Flight Into Terrain During Missed Approach, USAir Flight 1016, DC-9-31, N954VJ, Charlotte/Douglas International Airport, Charlotte, North Carolina, July 2, 1994

Micro-summary: **This McDonnell Douglas DC-9-31 crashed into trees and a residence while executing a missed approach and encountering a microburst.**

Event Date: **1994-07-02 at 1843 EDT**

Investigative Body: **National Transportation Safety Board (NTSB), USA**

Investigative Body's Web Site: **http://www.ntsb.gov/**

PB95-910403
NTSB/AAR-95/03
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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

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USAIR FLIGHT 1016, DC-9-31, N954VJ
CHARLOTTE/DOUGLAS INTERNATIONAL AIRPORT
CHARLOTTE, NORTH CAROLINA
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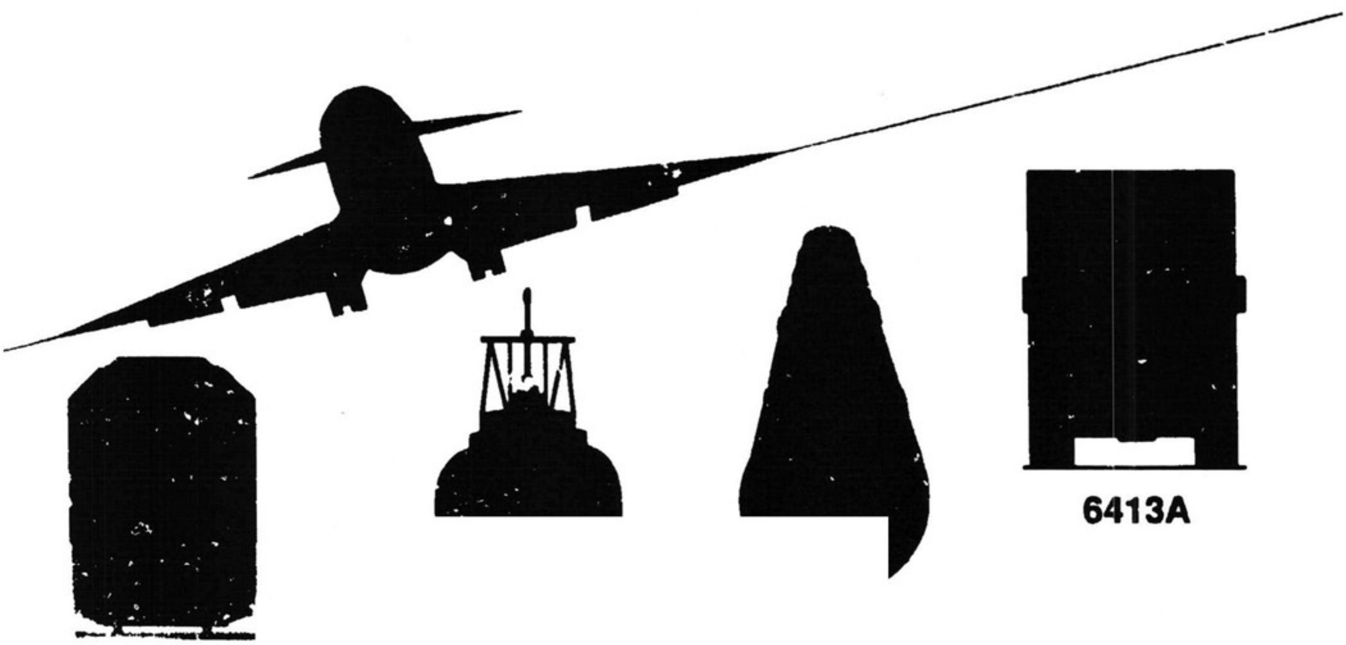

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Adopted: April 4, 1995
Notation 6413A

Abstract: This report explains the accident involving USAir flight 1016, a DC-9-31, which crashed near the Charlotte/Douglas International Airport, Charlotte, North Carolina, on July 2, 1994. Safety issues in the report include standard operating procedures for flightcrews and air traffic controllers, the dissemination of weather information to flightcrews, and flightcrew training. Safety recommendations concerning these issues were made to the Federal Aviation Administration, USAir, and the National Weather Service.

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EXECUTIVE SUMMARY

On July 2, 1994, about 1843 eastern daylight time, a Douglas DC-9-31, N954VJ, operated by USAir, Inc., as flight 1016, collided with trees and a private residence near the Charlotte/Douglas International Airport, Charlotte, North Carolina, shortly after the flightcrew executed a missed approach from the instrument landing system approach to runway 18R. The captain, first officer, one flight attendant, and one passenger received minor injuries. Two flight attendants and 14 passengers sustained serious injuries. The remaining 37 passengers received fatal injuries. The airplane was destroyed by impact forces and a postcrash fire. Instrument meteorological conditions prevailed at the time of the accident, and an instrument flight rules flight plan had been filed. Flight 1016 was being conducted under 14 Code of Federal Regulations Part 121 as a regularly scheduled passenger flight from Columbia, South Carolina, to Charlotte.

The National Transportation Safety Board determines that the probable causes of the accident were: 1) the flightcrew's decision to continue an approach into severe convective activity that was conducive to a microburst; 2) the flightcrew's failure to recognize a windshear situation in a timely manner; 3) the flightcrew's failure to establish and maintain the proper airplane attitude and thrust setting necessary to escape the windshear; and 4) the lack of real-time adverse weather and windshear hazard information dissemination from air traffic control, all of which led to an encounter with and failure to escape from a microburst-induced windshear that was produced by a rapidly developing thunderstorm located at the approach end of runway 18R.

Contributing to the accident were: 1) the lack of air traffic control procedures that would have required the controller to display and issue airport surveillance radar (ASR-9) weather information to the pilots of flight 1016; 2) the Charlotte tower supervisor's failure to properly advise and ensure that all controllers were aware of and reporting the reduction in visibility and the runway visual range value information, and the low level windshear alerts that had occurred in multiple quadrants; 3) the inadequate remedial actions by USAir to ensure adherence to standard operating procedures; and 4) the inadequate software logic in the airplane's windshear warning system that did not provide an alert upon entry into the windshear.

The safety issues in this report focused on standard operating procedures for both air traffic controllers and flightcrews, the dissemination of weather information to flightcrews, and USAir flightcrew training.

Safety recommendations concerning these issues were addressed to the Federal Aviation Administration, USAir, and the National Weather Service.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

FLIGHT INTO TERRAIN DURING MISSED APPROACH USAIR FLIGHT 1016, DC-9-31, N954VJ CHARLOTTE/DOUGLAS INTERNATIONAL AIRPORT CHARLOTTE, NORTH CAROLINA JULY 2, 1994

1. FACTUAL INFORMATION

1.1 History of Flight

On July 2, 1994, about 1843 eastern daylight time, a Douglas DC-9-31, N954VJ, operated by USAir, Inc., as flight 1016, collided with trees and a private residence near the Charlotte/Douglas International Airport, Charlotte, North Carolina (CLT), shortly after the flightcrew executed a missed approach from the instrument landing system (ILS) approach to runway 18R. The captain, first officer, one flight attendant, and one passenger received minor injuries. Two flight attendants and 14 passengers sustained serious injuries. The remaining 37 passengers received fatal injuries. The airplane was destroyed by impact forces and a postcrash fire. Instrument meteorological conditions (IMC) prevailed at the time of the accident, and an instrument flight rules (IFR) flight plan had been filed. Flight 1016 was being conducted under 14 Code of Federal Regulations (CFR) Part 121 as a regularly scheduled passenger flight from Columbia, South Carolina, to Charlotte.

The planned 3-day trip sequence for the crew began with the departure from Pittsburgh at 0945 on the morning of the accident. The scheduled trip segments for the crew included en route stops at New York's LaGuardia Airport (LGA), Charlotte (CLT), Columbia, South Carolina (CAE), followed by a return trip to CLT and a final stop in Memphis, Tennessee (MEM). The accident occurred on the fourth leg (flight 1016 from CAE to CLT), while the first officer was performing the duties of the flying pilot.

