):

Time .. UTC.
VIS1 .. 1 minute average visibility statute miles sensor 1.
VIS2 .. 1 minute average visibility statute miles sensor 2.
VIS3 .. 1 minute average visibility statute miles sensor 3.
WDIR .. 2 minute average wind direction degrees.
WSP .. 2 minute average wind speed knots.
GDIR .. Maximum 5 second average wind direction degrees.
GSP .. Maximum 5 second average wind speed knots.

Visibility (VIS) in statute miles is calculated using the following formula: (3 / Extinction Coefficient [kilometers]) X 0.621371 statute mile per kilometer [National Weather Service, September 1995].

Time	VIS1	VIS2	VIS3	WDIR	WSP	GDIR	GSP
2030	.55	.79	.87	087	14	093	16
2031	.59	.83	.78	090	14	092	17
2032	.58	.88	.77	092	14	100	14
2033	.52	.85	.80	093	13	089	13
2034	.41	.85	.63	091	12	089	13
2035	.44	.79	.57	090	11	097	12
2036	.40	.77	.60	084	11	077	12
2037	.47	.77	.58	077	12	064	15
2038	.49	.73	.62	071	14	054	15
2039	.57	.69	.52	065	15	063	18
2040	.82	.93	.70	062	16	066	18

WX .. Present weather.
PRESS1 .. Pressure inches of Hg. from pressure sensor 1.
PRESS2 .. Pressure inches of Hg. from pressure sensor 2.
PRESS3 .. Pressure inches of Hg. from pressure sensor 3.
Pressure sensors are located in the weather office.
T .. Temperature degrees F.
TD .. Dew point temperature degrees F.

Time	WX	PRESS1	PRESS2	PRESS3	T	TD
2035	R+	29.459	29.453	29.460	57*	58
2036	R+	29.455	29.449	29.456	57*	58
2037	R+	29.452	29.446	29.453	58	58

2038	R+	29.447	29.441	29.448	58	58
2039	R+	29.445	29.439	29.446	58	58
2040	R+	29.445	29.438	29.446	58	58

* From data printout.

ASOS Sensor Locations

Two visibility sensors (VIS1 and VIS3) are located about 1,480 feet southwest of the approach end of runway 13.

The third visibility sensor (VIS2) is located about 1,850 feet east of the approach end of runway 13.

The wind, temperature, and dew point sensors are located about 1,480 feet southwest of the approach end of runway 13.

Two ceilometers are located about 1,480 feet southwest of the approach end of runway 13. A third ceilometer is located about 1,850 feet east of the approach end of runway 13.

A review of the METAR (Aviation Routine Weather Report)/ SPECI (Special Weather Report) reports, 5-minute ASOS observations, 1-minute archive ASOS engineering data, and the ASOS maintenance log was made at the request of the NTSB by the National Weather Service. The following are summarized excerpts from the National Weather Service report dated December 27, 1996.

During the time period 1949Z to 2059Z all of the sensors were operational and the following sensors were in automatic mode of operation: ambient/dew point temperature; precipitation identification; wind speed and direction; and precipitation accumulation gauge. Heavy rain was reported during this time period but the precipitation gauge did not provide any accumulations. Therefore, ASOS placed a Maintenance Indicator sign ($) and a PNO (precipitation amount not available) at the end of the reports and observations. There were edit actions taken by the observer during this period where the sky condition, visibility, and precipitation accumulations were backed-up for unrepresentativeness. The observer also provided augmentation for Runway Visual Range (RVR) information. With the exception of the rain gauge, ASOS appears to be operating normally.

Rain Gauge Record

The amount of rain estimated from the rain gauge record for the time period 2030Z to 2045Z was 0.09 inch (rainfall rate 0.36 inch per hour). The rain gauge is located on the roof of the Marine Terminal Building (See Attachments 7 and 8).

National Weather Service Observing Handbook No. 7 Part 1 defines heavy rain as rain occurring at a rate of more than 0.30 inch per hour; more than 0.03 inch in 6 minutes.

Runway Visual Range (RVR)

RVR for the Runway 13 Touchdown was estimated from a plot of transmittance for the Runway 13 transmissometer obtained from the Federal Aviation Administration (FAA). According to the FAA [memo from the Manager of the Airways Facilities Division to the Manager of the Recommendations and Quality Assurance Division, dated November 22, 1996] one transmissometer serves as both the runway 13 and runway 22 touchdown RVR. When it became desirable to have RVR for runway 13 touchdown, it was determined that the transmissometer, as sited, could also serve runway 13. Readings would be valid if the runway 13 edge lights were set equal to, or higher than runway 22. To accomplish this a comparator circuit was devised. Since this transmissometer is correctly sited for both touchdowns, the one recording is acceptable for both runways. The following values were obtained from the plot of transmittance:

Runway 13 Touchdown

Chart Time	Transmittance %	RVR Feet
2030Z	78	3,500
2035Z	75	3,000
2040Z	80	3,500

The minimum value of transmittance for the chart time period 2030Z to 2040Z inclusive was 72%. This results in a RVR of 2,800 feet. The minimum value occurred at a chart time of about 2037Z.