The flightcrew spent approximately 40 minutes in Columbia before flight 1016 departed the gate on schedule at 1810. The weather information provided to the flightcrew from USAir dispatch indicated that the conditions at Charlotte were similar to those encountered when the crew had departed there approximately 1 hour earlier. The only noted exception was the report of scattered thunderstorms in the area.

Flight 1016 was airborne at 1823 for the planned 35 minute flight. At 1827:06, the captain of flight 1016 made initial contact with the Charlotte Terminal Radar Approach Control (TRACON) Arrival Radar West (ARW) controller and advised that the flight was at 12,000 feet mean sea level (msl), and that they had received the current Automatic Terminal Information Service (ATIS), identified as "Yankee."[1] The controller replied "USAir ten sixteen...expect runway one eight right." The captain acknowledged the transmission.

At 1828:12, the ARW controller issued a clearance to the flightcrew to descend to 10,000 feet. The captain acknowledged the transmission. At 1829:54, the cockpit voice recorder (CVR) recorded the first officer comment "there's more rain than I thought there was...it's startin...pretty good a minute ago...now it's held up."[2] Approximately 1 minute later, the captain radioed the ARW controller and stated "We're gonna swing just uh a five uh degrees to the right here just for about uh a quarter half mile." The ARW controller approved this request.

The flightcrew reported after the accident that while they were still south-southwest of the airport, they observed on their airborne weather radar two "cells," one located south and the second located east of the airport. The weather radar depicted the cell to the south of the airport as having a red center surrounded by yellow edges.[3]

At 1832:18, the CVR recorded the captain saying "looks like that's [rain] setting just off the edge of the airport." One minute later, the captain contacted the ARW controller and said "We're showing uh little buildup here it uh

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[1]Information Yankee was as follows: "1751 e.d.t., [clouds] 5,000 feet scattered, visibility six miles, haze, temperature 88° F, dewpoint 67° F, wind - 150 at 8 knots, altimeter 30.01 inches Hg., ILS approaches to runways 18L and 18R, localizer back course to runway 23 approach in use, if unable to comply with speed restrictions advise, read back all hold short instructions...."

[2]See appendix B for CVR Transcript.

[3]Weather radar color depictions: Green-light precipitation; Yellow-moderate precipitation; Red-heavy precipitation.

looks like it's sitting on the radial, we'd like to go about five degrees to the left to the...." The ARW controller replied "How far ahead are you looking [USAir] ten sixteen?" The captain responded "About fifteen miles." The ARW controller then replied "I'm going to turn you before you get there I'm going to turn you at about five miles northbound." The captain acknowledged the transmission, and, at 1833:57, the controller directed the crew to turn the aircraft to a heading of three six zero. At 1834:57, the flightcrew was issued a clearance to descend to 5,000 feet, and shortly thereafter contacted the Final Radar West (FRW) controller. The captain acknowledged the transmission.

At 1835:18, the FRW controller transmitted "USAir ten sixteen...maintain four thousand runway one eight right." The captain acknowledged the radio transmission and then stated to the first officer "approach brief." The first officer responded "visual back up ILS." Following the first officer's response, the controller issued a clearance to flight 1016 to "...turn ten degrees right descend and maintain two thousand three hundred vectors visual approach runway one eight right." About this same time, the tower supervisor made the remark in the tower cab that it was "raining like hell" at the south end of the airport, and the FRW controller observed on the airport surveillance radar (ASR-9) scope a VIP Level 3[4] cell "pop-up" near the airport.

At 1836:55, the FRW controller radioed flight 1016 and said "I'll tell you what USAir ten sixteen they got some rain just south of the field might be a little bit coming off north just expect the ILS now amend your altitude maintain three thousand." The captain acknowledged the transmission.

At 1837:33, the Charlotte Tower Local East Controller (LCE)[5] transmitted to the flightcrew of a DeHavilland DHC-8 that was landing on runway 23 "Piedmont thirty two eleven heavy heavy rain on the airport now wind one five zero at one four." At 1837:40, the FRW controller instructed flight 1016 to "turn right heading zero niner zero." At 1838:24, the controller said "USAir ten sixteen turn right heading one seven zero four from SOPHE [the outer marker for runway 18R ILS]...cross SOPHE at or above three thousand cleared ILS one eight right approach." The captain acknowledged this transmission and the FRW controller's subsequent instruction to contact the tower. At 1838:38, the CVR

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[4]VIP - Video Integrator Processor. See 1.7.2 for additional information.

[5]The Local Control East position was responsible for aircraft arriving and departing runways 5/23 and 18L/36R. Runway 18L is located 5,000 feet east of runway 18R.

recorded the captain saying "looks like it's sittin right on the...." The remainder of the captain's comment was inaudible due to an unrelated air traffic control (ATC) transmission broadcast through the cockpit speaker.

The captain testified at the Safety Board's public hearing that as they were maneuvering the airplane from the base leg of the visual approach to final, they had visual contact with the airport.

During the period of time that flight 1016 was on frequency with the FRW controller, the Charlotte Tower Local West Controller (LCW) had a radio conversation with the flightcrew of USAir 806 [a departing flight]. Concurrently, at 1839:02, the captain of flight 1016 commented to the first officer "if we have to bail out...it looks like we bail out to the right." This was followed by the captain saying "chance of shear."

At 1839:12, the flightcrew of USAir flight 806 said to the LCW controller "And eight oh six looks like uh we've gotten a storm right on top of the field here." The controller responded "affirmative." The flightcrew of USAir flight 806 elected to delay their departure.

At 1839:38, the captain of flight 1016 made initial contact with the LCW controller. The controller said "USAir ten sixteen... runway one eight right cleared to land following an F-K one hundred short final, previous arrival [USAir 677, a Fokker FK-28, that landed about 4 minutes earlier] reported a smooth ride all the way down the final." The captain responded "USAir ten sixteen I appreciate a PIREP [pilot report] from that guy in front of us" [The airplane referenced by the captain of flight 1016 was USAir flight 984, a Fokker FK-100, that had circled from runway 23 to land on runway 18R]. After receiving the flight conditions from USAir 984, the LCW controller relayed the report of a "smooth ride" to flight 1016.

About 1840:06, the first officer said "yep, laying right there this side of the airport, isn't it...the edge of the rain is I'd say." The captain responded "yeah." In his testimony, the captain stated that he had been monitoring the weather conditions on the airborne radar and that while on final approach he had his navigational radio tuned to the Charlotte VOR[6] for distance measuring information,

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[6]The Very High Frequency Omnidirectional Radio Range provides both directional and slant distance (DME) information.

although they had visually identified the runway during the initial portion of the final approach. The first officer testified that the "edge of the rain" that he observed was a "thin veil" through which he could see the runway and it was located "between us and the runway."

About 1836, a special weather observation was recorded and a new ATIS, identified as "Zulu," was being prepared. The ATIS specified, in part, that the weather conditions at the airport were:

> ...measured [cloud] ceiling 4,500 feet broken, visibility 6 miles, thunderstorm, light rainshower, haze, the temperature was 88 degrees Fahrenheit, the dewpoint was 67 degrees Fahrenheit, the wind was from 110 degrees at 16 knots....

This information was not broadcast until 1843; thus, the crew of flight 1016 did not receive the new ATIS. According to the National Weather Service, because of the rapidly changing weather conditions, a second special weather observation was taken at 1840, and it specified that an overcast ceiling was measured at 4,500 feet, the visibility was 1 mile, and that there were thunderstorms and heavy rainshowers at the airport.

At 1840:37, the LCE controller advised USAir flight 52, a Boeing 737 departing runway 18L, "...aircraft just departed ahead of you said smooth ride on departure wind is one zero zero at one niner gusting two one." USAir flight 52 was then issued a takeoff clearance.

At 1840:50, the LCW controller said "USAir ten sixteen the wind is showing one zero zero at one nine." The captain acknowledged the transmission. This was followed a short time later by the controller saying "USAir ten sixteen wind now one one zero at two one." This transmission was also acknowledged by the captain.

At 1841:05, the CVR recorded the captain saying "stay heads up" and the LCW controller's radio transmission of "windshear alert northeast boundary wind one nine zero at one three." Meanwhile, at 1841:08, the LCE controller had transmitted "Attention all aircraft windshear alert the surface wind one zero zero at two zero northeast boundary wind one niner zero at one six." However, this radio transmission occurred on a different radio frequency and was not heard by the crew of flight 1016.

At 1841:17, the LCW controller issued a landing clearance to Carolina 5211 [the aircraft following USAir flight 1016] and also reported that the wind was "...one zero zero at two zero, windshear alert northeast boundary wind, one niner zero at one seven." At 1841:54 the CVR recorded the captain's comment "here comes the wipers," followed 3 seconds later by the sound of rain.

At 1841:58, the first officer commented "there's, ooh, ten knots right there." This was followed by the captain saying "OK, you're plus twenty [knots]...take it around, go to the right."

The following exchange of conversation and sounds were recorded by the CVR:

1842:16	Radio transmission by Captain	USAir ten sixteen's on the go
1842:17.7	Captain	Max power
1842:18.5	First Officer	Yeah max power[7]
1842:18.5	Tower Controller	USAir ten sixteen understand you're on the go sir, fly runway heading, climb and maintain three thousand.
1842:19.4	First Officer	flaps to fifteen
1842:22.0	Captain	Down, push it down
1842:25.5	Radio transmission	Up to three we're takin a right turn by Captain here
1842:27.9	Tower Controller	USAir ten sixteen, understand you're turning right
1842:28.4	GPWS[8] aural alert	whoop whoop terrain
1842:28.5	Unidentified voice on CVR	**power
1842:32.7	Sound similar to stick shaker begins	
1842:33.5	Sound similar to stick shaker ends	
1842:35.6	Sound of ground impact	

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[7]The FDR recorded an increase in engine power to 1.82 EPR at 1842:23.

[8]The GPWS [ground proximity warning system] warns the flightcrew of a potentially dangerous flightpath relative to the ground. The following abnormal flight conditions will produce a "Pull Up" warning: an excessive sink rate below 2,500 feet above the ground (agl); excessive closure rate toward rising terrain; descent immediately after takeoff; aircraft not in landing configuration below 500 feet agl; and excessive deviation below the ILS glideslope.

Concurrent with the conversation and events of flight 1016, at 1842:07, the LCE controller requested a pilot report from USAir flight 52. The flightcrew responded "Clear after south end of field heavy rain on the roll." The controller responded "Heavy rain on the roll past midfield pretty smooth you say." The flightcrew corrected him and said "Well not through the whole roll pretty heavy rain and then on climb out no real bumps but after about a thousand feet or so you're in the clear."

The accident occurred during the hours of daylight at coordinates 35 degrees, 13 minutes north latitude, and 80 degrees, 57 minutes west longitude.

1.1.1 Statements of Witnesses

Passengers and flight attendants generally described the flight as routine until the airplane was on final approach. Several passengers stated that they felt the ride get "bumpy" because they were in a "storm." One passenger, seated in 14F, stated that the weather was "pouring down rain and was turbulent..." and that they hit an "air pocket" and dropped "like riding a roller coaster." The passenger stated that he heard the engines "reved up to a higher level" before the airplane began to climb and that he saw the trees before ground impact.

The passenger seated in 16A, a military air traffic controller, stated that he saw a runway at a 45-degree angle to his position on the left side of the airplane. He also stated "I saw the numbers and lights over the threshold as we passed by it at a 45-degree angle, and then passed over the runway at 200 feet..." He described the weather as "very bad," and from his window he saw "rain coming off the wing in contrails."

The flight attendants' descriptions of the accident were similar to those of the passengers. They sensed that there was "something wrong" when they felt the airplane pitch upward for the go-around and felt the airplane "sinking."

Ground witnesses, located near the approach end of runway 18R, stated that they observed flight 1016 emerge from the rain and clouds approximately 1/4 mile from the end of the runway on a heading that was about 45 degrees to the runway. The witnesses also stated that the rain was very intense and that the wind was "blowing very hard."

1.2 Injuries to Persons

Injuries	Flightcrew	Cabincrew	Passengers	Other	Total
Fatal	0	0	37	0	37
Serious	0	2	14	0	16
Minor	2	1	1	0	4
None	0	0	0	0	0
Total	2	3	52	0	57

1.3 Damage to the Airplane

The airplane was destroyed by impact and postaccident fire. The estimated value of the airplane was $5,000,000. (See figure 1).

Other Damage

The airplr ᵃ damaged a section of the airport's boundary security fence, several power a..d ᵃphone poles and transmission lines, an automobile, and a two-bedroom residence.

1.5 Personnel Information

1.5.1 The Captain

The captain holds an Airline Transport Pilot (ATP) certificate, No. 289442025, issued by the Federal Aviation Administration (FAA), with a multi-engine land airplane rating and a Douglas DC-9 type rating. Additionally, he holds a Flight Instructor (CFI) certificate with multi-engine land airplane and instrument ratings. He was issued an FAA First Class Airman Medical Certificate on June 15, 1994, with no limitations.

The captain was employed by USAir on April 24, 1985, as a first officer on the Boeing 737. He was upgraded in January of 1990 to captain on the DC-9, and was domiciled in Pittsburgh. According to company records, the captain had accumulated 8,065 hours of total flight time as of the date of the accident, with 1,970 hours accumulated in the DC-9. His last proficiency check was successfully accomplished on January 20, 1994, and his last line check was performed on March 20, 1994.

Figure 1.--Airplane wreckage.

He also holds the rank of captain in the 906th Reserve Fighter Group stationed at Wright Patterson Air Force Base, Ohio. He has served in that capacity since 1982, and has flown the Cessna T-37, the Northrop T-38, AT-38, and the McDonnell Douglas F-4. His most recent aircraft assignment was in the F-16. He was also a Distinguished Graduate from Air Force pilot training. In addition, he was the squadron safety officer, and was designated as a flight leader and mission commander.

1.5.2 The First Officer

The first officer holds an Airline Transport Pilot certificate, No. 253865343, with a multi-engine land airplane rating and a Mitsubishi MU-300 type rating. He also holds a flight instructor certificate; and he was issued an FAA First Class Medical Certificate on April 13, 1994, with no limitations.

The first officer was originally hired into that position on the Boeing 737 by Piedmont Airlines on October 12, 1987. Piedmont was subsequently purchased by USAir, and he continued his employment with that company. According to company records, he had 12,980 hours of total flight time as of July 2, 1994, with 3,180 hours in the Douglas DC-9. He successfully accomplished his last proficiency check on July 16, 1992, and had participated in a Line Oriented Flight Training (LOFT) program during his recurrent training that was conducted on March 15, 1994.

1.5.3 Flightcrew's 72-Hour History Prior to the Accident

The captain was off duty for 3 days before the beginning of the accident trip. On the morning of June 28, 1994, he flew with his National Guard squadron, which is based at Wright Patterson Air Force Base, Ohio, near his home. On June 30, he played golf; and on July 1, he went jogging, worked out at a local martial arts facility, and performed household errands. He regularly went to sleep between 2200 and 2300 and awoke about 0700. On the day of the accident, he awoke about 0455, drove to the airport in Dayton, Ohio, and departed on a flight to Pittsburgh at around 0745. The reporting time for the trip that included the accident flight was 0945, and the departure time for LGA was at 1045.