Runway 04 Touchdown

Chart Time	Transmittance %	RVR Feet
2030	85	4,500
2035	85	4,500
2040	84	4,500

The minimum value of transmittance for the chart time period 2030Z to 2040Z inclusive was 79%. This results in a RVR of 3,500 feet. The minimum value occurred at a chart time of about 2039Z.

Note: Light Setting 5, Day Conditions, Tasker 500, Baseline 250 feet.

Runway 13 Touchdown

LS3 .. Light Setting 3 .. Day Conditions
LS4 .. Light Setting 4 .. Day Conditions

Chart Time	Transmittance %	RVR LS3	RVR LS4
2030	78	3,000	3,000
2035	75	2,600	2,600
2037	72	2,200	2,200
2040	80	3,500	3,500

Attachment 9 .. Plot of Transmittance Runway 13 Touchdown.
Attachment 10 .. Plot of Transmittance Runway 04 Touchdown.
Attachment 11 .. Conversion Table Transmittance to RVR LS5.
Attachment 12 .. Conversion Table Transmittance to RVR LS3 and LS4.

According to the FAA [reference above 11/22/96 memo] the transmissometer at the approach end of runway 31 was installed to provide departure minimums for that runway. The equipment was designated as runway 13 rollout to simplify paperwork since there was no runway 31 identifier when the RVR was installed. Runway 13 is a Category I and has no "rollout" RVR.

According to the FAA there is no plot of transmittance for the runway 31 transmissometer (Telephone conversation FAA Eastern Region 12/16/96).

14 CFR 91.175(h) ...
Comparable values of ground visibility and RVR ..

RVR	Visibility (statute miles)
1,600	1/4
2,400	1/2
3,200	5/8
4,000	3/4
4,500	7/8
5,000	1
6,000	1 1/4

Low Level Wind Shear Alert System (LLWAS)

A Phase II LLWAS was installed and operational at KLGA at the time of the accident. The KLGA LLWAS consists of 6 wind sensors. One wind sensor is located near the center of the airport and 5 wind sensors are placed in locations surrounding the airport (See Attachment 13). Alerts are generated for the following sectors: centerfield, northeast, southeast, southwest, and northwest.

According to an individual at MIT Lincoln Laboratories, in the Phase II LLWAS there are station, triangle, and edge alerts. The Phase II LLWAS is designed to issue a station alert if there is an indication of an anomalous wind at any sensor. In the Phase II LLWAS the test for an anomalous wind is that the sensor wind differ from the network mean by a statistically and operationally significant amount. This test requires at least a 15 knot vector difference, and may require a larger difference if the winds on the network have a recent history of severe gustiness. For the Phase II LLWAS four consecutive station alerts are required before a wind shear alert is issued (there are ten seconds between polls for the Phase II LLWAS). The Phase II LLWAS also estimates wind field divergence on all triangles and edges of reasonable size that can be formed by locations of the sensors. If excessive divergence is detected for four consecutive polls a wind shear alert is issued. Because of the small number of sensors most Phase II LLWAS alerts are based on station alerts. When an alert status is detected at a station, edge, or triangle, a sector alert is issued. The Phase II LLWAS has a 7 percent chance that an issued alert is false (93 percent chance that an alert is valid). According to an individual who was associated with the LLWAS program " This system, if it does issue an alert, it should be taken seriously." The precise location of a wind shear event at an airport can not be accurately determined by a Phase II LLWAS. Therefore, a Phase II LLWAS sector alert should be interpreted as indicating a possible hazardous wind shear not necessarily confined to a particular location (sector) but possible at any location on the airport.

The following information was obtained from LLWAS data provided by the FAA on October 22, 1996.

Northwest (NW) wind sensor data and Center Field Average (CFA) wind data.. Wind = Wind Direction Degrees Magnetic / Wind Speed knots.

The Northwest Wind Sensor is located about 5,468 feet northwest of the approach end of runway 13.

Time	Wind (NW)	CFA Wind
20:36:56	070/09	100/11
20:37:06	080/08	100/11
20:37:16	080/08	100/11
20:37:26	080/08	090/12
20:37:36	080/12	090/12
20:37:46	080/13	090/12
20:37:56	080/12	090/12
20:38:06	090/14	090/13
20:38:16	080/16	090/13
20:38:26	080/14	090/13
20:38:36	080/13	090/14
20:38:46	080/14	090/14
20:38:56	080/14	090/14
20:39:06	080/15	090/14

No gusts were reported from 20:00:06Z to 20:49:56Z inclusive.

No system alarms were noted from 20:00:06Z to 20:49:56Z inclusive.

LLWAS data are contained in Attachments 14,15,16.