The first officer flew a 4-day trip that ended around 0930 on July 2. On June 30, he arrived at the destination airport (Tri-City Regional Airport, Blountville, Tennessee) at 2230, had a light dinner, and went to sleep around 0130.

He awoke on July 1 at 0900 and arrived at the destination airport (Lambert-St. Louis International Airport, St. Louis, Missouri) at 2040, and went to sleep about 2330 eastern time. On the day of the accident, he arose about 0615 and flew the leg to Pittsburgh that departed St. Louis at 0810. He arrived in Pittsburgh at 0930.

1.6 Airplane Information

N954VJ was registered to and owned by USAir, Incorporated, of Arlington, Virginia. The airplane, a Douglas DC-9-31, serial number 47590, was manufactured on August 9, 1973. The airplane was placed in service with USAir and had been continuously operated since 1974. It had accumulated a total of 53,917 hours and 63,147 cycles at the time of the accident.

The airplane was equipped with two Pratt & Whitney JT8D-7 engines. The left engine was installed on the airplane on January 31, 1994, and had a total of 61,338 hours, of which 965.50 hours had been accumulated since the installation. The right engine was installed on July 3, 1992, and had a total of 60,678 hours, of which 4,217.23 hours had been accumulated since the installation.

The airplane's maintenance records were reviewed for the 2-month period prior to the accident. The last "transit check" was accomplished on July 1, 1994; and the last "A" check was performed on June 29, 1994. There were no discrepancies noted in the logbook that would have been cause for the airplane to be unairworthy. Additionally, there were no known discrepancies noted in the logbook regarding the windshear alert system or the right thrust reverser.

1.6.1 Dispatch Information

The dispatch paperwork indicated that flight 1016 was released from Columbia (CAE) with a gross takeoff weight of 86,325 pounds. The airplane had a calculated zero fuel weight of 72,325 pounds, a maximum zero fuel weight of 87,000 pounds, and a maximum takeoff weight of 99,400 pounds (the certificated maximum takeoff weight was 105,000 pounds). The computed weight for flight 1016 included 14,000 pounds of fuel, 9,000 pounds for passengers and 1,575 pounds for cargo. The center of gravity was 25.3 percent mean aerodynamic chord (MAC).

The planned fuel burn for the flight to Charlotte was calculated to be 4,100 pounds; thus, 82,225 pounds was the estimated landing weight and also the estimated weight of the airplane at the time of the accident.

The landing reference speeds were calculated for a weight of 83,000 pounds. The speeds were:

Maneuvering Speed - V_{zf}:	191 knots
Flaps 15 degrees:	139 knots
Flaps 25 degrees:	126 knots
Flaps 40 degrees:	121 knots
Go-Around Target Speed:	128 knots at 15 degrees of flaps
Stick shaker Speed - Flaps 15:	109 knots
Flaps 40:	99 knots

The two-engine operating, go-around engine pressure ratio (EPR) calculated for flight 1016, based on a field elevation of 749 feet msl and an outside air temperature of 88 degrees Fahrenheit, was 1.93.

1.6.2 Airplane Systems

1.6.2.1 On-Board Windshear Detection System

In accordance with 14 CFR 121.358, airplanes manufactured prior to 1991 are required to be equipped with an approved low-altitude windshear alert system. In 1991, USAir installed in N954VJ the Honeywell Standard Windshear Detection System. The system is approved under a Supplemental Type Certificate and is a "reactive" system designed to provide the flightcrew with warnings whenever a "severe" windshear is detected. The USAir DC-9 Pilot's Handbook defines a severe windshear as: "...a windshear of such intensity and duration that it would exceed the performance capabilities of the particular airplane type, and likely cause an inadvertent loss of control or ground contact."

Windshear detection is accomplished by a dedicated windshear computer that integrates data from existing airplane sensors (angle-of-attack (AOA) vanes, wing flap position sensors, engine N_1 tachometers, and attitude sensors) with data from internal accelerometers. The computer uses these data to compute and compare the airplane's aerodynamic acceleration and inertial acceleration. A windshear is indicated by a difference in these accelerations. Further, the computer compares the intensity and duration of any windshear to a series of computed threshold values. These threshold values are designed to prevent nuisance warnings that may occur in the presence of turbulence. When the threshold values are exceeded by a measured windshear, the cockpit windshear annunciations are activated.

The windshear detection system employs a series of crosscheck and tolerance threshold features to ascertain when severe windshear criteria are met. They distinguish between windshears of varying intensities and durations to preclude nuisance windshear annunciations. The windshear computer is also capable of detecting increasing and decreasing performance windshears in the longitudinal and vertical axes. The increasing performance detection results from a significant and/or sustained increase in headwind, decrease in tailwind, or updraft. Conversely, decreasing performance detection results from a significant and/or sustained decrease in headwind, increase in tailwind, or downdraft.

Additionally, it has been determined that a "unique" temperature profile exists in a microburst environment. The windshear detection system, capable of measuring the change in temperature commensurate with altitude during the descent phase of flight, then calculates the temperature lapse rate to predict the potential presence of a microburst. The temperature lapse rate detection will be indicated when the temperature profile from the airplane's descending flightpath shows a temperature increase, typically a dry adiabatic condition, followed by a temperature decrease, which is typically a cold outflow condition. This function begins at approximately 10,000 feet pressure altitude and continues until aircraft touchdown.

This system, as installed on the DC-9-30 series airplanes, is a detection system only and does not provide flight guidance through the flight director or autopilot systems.

The activation of the windshear detection annunciations can occur in three phases of flight. The following conditions and annuciations are described in the USAir DC-9 Pilot's Handbook and provide the flightcrew with windshear detection information for "normal" flight modes with the autopilot disengaged:

Takeoff Mode (T/O) -- The takeoff mode is defined to include flight from liftoff until the aircraft climbs through a change in pressure altitude of 1,500 feet, or three minutes have elapsed.

In the approach flight regime, the windshear computer operation is divided into two modes, Approach (APPR) and Go-Around (G/A). The operation of the windshear detection system in these modes is:

> Approach Mode (APPR) -- The aircraft is in the approach mode when the calibrated airspeed is reduced to less than 175 knots with the landing gear extended or the flaps extended to a predetermined approach setting, until either touchdown (weight-on-wheels), or a go-around is initiated.
>
> Go-Around (G/A) -- The aircraft is in the G/A mode when any engine N_1 is greater than 90 percent while in the APPR mode, the designated go-around switch is engaged while increasing or decreasing windshear is being annunciated, and remains in the G/A mode until the aircraft has climbed 1,500 feet from the altitude at which the go-around was initiated, three minutes have elapsed, or touchdown (weight-on-wheels) has occurred.

There are two types of windshear annunciations in the cockpit to enunciate a windshear to both the captain and first officer. The flashing red windshear "WARNING" illuminates upon the windshear computer detection of a decreasing performance windshear; and the flashing amber windshear "CAUTION" illuminates upon the windshear computer detection of an increasing performance windshear. The "CAUTION" and "WARNING" annuciations are independent of each other, with the flashing red warning taking precedence over the flashing amber caution annunciation. The windshear annunciations will extinguish once the aircraft has exited the detected windshear condition.

An aural windshear warning annunciation is also associated with the visual annunciations. A dedicated cockpit loudspeaker will broadcast the aural warning in conjunction with the flashing red windshear "WARNING" annunciation. The aural warning broadcasts the message "WINDSHEAR, WINDSHEAR, WINDSHEAR" only during the initial and subsequent windshear computer detections of a decreasing performance windshear.

The flight crewmembers stated after the accident that they did not receive any aural or visual warnings in the cockpit from the windshear alert system prior to or during any portion of the flight. The CVR confirmed that the aural windshear alert did not activate. Based on the crew's information and the CVR, a study was performed at Honeywell using the data from the digital flight data recorder (FDR) as an input to a six-degrees of freedom, ground-based engineering simulator. The purpose of the study was to determine if the conditions for windshear detection were satisfied to activate the windshear warning system.