WSR-88D data from Upton, New York (KOKX)

The following estimated winds for 2040Z are from the KOKX WSR-88D Velocity Azimuth Display Vertical Wind Profile (Product time 2134Z) (See Attachment 17):

Height	Wind [Direction degrees / Speed Knots]
1,000	083/60
2,000	090/65
3,000	105/70
4,000	108/70
5,000	109/65

A meteorologist at the NWS Forecast Office at Upton, New York was interviewed by phone on October 22, 1996. The following is a summary of the interview:

A WSR-88D image for 2040Z at the .5 degree elevation scan was reviewed. At KLGA the beam height is at about 4,500 feet. The reflectivity image indicated heavy showers a few miles south of KLGA. Radial Velocities were 26 knots northeast of KLGA and 45 knots southwest of airport. A WSR-88D horizontal shear calculation indicated 10 knots per 2 nautical miles in the area of KLGA. A mesocyclone signature or significant shear was not seen. For a beam height near 9,000 feet velocities of 22 to 30 knots south of KLGA and 40 to 50 knots north of KLGA were noted. A WSR-88D horizontal shear calculation showed 10 knots per 2.5 nautical miles. The meteorologist commented that he saw nothing real significant in these data. He saw no signatures of rotation and the data indicated all targets moving away from radar. He also commented that the WSR-88D did not identify anything in the area that met "storm" criteria. Spectrum Width values in the area were 8 to 12 knots. The meteorologist stated that the 10/20/0000Z upper air observation was not available because of equipment failure and the strong winds.

Review of KOKX WSR-88D Data

An Archive Level II doppler weather radar tape from the Upton, New York (KOKX) WSR-88D doppler weather radar was obtained from the National Climatic Data Center in Asheville, North Carolina. The data on the tape were reviewed on a Hewlett Packard X-Station using Motif Interactive Radar Analysis Software (Motif-IRAS).

Reference : Priegnitz, D.L., 1995 : IRAS: Software to display and analyze WSR-88D radar data, Eleventh

International Conference on Interactive Information and Processing for Meteorology, Oceanography, and Hydrology, Boston, American Meteorological Society, 197-199.

The approach end of runway 13 at KLGA is located about 265 degrees at 46 nautical miles from KOKX. At a radar elevation angle of .48 degrees the center of the beam at the approach end of runway 13 is at a height of about 3,943 feet. The beam width is about 4,635 feet.

Attachments 18 and 19 are Plan Position Indicator (PPI) Motif-IRAS KOKX WSR-88D Radar Reflectivity Images for the times of 2034:16Z and 2040:08Z. The images are color enhanced. The color bar at the bottom corresponds to radar reflectivities in dBZ. Range rings are every 10 kilometers and the azimuth interval is 5 degrees. True north is to the top. The overlay is centered at the approximate location of the approach end of runway 13 at KLGA. The elevation angle is .48 degrees.

Attachments 20 and 21 are Constant Altitude PPI (CAPPI) Motif-IRAS KOKX WSR-88D Radar Reflectivity Images for the times of 2034:16Z and 2040:08Z. The images are color enhanced. The color bar at the bottom corresponds to radar reflectivities in dBZ. Range rings are every 10 kilometers and the azimuth interval is 5 degrees. True north is to the top. The overlay is centered at the approximate location of the approach end of runway 13 at KLGA. Altitudes are in kilometers (km). The elevation angle is .48 degrees.

Values of radar reflectivity in dBZ, radial velocity [VR] in meters per second, and spectrum width [SW] in meters per second were generated using Motif-IRAS. Values are noted in the following Table:

DIST .. Distance in kilometers from approach end of runway 13 at KLGA (along 310 degrees true radial).
dBZ1 .. Radar reflectivity in dBZ for 2034:16Z.
dBZ2 .. Radar reflectivity in dBZ for 2040:08Z.
VR1 .. Radial velocity (easterly component) in meters per second for 2034:16Z.
VR2 .. Radial velocity (easterly component) in meters per second for 2040:08Z.
SW1 .. Spectrum width in meters per second for 2034:16Z.
SW2 .. Spectrum width in meters per second for 2040:08Z

DIST	dBZ1	dBZ2	VR1	VR2	SW1	SW2
0	47.5	44.0	21.0	22.5	3.5	3.5
1	48.0	44.5	21.5	24.5	4.5	4.0
2	47.5	42.0	21.0	23.0	5.5	[illegible]
3	42.5	38.5	23.0	23.5	3.0	[illegible]
4	42.5	38.5	23.5	25.5	2.5	3.5
5	42.5	38.5	24.0	25.5	3.0	3.5

6	41.0	38.0	24.0	25.0	3.0	2.5
7	39.0	35.0	24.0	23.5	3.5	2.5
8	39.0	36.0	25.5	24.5	3.5	3.0
9	39.0	37.5	23.5	25.5	3.5	3.0
10	37.5	34.5	23.5	25.5	3.0	3.0

dBZ1 maximum and minimum values = 48.0 dBZ and 37.5 dBZ. Rainfall rates corresponding to the above dBZ values are 1.79 and 0.29 inches per hour respectively. Liquid water contents corresponding to the above dBZ values are 1.90 and 0.48 grams per cubic meter.

dBZ2 maximum and minimum values = 44.5 dBZ and 34.5 dBZ. Rainfall rates corresponding to the above dBZ values are 0.93 and 0.18 inches per hour respectively. Liquid water contents corresponding to the above dBZ values are 1.20 and 0.32 grams per cubic meter.

dBZ1 at approach end of runway 13 = 47.5 dBZ. This corresponds to a rainfall rate of 1.52 inches per hour and a liquid water content of 1.78 grams per cubic meter.

dBZ2 at approach end of runway 13 = 44.0 dBZ. This corresponds to a rainfall rate of 0.93 inches per hour and a liquid water content of 1.12 grams per cubic meter.