The study used aircraft performance and derived wind information from the FDR. The study determined that a longitudinal shear that exceeded the computed threshold was encountered when the airplane was on the missed approach; thus, the flightcrew should have received both the red warning lights and the aural windshear warning. However, the warning would not have occurred until the airplane was at an altitude of between 100 and 150 feet above the ground, or approximately 3 to 4 seconds before ground impact.

A further study of the windshear warning system and data from flight 1016 was performed to determine the reason the warning system failed to activate. Although the data was inconclusive, the Honeywell windshear computer was designed to detect numerous types of internal and aircraft sensor faults, which may have resulted in the overall system failure at the time of the windshear encounter. In the study, the FDR data revealed that at the time of the windshear encounter, the wing flaps were in the process of retracting from 40 degrees to 15 degrees.[9] According to a Honeywell engineer, the windshear detection algorithms are designed to be as sensitive as possible while maintaining the immunity to nuisance alerts. This is accomplished by incorporating crosschecks and compensation terms to desensitize the system whenever necessary to prevent nuisance alerts. One such compensation term in the detection system is designed to desensitize the detection thresholds as a function of the flap rate. It was determined by Honeywell that had the warning system activated on flight 1016, it would have done so approximately 5 seconds earlier, or about 8 to 9 seconds prior to ground impact, if the detection threshold had not been desensitized due to the flaps being in transition.

Examination of the Supplemental Type Certificate (STC) criteria used by the FAA to certify the Honeywell system revealed that the system evaluation was conducted in a simulator. The simulations involved many different types of windshear profiles and flap settings, and the system activated successfully within 5 seconds of each severe windshear encounter. The system was not evaluated with the flaps in transition; thus, the evaluation process neither revealed the system's

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[9] According to data supplied by Douglas Aircraft Company, it takes approximately 12 seconds for the flaps to transition from 40 degrees to 15 degrees on the DC-9-31.

delayed activation feature when the flaps were moving, nor was it a requirement of the certification tests.

1.7 Meteorological Information

1.7.1 General Weather Information

The Safety Board performed a comprehensive study of the weather conditions that existed in the Charlotte area at the time of the accident. The weather information discussed in this section, while not all inclusive, will present an overview of the weather conditions that were encountered by flight 1016.[10]

The flightcrew of USAir 1016 did not receive arrival information "Zulu" which was current at 1836. The information was as follows:

> Special weather observation [clouds] measured four thousand five hundred broken visibility was six miles in thunderstorm, light rain shower and haze, the temperature was 88 degrees Fahrenheit, the dewpoint was 67 degrees, the wind was from 110 degrees at 16 knots, the altimeter was 30.01 inches of mercury (Hg). ILS approaches were being conducted to runway 18L and 18R, and the localizer back course approach to runway 23 was in use....

The following surface weather observations were made by the National Weather Service (NWS)[11] at Charlotte:

> 1751...Record...5,000 feet scattered; visibility 6 miles; haze; temperature 88 degrees F; dew point 67 degrees F; winds 150 degrees at 8 knots; altimeter setting 30.02 inches of Hg.

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[10]A detailed description of the meteorological information developed during the investigation is contained in the Appendix section of this report.

[11]The surface weather observations for Charlotte are made by the National Weather Service (NWS). The NWS office is located about 1 mile southeast of the air traffic control tower. The weather station clock was checked subsequent to the accident and was found to be within 5 seconds of the time standard. The MAPSO (Microcomputer Aided Paperless Surface Observations) time was found to be within 1/2 minute of the weather station clock. It was determined by observation on July 4, 1994, that the Automated Weather Information System (AWIS) clock was about 3 minutes slow; thus, the times noted have not been adjusted to reflect these differences.

The weather information was disseminated on the Automated Weather Information System (AWIS) at 1750. This system is used by the Charlotte tower to receive weather information from the Charlotte weather office. The weather observation was disseminated to other aviation-related parties via computer at 1752.

At 1836, the following weather observation was disseminated on AWIS and transmitted to outside aviation interests at 1837:

> 1836...Special...Measured ceiling 4,500 feet broken; visibility 6 miles; thunderstorm, light rain showers, haze; winds 170 degrees at 9 knots; altimeter setting 30.02 inches of Hg.; thunderstorm overhead; occasional lightning cloud to ground.

At 1841, the following observation was disseminated on AWIS and transmitted to outside aviation interests at 1842:

> 1840...Special...Measured ceiling 4,500 feet overcast; visibility 1 mile; thunderstorm, heavy rain showers, haze; winds 220 degrees at 11 knots; altimeter setting 30.03 inches of Hg.; runway 36L (visual range) greater than 6,000 feet; thunderstorm overhead; occasional lightning cloud to ground.

At 1851, the following observation was disseminated on AWIS and transmitted via telephone at 1852. However, the visibility in the 1850 observation was corrected to 1 mile, and the corrected observation was transmitted to outside aviation interests at 1855:

> 1850...Record...Measured ceiling 4,500 feet overcast; visibility 6 miles; thunderstorm, heavy rain showers, haze; temperature 77 degrees F; dew point 73 degrees F; winds 080 degrees at 5 knots; altimeter setting 30.02 inches of Hg.; runway 36L visual range greater than 6,000 feet; thunderstorm began 1833; thunderstorm north occasional lightning in cloud, cloud to ground; breaks in the overcast; rain began 1834.

The following was obtained from the surface weather observation form for Charlotte:

> Thunderstorm began 1833 and ended 1900.

Light rain showers began 1834 and ended 1837.
Heavy rain showers began at 1837 and ended at 1901.

The 1840 special weather observation was disseminated to the tower facility at approximately 1844, 2 minutes after the accident. The TRACON did not broadcast an arrival ATIS containing this information.

In addition, there were no Convective SIGMETS [significant meteorological information], SIGMETS, or Atlanta Air Route Traffic Control Center (ZTL) Center Weather Advisories in effect for the area at the time of the accident.

The gust recorder record from the NWS wind sensor, positioned atop an approximate 20 foot tower located about 300 feet northwest of the NWS office, measured the wind speed at 1830 and 1900. The wind speeds varied between 4 and 16 knots, with the 4 knot measurement recorded about 1854, and the 16 knot wind velocity recorded about 1840.

According to the July 2, 1994, NWS Rain Gauge Record, between 1845 and 1900 approximately 0.33 inch of rainfall was measured. The Federal Meteorological Handbook No. 1 classifies an hourly rainfall rate of less than 0.1 inch as light. Similarly, a rainfall rate of between 0.11 and 0.3 inch is classified as moderate, and a rate of more than 0.3 inch per hour is classified as heavy. Also, the NWS Barograph Record indicated a station pressure of about 29.20 inches of Hg. at 1800 and 29.21 inches of Hg. at 1900. The maximum pressure change during this period was about .02 inch of Hg., which occurred about 1835.

The Safety Board found that the dispatch documentation prepared by the contract weather service for flight 1016 did include the 1651 Columbia, South Carolina (CAE), surface weather observation and the CAE forecasts. In addition, the weather information included the 1651 Charlotte (CLT) surface weather observation, which stated, in part: [clouds] 5,000 feet scattered, visibility 6 miles in haze; and a forecast for CLT prepared by a contractor indicating the following: [clouds] 4,000 feet scattered, 25,000 feet broken; occasional 4,000 feet broken; visibility 4 miles; thunderstorm, light rain showers. This forecast was issued at 0817 and was valid at the time of the accident.

1.7.2 Witness Descriptions of Weather Conditions

Ground Witnesses.--Several ground witnesses were interviewed and were in agreement that the storm was located over the airport and that it began "raining really hard" in a very short period of time, and that the visibility was reduced to 1/4 mile or less because of the intense rain. In addition, the witnesses stated that a strong "gusty" wind and a noticeable decrease in air temperature accompanied the rain. Two of the witnesses estimated that the wind was blowing between 30 and 60 miles per hour. One witness described the wind as a "mini hurricane."

The witness accounts varied because of their different locations relative to the accident site, but they were in general agreement that the storm lasted 15 to 20 minutes, and that it was followed by "clear blue skies."

A witness who saw flight 1016 on the approach stated that the "airplane and the noise from the engine disappeared into a wall of water." Many of the witnesses described the initiation of the rain as a "downpour."

Pilots on the Ground.--Several air carrier flights were in the process of departing the terminal area at the time of the accident. All of the crewmembers who observed the storm approaching the airport stated that it approached from the south-southwest and moved across the airport in a northerly direction very quickly. All of the pilots saw the precipitation and used the same general terms to characterize the rainfall as "a wall of water," and a "curtain of water." One pilot stated that it was the "heaviest" he had been through in a very long time.

The first officer of USAir flight 806 [the flight that delayed departure because of the weather] stated that during the pushback from the gate, he observed two cloud-to-ground lightning strikes to the east, southeast of the airport. In addition, he saw the "wall of water approach from the south, about 1/3 of the way up runway 36L," and he made a radio call to the tower advising them that there was a thunderstorm over the airport. The first officer also stated that he watched USAir flight 983 (a Fokker FK-100) "disappear into the rain that was moving up the field," and that he was unable to see the airplane turn off the runway because of the intensity of the precipitation.

The captain of USAir flight 797 stated that his aircraft was located near the approach end of runway 18R, and that he was waiting to depart. The captain said that while they were taxiing out from around the C concourse, there was no rain, but that he did see the shower to the south of airport. He turned on the aircraft radar and "painted" a small isolated cell to the south-southeast of the threshold of 36L. The captain stated that the ground visibility was hazy as they taxied north on the E taxiway, and that he did see the reflection of lightning behind them as he taxied to the end of E taxiway. He also said that he observed the FK-100 make the approach to 18R (USAir Flight 983) and that the rain came from behind them with the intensity increasing rapidly shortly after the FK-100 was rolling out. The visibility decreased rapidly in the precipitation. The captain described the rain as very heavy, with visibility reduced to almost zero with no noticeable indication of wind as they sat facing north. He also said that the rain stopped falling with the same abruptness that it had started and that, as the visibility improved, he saw the smoke [from flight 1016] rising out of the tree line.

The captain of a second USAir flight awaiting departure at the approach end of runway 18R stated that his flight was delayed for about 40 minutes at the gate, and that while they were waiting, it started to rain, with the sky going from sunshine to darkness very quickly. The rain was heavy as they pushed back from the gate. The tug driver stated that this was going to be his last push because of the lightning and weather conditions. The captain turned on the radar as he came around the corner of the C and B concourses and checked the 5, 10, 20, 40, 80 mile ranges and did not see any weather returns on the radar. Although they did not paint any precipitation on the radar, he did say that they were taxiing through the "heaviest rain he had been through in a long time." He described the precipitation as a "wall of water." He also said that when they arrived at spot 2 about 1 or 2 minutes after the tower started calling for 1016, he noticed that the visibility was reduced to less than 1,500 feet, with dark, low clouds and precipitation all around them. He did not notice any wind, but he was able to detect variations in the intensities of the precipitation from different areas of the storm. One of the heaviest areas of precipitation was over the end of 18R.

Pilots in Flight.--There were several aircraft landing at Charlotte at the time of the accident. The captain of USAir flight 983, the aircraft that landed ahead of flight 1016, stated that they arrived from the northeast down the Magic Arrival and were cleared for a visual approach to runway 23. As they approached, they observed the rain shower in the vicinity of runways 18R and 23, with lighter precipitation falling to the north. They observed the shower moving to the north, but the speed of the rain did not seem very fast. The captain said the visibility was good as they approached the airport and did not consider the rain shower over the airport to be a problem because he could see 18R. He also stated that on his radar, the cell appeared to be 2 to 3 miles wide, and located south-southeast of the airport center. The captain stated that by the time they completed the approach and touched down, the rain intensity had increased and was very heavy, with the taxiway and ramp covered with standing water and puddles.

The captain and first officer of CCAir flight 5211, the aircraft following USAir flight 1016 on the approach to runway 18R, agreed that as they were approaching the airport, their onboard radar depicted a small weather cell south-southeast of the airport center. The radar showed the heaviest rain slightly east of the airport center, with a band of heavy rain showers extending west toward the airport boundary, northwest past the threshold of 18R to the airport boundary and south to the midpoint of 18R. The crew visually confirmed the precipitation and could see the side boundaries of the precipitation. The radar (on high gain) painted some red color in the cell to the east of 18R; however, the captain's general impression was that the rain shower was not a threat as they approached the runway. The captain stated that he heard the LLWAS [low level windshear alert system] alert issued by the tower, but understood it to say that it was the northwest boundary sensor showing 90 degrees from the centerfield wind (the alert issued stated the northeast boundary). He also said that upon entry into the precipitation, it increased from moderate to heavy almost immediately. The crew characterized their "ride" as smooth until they penetrated the precipitation, at which time they encountered moderate turbulence that continued to increase as they descended.

Flight 5211 was instructed by the tower to execute the missed approach when the airplane was approximately 600 feet above ground level (agl). The captain stated that the airspeed during the missed approach was about 145 knots (normal for this situation should have been 130 knots). He also stated that during their penetration of the precipitation, the crew decided that the most expeditious route out of the rain was to alter course to the right of runway 18R. When they initiated the go-around, they followed that path and broke out of the heavy precipitation approximately 1/2 mile to the west and 1/3 of the way down the runway.

1.7.3 Low Level Windshear Alert System (LLWAS)

The Charlotte/Douglas International Airport was equipped with a Phase II LLWAS, which was operational at the time of the accident.

The LLWAS consists of six wind sensor remote stations, each located strategically throughout the airport property. The location of sensors varies from airport to airport and is determined by terrain and obstacle clearance. The sensors at the airport are identified and located at the following positions: the centerfield indicator, also known as the "centerfield" or sensor 1, is to the east of runway 18R/36L at a height of 15 feet agl; sensor 2 is northeast of the airport, for aircraft approaching either runway 18L or runway 23, at a height of 56 feet agl; sensor 3 is south of the airport, for aircraft approaching runway 36R, at a height of 67 feet agl; sensor 4 is south of the airport, for aircraft approaching runway 36L, at a height of 57 feet agl; sensor 5 is southwest of the airport, for aircraft approaching runway 5, at a height of 57 feet; and sensor 6, at height of 61 feet agl, is approximately 1/2 mile from the runway 18R threshold.

Each remote station collects wind speed and direction data at its location and transmits the data back to the master station. One remote station is designated as the centerfield station. Besides collecting wind speed and wind direction data, the centerfield station also provides gust data.

Each tower display provides readings from the centerfield and five other remote stations. At the Charlotte/Douglas International Airport, only four additional sensors are displayed, the centerfield sensor is displayed twice and sensor 5 is not displayed unless it is replacing a failed station. The centerfield average is displayed on the top line, and line 2 displays the instantaneous reading. Line 3 displays the information from sensor 2; line 4 displays information from sensor 3; line 5 displays information from sensor 4; and line 6 displays information from sensor 6. The centerfield line provides the same information as on the TRACON displays. Each of the other lines identifies a remote station's current wind speed and wind direction reading.

The Phase II LLWAS provides three type of alerts: station, triangle, and edge. The LLWAS was designed to issue a station alert if there is an indication of an anomalous wind condition at any sensor. In this particular LLWAS, a positive test result for an anomalous wind occurs when the sensor wind differs from the network mean wind by a statistically and operationally significant amount. This test requires, at a minimum, 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 windshear alert is issued (there are 10 seconds between polls for the Phase II LLWAS). The LLWAS algorithm also estimates wind field divergence on all triangles and edges of reasonable size that can be formed by locations of the sensors. If excessive wind divergence is detected for four consecutive polls, a windshear alert is issued in the tower. However, because of the small number of sensors, most Phase II LLWAS windshear alerts are based on station alerts. Thus, when an alert is detected at a station, edge, or triangle, a sector alert is also issued.