Liquid water content calculated using $M = 3.44X10^{-3}Z^{.5714}$ (Greene and Clark; Monthly Weather Review; July 1972).
M = Liquid Water Content grams per cubic meter.
Z = Weather radar reflectivity millimeters to the sixth power divided by meters cubed ($Z = 10^{dBZ/10}$).

Rainfall rate calculated using $R = (Z/300)^{.714}$ (Federal Meteorological Handbook Number 11; June 1990; Chapter 5).
R = Rainfall Rate in millimeters per hour.
Z = Weather radar reflectivity millimeters to the sixth power divided by meters cubed ($Z = 10^{dBZ/10}$).

VIP/DBZ Conversion Table

NWS VIP	WSR-88D LVL	PREC MODE DBZ	RAINFALL
0	0 1 2	<5 5 to 9 10 to 14	
1 Very Light	3 4 5	15 to 19 20 to 24 25 to 29	.01 in/hr .02 in/hr .04 in/hr
2	6	30 to 34	.09 in/hr

Light to Moderate	7	35 to 39	.21 in/hr
3 Strong	8	40 to 44	.48 in/hr
4 Very Strong	9	45 to 49	1.10 in/hr
5 Intense	10	50 to 54	2.49 in/hr
6 Extreme	11 12 13 14 15	55 to 59 60 to 64 65 to 69 70 to 74 GTE 75	>5.67 in/hr

Satellite Data

Geostationary Operational Environmental Satellite (GOES) 8 Data were reviewed on the Safety Board's McIDAS Workstation. Images for Bands 1,2,3,4 were generated.

Attachments 22 and 23 .. GOES visible images (Band = 1) for 2032Z and 2045Z; 1 kilometer resolution; cross box = location of KLGA; images are contrast stretched. The 2045Z image shows convection in the area of KLGA.

Attachments 24 and 25 .. GOES infrared images (Band = 2) for 2032Z and 2045Z; 4 kilometer resolution; cross box = location of KLGA; images are color enhanced using the Color Enhancement Table ICE4.

Attachments 26 and 27 .. GOES infrared images (Band = 3) for 2032Z and 2045Z; 8 kilometer resolution; cross box = location of KLGA; images are contrast stretched.

Attachment 28 and 28A .. GOES infrared images (Band = 4) for 2032Z and 2045Z; 4 kilometer resolution; cross box = location of KLGA; images are color enhanced using Color Enhancement Table ICE4. Displaying these images in succession on a video monitor (looping) shows cloud movement to the northwest. Radiative temperatures (cloud top temperatures) at KLGA for 2032Z and 2045Z are about -34.2 and -36.2 degrees C respectively. Using upper air data from Albany, New York for October 20 at 0000Z, radiative temperatures of -34.2 and -36.2 degrees C result in cloud tops near 29,000 feet. See Attachment 28B.

Color Enhancement Table ICE4

Segment #	Temperature (degrees C)	(degrees K)
1	-.7 to -2.7	272.5 to 270.5
2	-3.2 to -15.2	270.0 to 258.0
3	-15.7 to -31.2	257.5 to 242.0
4	-32.2 to -41.2	241.0 to 232.0
5	-42.2 to -52.2	231.0 to 221.0
6	-53.2 to -58.2	220.0 to 215.0
7	-59.2 to -62.2	214.0 to 211.0
8	-63.2 to -80.2	210.0 to 193.0
9	-81.2 to -109.2	192.0 to 164.0

Upper Air Data

Upper air data from Albany, New York for October 20, 1996 at 0000Z is as follows:

LEVEL...Height Millibars
TEMP...Temperature Degrees C
DEW PT...Dew Point Temperature Degrees C
DIR...Wind Direction Degrees True
SPEED...Wind Speed Meters per Second
HEIGHT...Height Meters Above Mean Sea Level

Albany is located about 119 nautical miles north of KLGA.

STATION:72518 DAY/TIME:96294 000000 LAT/LONG:427500 737999

LEVEL	TEMP	DEW PT	DIR	SPEED	HEIGHT
1000.0	11.6	6.6	70.0	8.2	89.0
984.0	10.6	3.6	66.9	12.7	223.8
974.5	9.9	3.7	65.0	15.4	304.0
939.2	7.1	3.9	75.0	16.4	609.0
925.0	6.0	4.0	75.0	16.9	735.4
905.0	5.1	3.4	85.0	18.5	914.0
871.7	3.5	2.3	100.0	22.1	1219.0
850.0	2.4	1.6	105.0	24.6	1424.7
840.0	3.0	2.1	108.6	25.6	1520.7
837.0	3.0	-5.0	109.6	25.9	1549.7
833.0	3.6	-6.4	111.1	26.3	1588.6
825.0	5.8	-19.2	114.0	27.1	1667.2
821.0	6.8	-18.2	115.5	27.5	1707.1
808.9	6.5	-17.3	120.0	28.8	1829.0
779.3	5.8	-15.2	120.0	29.8	2134.0
769.0	5.6	-14.4	120.0	29.6	2243.1
760.0	4.8	-14.2	120.0	29.5	2339.2
750.7	4.1	-8.3	120.0	29.3	2439.0
746.0	3.8	-5.2	120.0	29.0	2490.6
723.1	1.5	-5.7	120.0	27.7	2743.0
720.0	1.2	-5.8	120.0	27.9	2777.7
700.0	0.4	-9.6	120.0	29.3	3004.3
690.0	0.0	-9.0	120.0	31.2	3119.7

688.0	0.2	-4.7	120.0	31.5	3143.0
675.0	-0.9	-1.9	120.0	34.0	3295.9
670.2	-1.0	-1.9	120.0	34.9	3353.0
662.0	-1.3	-1.9	120.0	34.6	3451.4
644.8	-2.3	-3.1	120.0	33.9	3658.0
596.4	-5.2	-6.5	125.0	28.8	4268.0
551.7	-8.1	-10.0	125.0	24.6	4878.0
500.0	-11.7	-14.4	130.0	23.1	5649.3
471.0	-14.7	-17.4	130.0	21.6	6097.0
417.0	-20.8	-23.6	130.0	20.0	7012.0
400.0	-22.9	-25.7	130.0	21.0	7324.0
383.6	-25.3	-28.6	125.0	21.6	7621.0
309.4	-37.5	-43.2	125.0	31.3	9146.0
300.0	-39.3	-45.3	130.0	32.4	9365.2
250.0	-50.3	-56.3	130.0	36.5	10585.2
246.7	-51.0	-57.0	130.0	37.0	10670.0
235.3	-53.7	-59.7	135.0	40.6	10975.0
233.0	-54.3	-60.3	135.0	40.6	11037.6
220.0	-57.5	-63.5	144.5	35.7	11406.5
200.0	-57.7	-65.7	160.0	27.7	12008.4
194.1	-58.3	-66.3	165.0	28.2	12195.0
167.7	-61.0	-69.0	170.0	36.0	13109.0
155.0	-62.5	-70.5	165.0	24.1	13599.6
151.0	-62.7	-70.7	165.0	19.6	13760.9
150.0	-62.1	-70.1	165.0	18.5	13802.0
144.7	-61.5	-69.9	165.0	14.9	14024.0
128.0	-59.3	-69.3	168.1	11.6	14789.3
119.0	-60.6	-70.6	170.0	9.7	15243.0
114.0	-61.3	-71.3	174.4	9.3	15511.7
113.3	-61.2	-71.3	175.0	9.2	15548.0
100.0	-59.3	-70.3			16328.9
93.8	-61.3	-72.3			16728.1
86.2	-62.7	-73.7			17250.9
66.5	-58.5	-70.5			18866.9
44.6	-62.3	-74.3			21357.1
14.3	-56.7	-70.7			28477.9

PARCEL: DEW PT.= 277.1 POT. TEMP= 285.4 EQUIV.POT.TEMP= 300.3 MIX= 5.7
PRECIP.WATER= 19.2 CONV.TEMP= 29.6 FCST MAX= 0.0 LIFTED INDEX= 17.0
TOTALS= 27.4 EQUIL.PRES.= 771.1 K-INDEX= 5.7 SWEAT INDEX=159.8

Astronomical Data

At KLGA for a date / time of October 19, 1996 / 2038Z:

Altitude of Sun .. 15.2 degrees.
Bearing to Sun .. 241.3 degrees.
Altitude of Moon .. 24.5 degrees.
Bearing to Moon .. 143.8 degrees.
Percent Illumination of Moon .. 51 %

Area Forecast (FA)

Information pertinent to the investigation contained in the National Weather Service FA (BOSC FA 191745) issued October 19 at 1745Z and valid until October 20 at 0600Z is as follows:

Southeast New York..
Clouds broken to overcast at 1,500 feet layered through Flight Level 20,000 feet. Visibility 3 to 5 miles in light rain, mist. Wind 070 degrees at 15 knots gusts 30 to 35 knots.

The FA was issued by the Aviation Weather Center in Kansas City, Missouri.

An Area Forecast (FA) is a forecast of Visual Flight Rules (VFR) clouds and weather conditions over an area as large as the size of several states. It must be used in conjunction with the AIRMET Sierra bulletin for the same area in order to get a complete picture of the weather. The Area Forecast together with the AIRMET Sierra bulletin are used to determine forecast enroute weather and to interpolate conditions at airports that do not have terminal forecasts.

The Area Forecast consists of a:

a) Synopsis section which is a brief summary of the location and movement of fronts, pressure systems, and circulation patterns for an 18 hour period.

b) VFR clouds and weather section which is a 12 hour forecast, in broad terms, of clouds and weather significant to flight operations plus a 6 hour categorical outlook.

Reference: Aviation Weather Center, Kansas City, Missouri.