The Phase II designation for the Charlotte LLWAS denotes that the system computer software was upgraded from the original Phase I system. The upgrade was intended to reduce the number of false alerts (down to 7 percent probability of false alerts) and to provide modest (62 percent probability of detection) microburst protection. The Phase II systems are considered to be interim systems that were intended to "bridge the gap" between the original system (not designed to detect microbursts) and a dedicated microburst detection system.

As planned, a dedicated microburst detection system would consist of either a Phase III LLWAS system (15 or more sensors), a terminal Doppler weather radar (TDWR) or both. The Phase III LLWAS system has a 97 percent probability rate of detecting microbursts and reduces the false alert probability to 4 percent.

FAA Order 6560.15, which was used to train controllers, provides a complete description of the 6-station LLWAS manufactured by Fairchild Weston Systems Inc. It states, in part, "The LLWAS System is designed to scan the airport runway vicinity for certain weather conditions that may be unfavorable for airplane takeoff/landing activities, and then to warn ATCs via alarm whenever an unfavorable condition exists." Weather conditions that LLWAS detects include the following:

> Windshear - the point of occurrence of a wind velocity change. While most windshear occurrences are incidental, a windshear that results in a significant increase in tailwind can pose a threat to aircraft near the ground (during takeoffs and landings) at the point of windshear. Usually, a windshear is an instantaneous occurrence....
>
> Microburst - the occurrence of a column of air perpendicular to the ground and with acceleration towards the ground. This occurs when a mass of cooler and/or moister air is moving over a mass of warmer and/or drier air in an opposite direction. At a weak point in

> the lower air mass, gravity pulls the higher, heavier air through to the ground, creating the column.
>
> Gravitational acceleration can cause the microburst to reach velocities in the 10 to 30 knot range on its downward path. When the microburst column impacts with the ground surface, the air is dispersed in all directions parallel to the earth at even greater velocities because of the pressure exerted by the ground. This poses the greatest threat to aircraft near the ground (during takeoffs and landings) whose path cuts through the microburst area. An airplane going through a 60 knot headwind can suddenly face an abrupt change to a 60 knot tailwind. Microbursts can range from 300 yards to 3 miles in width, and can last in the order of 15 minutes....

The LLWAS system has several limitations: winds above the sensors are not detected; winds beyond the peripheral sensors are not detected; updrafts and downdrafts are not detected; and if a shear boundary happens to pass a particular peripheral sensor and the centerfield sensor simultaneously, an alarm will not occur. However, since the downward flow in macrobursts and microbursts turns horizontally as it approaches the ground, an outward flowing shear boundary is established which eventually affects one of the sensors and places the system on alert.[12]

Although the Charlotte LLWAS system was recertified after the accident, it was the subject of several internal communications within the FAA between April and June of 1993. The system was identified as having problems, specifically, "inaccurate reporting of wind conditions." The Safety Board found that while funding requests for system upgrades were made, there had been no modifications to the system at the time of the accident. In addition, on August 4, 1994, the FAA cited in its written response to the Safety Board regarding the performance of the Charlotte LLWAS system "...at the time of the installation of the CLT LLWAS, the concern was to detect gust fronts. not microbursts" and the siting "...standards were less stringent than those now currently used." The FAA further stated that a Site Performance Evaluation Study (SPES), conducted at Charlotte after the accident, determined that sensor 2 (northeast boundary) and sensor

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[12]Excerpted from Aircraft Accident Report--"Delta Air Lines, Inc., Lockheed L-1011-385-1, N726DA, Dallas/Fort Worth International Airport, Texas, August 2, 1985" (NTSB/AAR-86/05)

6 (northwest boundary) were sheltered by obstacles "...significant enough to degrade the system."

A research engineer from the Massachusetts Institute of Technology (MIT) Lincoln Laboratory testified at the Safety Board's public hearing about the design characteristics and system testing that was performed on the LLWAS systems currently installed at airports around the United States. In addition, he studied the LLWAS system at Charlotte after the accident and stated that approximately 1 minute prior to the accident, sensor 6 (northwest) failed to achieve the alarm threshold by 0.7 (seven tenths) of a knot (wind speed). In characterizing this finding and the LLWAS system, he explained that the philosophy regarding the "modest microburst protection" is achieved with the mathematical algorithms used for calculating the differences in the wind vectors. He stated that the system has a certain amount of conservatism built in to reduce the number of false alerts. The conservatism is such that "the system didn't give alerts as early as we would have liked...." However, the engineer also stated that although the northwest sensor is sheltered in wind conditions from the north, east, and west, its performance was not significantly degraded and provided reliable measurements during the event of July 2. He testified that "the winds were from a southerly direction...where it [the sensor] had a good exposure during this period...I don't see anything in those data that make me feel suspicious of the system. It looked like a normal behavior of an LLWAS during a windshear event. The story it tells is believable."

A review of the recorded CLT LLWAS sensor readings and the ATC tower transcript revealed that at approximately 1840:37,[13] on the day of the accident, sensor 1, located at centerfield, was the first to activate with a wind indication of 100 degrees at 21 knots. At 1841:07, in addition to the centerfield sensor activation, sensors 2 (northeast boundary) and 3 (southeast boundary) activated and indicated the wind to be from 190 degrees at 13 knots and 100 degrees at 08 knots, respectively. Within approximately 10 seconds, the LCW transmitted only the northeast boundary alert to the crew of flight 1016. At 1842:57, in addition to the other sensors, sensor 6 (runway 18R threshold) activated and indicated that the wind was 180 degrees at 35 knots. At 1843:07, all sensors (all quadrants) were indicating a windshear alert until 1844:27. Windshears were no longer detected on any sensors at 1851:57 and beyond. (Plots of LLWAS alerts and the locations of LLWAS wind sensors are contained in appendix C).

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[13]Clock time uncorrected for 10-second error. Tabulated data 10 seconds fast.

1.7.4 Doppler Weather Surveillance Radar (WSR-88D)

The Doppler WSR-88D radar is also known as NEXRAD (Next Generation Radar). This new generation radar supersedes the WSR-57 radar with enhancements that include Doppler radar technology, increased resolution and sensitivity, and a highly automated end product for the user. The WSR-88D radar network was established to "support public weather forecasts and warnings," and is not a dedicated aviation facility.

The principal improvement to the previous radar systems is the Doppler technology because it enables the radar to detect and quantify air motion. This is useful for observing wind flow fields associated with weather events. The WSR-88D uses a significantly narrower beam width (0.95 degrees versus 2.2 degrees) that provides greater resolution in a finer scale of the display information. The enhanced resolution permits the detection of small, highly reflective cores in the volume of air above the ground. The descent of these cores is typically associated with microbursts. The greater sensitivity also enables the system to detect smaller strength attributes associated with gust fronts, outflow boundaries and very light precipitation.

The WSR-88D is a highly automated radar system that utilizes sophisticated computer algorithms and processing capabilities to provide users with meteorological and hydrological products, as opposed to raw data. One of these products, the Vertically Integrated Liquid (VIL) content, is a parameter that enables the radar to determine the updraft strength of a thunderstorm. The radar is also capable of "relative velocity mapping," which quantifies the internal motion of a "fast" moving thunderstorm. Areas of wind divergence that occur near the ground can be detected by Doppler weather radar and are typically indicative of microburst activity.

WSR-88D data can be accessed via several means from remote facilities, which include a Principal User Processor (PUP), Meteorological Weather Processor (MWP), NEXRAD Information Dissemination Service (NIDS), and, with the proper computer software, telephone inquiries to individual radar facilities.