In-Flight Weather Advisories

The following in-flight weather advisories were issued by the Aviation Weather Center in Kansas City, Missouri:

AIRMET Tango Update 3 for Turbulence .. and Low Level Wind Shear..
Issued October 19 at 1345Z and valid until October 19 at 2000Z.

..See SIGMET Uniform series for severe turbulence.

Occasional moderate turbulence below Flight Level 18,000 feet [FL 180] in area of moderate to strong winds associated with surface low off the New Jersey coast and strong upper trough. The area encompassed by this AIRMET included KLGA. See Attachment 29.

Occasional moderate turbulence between FL 180 and FL 400 ..associated with strong upper trough and jetstream. The area encompassed by this AIRMET included KLGA. See Attachment 29A.

The AIRMET also noted .. Low Level Wind Shear potential over large portion of the mid Atlantic / Southern New England States.

AIRMET Zulu Update 2 for Ice and Freezing Level..
Issued October 19 at 1345Z and valid until October 19 at 2000Z.

Occasional moderate rime or mixed icing in cloud and in precipitation between 11,000 feet and FL 240.
Freezing level 4,000 to 6,000 feet. The area encompassed by this AIRMET included KLGA. See Attachment 30.

AIRMET Sierra Update 2 Correction [COR] for IFR..
Issued October 19 at 1415Z and valid until October 19 at 2000Z.

Occasional ceiling below 1,000 feet and visibility below 3 miles in precipitation, mist, and fog. The area encompassed by this AIRMET included KLGA. See Attachment 31.

AIRMET Tango Update 4 for Turbulence..and Low Level Wind Shear..
Issued October 19 at 1945Z and valid until October 20 at 0200Z.

..See SIGMET Uniform and Whiskey Series for Severe Turbulence Conditions..

Occasional moderate turbulence below 15,000 feet in areas of strong winds associated with surface low and general rough terrain. The area encompassed by this AIRMET included KLGA. See Attachment 32.

Occasional moderate turbulence between FL 180 and FL 380 associated with strong upper trough and shear zones aloft. The area encompassed by this AIRMET included KLGA. See Attachment 33.

The AIRMET also noted Low Level Wind Shear potential over a number of states including Southeastern New York.

AIRMET Zulu Update 3 for Ice and Freezing Level..
Issued October 19 at 1945Z and valid until October 20 at 0200Z.

Occasional moderate rime or mixed icing in cloud and in precipitation between 11,000 feet and FL 220. Freezing level sloping upward 8,000 to 10,000 feet northeast of an Atlantic City, New Jersey [ACY] to Syracuse, New York [SYR] line. The area encompassed by this AIRMET included KLGA. See Attachment 34.

AIRMET Sierra Update 3 for IFR..
Issued October 19 at 1945Z and valid until October 20 at 0200Z.

Ceiling below 1,000 feet and visibility below 3 miles in moderate rain, mist, and fog. The area encompassed by this AIRMET included KLGA. See Attachment 35.

SIGMET Uniform 2 issued October 19 at 1645Z and valid until October 19 at 2045Z..

Moderate occasional severe turbulence below 16,000 feet in area of strong winds and generally rough terrain.
KLGA was included in the area encompassed by this SIGMET. See Attachment 36.

SIGMET Uniform 3 issued October 19 at 2000Z and valid until October 20 at 0000Z..

Moderate occasional severe turbulence below 14,000 feet in the area of strong winds and general rough terrain.
KLGA was included in the area encompassed by this advisory. See Attachment 37.

SIGMET Uniform 4 issued October 19 at 2030Z and valid until October 20 at 0030Z..

Moderate occasional severe turbulence below 14,000 feet in the area of strong winds. Low level wind shear also expected.
KLGA was included in the area encompassed by this advisory. See Attachment 38.

AIRMETs and SIGMETs are issued by the Aviation Weather Center in Kansas City, Missouri.

An AIRMET (AIRman's METeorological Information) advises of weather that maybe hazardous other than convective activity, to single engine, other light aircraft, and Visual Flight Rule (VFR) pilots. However, operators of large aircraft may also be concerned with these phenomena. The items covered are:

In the AIRMET Sierra bulletin:
a) Ceilings less than 1,000 feet and/or visibility less than 3 miles affecting over 50% of the area at one time.
b) Extensive mountain obscuration.

In the AIRMET Tango bulletin:
a) Moderate turbulence.
b) Sustained surface winds of 30 knots or more at the surface.

In the AIRMET Zulu bulletin:
a) Moderate icing.
b) Freezing levels.

AIRMETs are routinely issued for 6 hour periods beginning at 0145Z during Central Daylight Time and at 0245Z during Central Standard Time.

References: Weather Service Operations Manual Chapter D-22; Aviation Weather Center, Kansas City, Missouri.

A SIGMET (SIGnificant METeorological Information) advises of weather potentially hazardous to all aircraft other than convective activity. In the conterminous U.S., items covered are:

a) Severe Icing.
b) Severe or extreme turbulence or clear air turbulence not associated with thunderstorms.
c) Widespread dust storms, sandstorms, or volcanic ash lowering surface and/or in-flight visibility to less than 3 miles.
d) Volcanic eruption.

References: Weather Service Operations Manual Chapter D-22; Aviation Weather Center, Kansas City, Missouri.

The following Urgent Center Weather Advisory (UCWA) was issued by the meteorologist at the New York Center Weather Service Unit:

UCWA issued October 19 at 2000Z and valid until October 19 at 2100Z..[ZNY1 UCWA 01 192000 - 192100].

Strong low level wind shear. Gain/loss up to 30 knots reported within 200 feet of the surface New York Metro area. Severe turbulence also reported.
The area encompassed by this advisory included KLGA. See Attachment 39.

A Center Weather Advisory (CWA) is an aviation weather warning for conditions meeting or approaching national In-Flight Advisory (AIRMET, SIGMET, or Convective SIGMET) criteria. The CWA is primarily for use by air crews to anticipate and avoid adverse weather conditions in the en route and terminal environments. The CWA should reflect conditions at the time of issuance and/or be a short range forecast. CWA's are issued by Center Weather Service Unit Meteorologists at the Air Route Traffic Control Centers.

Reference: Weather Service Operations Manual Chapter D-25, 10/25/96.

Meteorological Impact Statement (MIS)

The following MIS (ZNY MIS 01 Valid 191435 to 200200) was issued by a meteorologist at the New York Center (ZNY) Center Weather Service Unit. The MIS was issued October 19 at 1435Z and was valid until October 20 at 0200Z.

.. For ATC Planning Purposes Only ..
Moderate occasional severe turbulence below Flight Level 20,000 feet mainly west through southwest portions of ZNY in area of strong winds and general rough terrain. See SIGMET Uniform 1 valid until 1745Z. Occasional moderate turbulence remaining ZNY including New York Metro with Low Level Wind Shear.
Frequent moderate icing in cloud and in precipitation throughout ZNY from 9,000 to 20,000 feet.
IFR/Low IFR ceilings / visibility throughout in moderate rain showers / heavy rain. Winds east to east-northeast 20 knots frequent gusts to 35 to 40 knots. Winds aloft from Flight Level 2,000 to 5,000 feet east to southeast near 50 knots with Wind Shear potential.

A Meteorological Impact Statement (MIS) is an unscheduled flow control and flight-operations-planning forecast. It details weather conditions that are expected to adversely impact the flow of air traffic in the Center Weather Service Unit (CWSU) area of responsibility. The MIS is a forecast and briefing product intended for those personnel at Air Route Traffic Control Centers, the Air Traffic Control System Command Center, and large terminal air traffic control facilities responsible for making flow control and flow control-related decisions. MISs are issued by National Weather Service Meteorologists at CWSUs in the Air Route Traffic Control Centers.

Reference: National Weather Service Operations Manual, Chapter D-25.

Terminal Aerodrome Forecast (TAF)

The TAF for KLGA issued by he National Weather Service Forecast Office in Upton, New York is as follows:

October 19 at 1800Z .. Winds 080 degrees at 30 knots with gusts to 42 knots; visibility 3 miles; light rain; mist; ceiling 800 feet overcast; wind shear at 2,000 feet/wind 100 degrees at 50 knots.

Tempo October 19 at 1800Z to October 20 at 1200Z .. Visibility 1 mile; moderate rain; mist; ceiling 400 feet overcast.

Becoming October 20 at 1100Z to October 20 at 1200Z .. winds 060 degrees at 26 knots gusts to 36 knots; visibility 5 miles; light rain; mist; ceiling 1,000 feet overcast.

Local Airport Advisory

A Local Airport Advisory for high winds for KLGA issued by the National Weather Service Forecast Office in Upton, New York is as follows:

October 19 at 1200Z to October 20 at 1200Z...
Winds from the east-northeast 20 to 30 knots with gusts to 35 to 50 knots possible/forecast during the period.

The advisory was disseminated to the weather office at KLGA at 0952Z on October 19.

Flight Release Weather

The following weather information was included in the Flight Release of DAL 554:

KLGA observation for 1651Z .. Winds 080 degrees at 23 knots gusts to 38 knots; visibility 2 miles; moderate rain; mist; ceiling 1,200 feet broken, 1,800 feet broken, 2,200 feet overcast; temperature 16 degrees C; dew point 14 degrees C; altimeter setting 29.54 inches of Hg.; peak wind 070 degrees at 38 knots at 1647Z; tower visibility 2 1/2 miles; pressure falling rapidly.

Destination forecast for KLGA generated by Delta Air Lines Meteorological Staff:

LGA Amendment 1 (AMD 01) .. 1720Z to 2200Z ..
Ceiling 600 feet broken, 1,200 feet overcast; visibility 2 miles; light rain; fog; winds 090 degrees at 24 knots gusts to 42 knots; occasional ceiling 400 feet overcast; visibility 1 mile; moderate rain; fog; isolated thunderstorm.

Enroute surface weather.

Government Weather Alerts ..SIGMET Uniform 2 [see In Flight Weather Advisory Section].

Delta Meteorological Staff Airport Alerts..
LGA .. October 19 at 1711Z to October 20 at 0000Z .. Moderate to

strong turbulence climb / descent below Flight Level 7,000 feet with low level wind shear likely due easterly surface winds gusts to 35 knots becoming westerly surface winds accompanying 2000Z to 2200Z surface frontal passage. According to a Delta Air Lines' meteorologist strong turbulence = severe turbulence.

Delta Air Lines has a staff of 18 meteorologists and one manager. The office is located in Atlanta, Georgia. They provide upper air forecasts for turbulence and expected areas of thunderstorms. Surface meteorologists provide forecasts for 14 Delta terminals. Other terminal forecasts are provided as necessary.

Questions to Delta Airlines and Responses

The following are answers to written questions submitted to Delta Air Lines by the NTSB Meteorological Group Chairman:

1) QUESTION: Which National Weather Service in flight weather advisories, AIRMETs, SIGMETs, Convective SIGMETs, and Center Weather Advisories, are included in the Flight Release? For those advisories not included why are they not included? What Delta Air Lines' weather products are included in the Flight Release?

ANSWER: All Delta flight releases include SIGMETs and Convective SIGMETs, issued by the National Weather Service, that are pertinent to the route of flight.

AIRMETs are not included since they are advisories issued only to amend the area forecasts concerning weather phenomena which are potentially hazardous to aircraft having limited capability. Center Weather Advisories are not included since they are issued for ATC use to alert pilots of existing or anticipated adverse weather conditions within the next 2 hours. The information from both AIRMETs and CWAs is reviewed by Delta's meteorologists for possible dissemination in the form of a DELTA AIRPORT ALERT.

Delta's meteorologists provide terminal forecasts to selected cities. They also provide Turbulence Alerts and Thunderstorm Alerts. Airport Alerts for icing and low level wind shear not associated with thunderstorms are also issued for departure, destination and alternate airports.

2) QUESTION: Which National Weather Service in flight weather advisories, AIRMETs, SIGMETs, Convective SIGMETs, and Center Weather Advisories, are disseminated to Flight Crews while enroute? How are they disseminated? For those advisories not disseminated why are they not disseminated? What Delta Air Lines' weather products are disseminated to enroute flight crews? How are they disseminated?

ANSWER: All new SIGMETs or Convective SIGMETs are reviewed by the dispatcher and if contents have changed from previous SIGMETs the advisory will be disseminated to the flight via Radio or ACARS. The same is true for Delta Alerts issued by the Delta Meteorologists.

3) QUESTION: Which advisories, AIRMETs, SIGMETs, Convective SIGMETs, and Center Weather Advisories, does 14 CFR 121.601 require to be provided to Flight Crews? For those advisories not required to be provided to flight crews why are they not required?

ANSWER: 14 CFR 121.601 only states that prior to and during a flight the dispatcher shall provide all available weather information that may affect the safety of the flight.

4) QUESTION: How does Delta Air Lines satisfy the weather dissemination requirements of 14 CFR 121.601?

5) ANSWER: Delta Air Lines satisfies the weather dissemination requirements of 14CFR 121.601 via the Meteorology briefing message attached to each flight release, and through the dispatcher's use of Radio or ACARS.

6) QUESTION: How is weather information accessed by Delta Air Lines' meteorologists and dispatchers? How are Center Weather Advisories accessed?

ANSWER: Weather information is accessed from the NWS via FAA teletype circuits; DIFAX charts and via an outside vendor. The information in turn is provided to the dispatcher thru Delta's computer system. Center Weather Advisories are accessed on one of the weather circuits, located in the Meteorology section.

7 QUESTION: Were the contents of the National Weather Service SIGMET Uniform 3 (BOSU WS 192000Z) provided to the flight crew of DAL 554? When and how was the information contained in this SIGMET provided? If the information contained in this SIGMET was not provided to the flight crew why was it not provided?

ANSWER: The contents of NWS SIGMET Uniform 3 were not provided to the flight crew of DAL 554. SIGMET Uniform 3 was not provided to the flight crew of DAL 554 since only the flight level top of possible turbulence was changed and the valid time of SIGMET Uniform 2 included the arrival period of DAL 554.

8) QUESTION: Were the contents of New York Center Weather Advisory 01 (ZNY1 UCWA 01 192000Z-192100Z) provided to the flight crew of DAL 554? When and how was the information contained in the Center Weather Advisory provided? If the Center Weather Advisory was not provided to the flight crew why was it not provided?

ANSWER: The contents of New York Center Weather Advisory 01 were not provided to the flight crew of DAL 554 nor to the dispatcher. Center Weather Advisories, by definition, are issued for ATC use. The Delta Meteorologists had already issued an AIRPORT ALERT for LGA at 19/1711Z for moderate to strong turbulence below flight level 7,000 feet with low level wind shear likely.

LLWAS Sensor Locations

STATION #1: CENTERFIELD @ LGA RTR SITE
#2: NORTH @ MM-22 PIER
#3: NORTH-EAST @ FLUSHING ARPT
#4: SOUTH-EAST @ WORLD'S FAIR
#5: SOUTH-WEST @ MM-4, JACKSON HEIGHT
#6: NORTH-WEST @ RIKERS ISLAND EAST ELMHURST