According to the NWS, there are plans for the installation of 162 WSR-88D radar systems throughout the United States. As of August 1994, approximately 90 systems had been implemented; however, only 10 have been commissioned thus far. The commission rate is behind schedule because of difficulties in maintaining spare parts; however, the planned installation rate of four per month will continue through early 1996.

1.7.5 Weather Radar Information From CAE WSR-88D

The WSR-88D Doppler weather radar is located in Columbia, South Carolina (CAE), on a heading of about 186 degrees, and 77 nautical miles from runway 18R at Charlotte. This radar unit was operational on the day of the accident. During the course of this investigation, an extensive data set was collected from the CAE WSR-88D Doppler weather radar. The data set included, but was not limited to, base reflectivity, base and relative velocity, vertically integrated liquid (VIL), and echo tops. These data were collected at elevation angles of .5, 1.5, 2.4, and 3.4 degrees. The height of the CAE WSR-88D radar beam center varies as a function of elevation angle as noted below:

Elevation Angle	Beam Center (Approx. Feet)
.5	8,400
1.5	16,500
2.4	23,900
3.4	32,000

A meteorologist with the NWS testified at the Safety Board's public hearing regarding the WSR-88D data obtained from the Columbia, South Carolina, NWS office. The following is a summary of the meteorologist's testimony:

> 1823 (the time USAir flight 1016 was airborne) By convention the beginning of the volume scan time is assigned the date time stamp for all products associated with that volume scan (.5 degree elevation). Therefore, the time of the 1.5 degree elevation scan would be about 1 minute 20 seconds after the .5 degree elevation scan time and for the 2.4 degree elevation scan about 2 minutes 40 seconds after the .5 degree scan time.

The 1823 base reflectivity of .5 degree elevation scan is showing an echo to the south-southwest of the CLT airport to have very light reflectivity, somewhere between 5 and 15 dBZ (weak echo). For this very light reflectivity the precipitation is probably not reaching the ground yet in a detectable manner, but it does show evidence that the thunderstorm or shower is growing. The 1.5 degree and 2.4 degree elevation scan is showing mid level reflectivity of somewhere around 25 to 30 dBZ (weak to moderate). There is still not enough organization in the base velocity of the cell to say anything about it yet. There is not anything that the forecaster would pay particular attention to at this point in terms of looking for circulation patterns or anything like that. The VIL is still low and the echo top is indicating somewhere around 20,000 or 25,000 feet. The relative velocity data at the .5 degree elevation scan is not showing much. However, some significant velocity signatures are being seen in the 1.5 and 2.4 degree elevation scan data. A velocity signature indicative of divergence is being seen in the data in the upper levels of the storm. This is what you get with any growing rain shower or thunderstorm, but it is just confirmation that this storm is still in the growth phase.

The 1829 base reflectivity of .5 degree scan is showing a reflectivity of the cell up to about 40 dBZ (strong echo) which would be approximately the threshold of a VIP level 3. The cell is located south-southeast of the center of the airport. At mid levels, the reflectivity has increased to 50 dBZ (intense echo), which is approximately the threshold of VIP level 5. Growth of the overall strength of the echo at the higher elevation angles is occurring. Because of the strength of the echo return at mid levels you would start suspecting it was a thunderstorm not a rain shower. Heavy rain will occur at the ground with this storm in about 5 to 10 minutes. The echo top is somewhere between 25,000 and 30,000 feet. The relative velocity map at the .5 degree scan is showing flow away from the radar, it is probably just the general ambient flow (southerly). The low and upper levels show a clear divergence signature. And a divergence signature can now be seen at the 3.4 degree elevation scan. This indicates that this is still a growing storm.

The 1835 base reflectivity of .5 degree scan is showing a 50 dBZ or approximately VIP level 5 echo. It is highly likely that significant if not heavy rain is occurring at the ground at this time. At the 1.5 degree scan the 50 dBZ area has expanded. The storm still has been growing at this point. The strongest gradient of the storm is toward the north-northwest. Part of the storm is off the northwest edge of the runway. There is nothing remarkable in the Base Reflectivity data and the echo seems to be a routine summer thunderstorm. Reviewing the composite reflectivity, base velocity, vertically integrated liquid (VIL), and echo top products the meteorologist stated "it's hard to get anything that would be significant to a forecaster. Once again he's monitoring the VIL and he sees it's still only up to about 20, so he's not going to have any concern that this storm might have severe weather size hail or winds with it. Echo top is still showing about 30,000 feet." The relative velocity map at the .5 degree scan indicates the possibility of some outflow boundary being detected, even though this is pretty high above the ground. In the northwest part of the echo there is an indication of convergence. This may indicate the actual inflow area of the storm. This would not raise "any kind of alarms to a forecaster." The relative velocity 3.4 degree scan is not showing a divergence signature while at 1829 it was. This indicates that the storm has started into its decay cycle. It's no longer growing. There's still a strong storm and there is still a divergence signature at the 1.5 and 2.4 degree elevation angles. However, the forecaster would normally be looking to see whether this storm did not continue to decay over the next volume scan or so. The implication of this decay on the ground are the possible development of downdrafts in the storm. The meteorologist stated that "there's nothing we can see in this data (CAE WSR-88D data) that would either confirm or invalidate the idea of a microburst. It certainly would be possible but we just don't have the evidence with this data to say yes or no."

The 1841 base reflectivity data at the .5, 1.5, 2.4, and 3.4 elevation angles showed that the storm has indeed begun to lose not the maximum reflectivity but the area of 50 dBZ at the higher elevations is smaller. The reflectivities at the higher elevations are significantly lower than in the previous volume scan. This confirms the earlier indications that the storm was beginning its decay phase and is now well into that decay phase. The decrease in high reflectivities at the higher altitudes in the storm are possibly indicative of a descending reflectivity core. Some sort of outflow would be expected on the ground given a descending reflectivity core. The speed of such an outflow can not be quantified with these data. Depending on the size of the outflow the outflow could be classified as a microburst. There was nothing remarkable in the composite reflectivity, base velocity, VIL, and echo top data. According to the meteorologist "...I don't really see anything that a forecaster would pay much attention to on here, other than to continue to corroborate that the VIL is still not threatening in its magnitude." The relative velocity data further corroborate the decaying phase of the storm. A divergent signature does not appear at any level.

The data recorded at 1847 revealed the [storm] cell was continuing to decrease in intensity. There has been movement during this time and the mid level core is now north-northwest of the runway. The VIL has dropped back to the 10 level and the echo tops are now perhaps 25,000 feet.

The meteorologist stated that he did not observe any anomalies in the data that would have indicated severe weather potential. He also stated "it's a decent thunderstorm, summer thunderstorm, with heavy rain...there was not anything of particular significance to the fact that the storm was a VIP level 5 or 6 and the radar tops were only 30,000 feet. A VIP level 5 or 6 thunderstorm in the southeast during the summer is not atypical...."

It was determined during the investigation that the airport runway configuration and location of the Charlotte/Douglas International Airport on the map background of the CAE WSR-88D image were not accurately depicted. The meteorologist testified that these anomalies can be misleading and that the airports on the CAE WSR-88D map background are indicated by a generic airport symbol.

1.8 Navigational Aids

Not Applicable.

1.9 Communications

There were no known communications equipment difficulties. Communications regarding the dissemination of weather information are discussed in other portions of the report.

1.10 Aerodrome Information

The Charlotte/Douglas International Airport is owned and operated by the City of Charlotte and is located in Mecklenberg County, approximately 4 nautical miles east of downtown Charlotte. The airport field elevation is 749 feet, and the touchdown zone elevation for runway 18R is 743 feet.

The airport consists of three 150-foot-wide runways, identified as 5-23 which is 7,501 feet long; 18L-36R, which is 7,845 feet in length and runway 18R-36L, which is 10,000 feet in length. The parallel runways are separated by 5,000 feet, and runway 5-23 intersects runway 18L-36R.

Runway 18R is equipped with high intensity runway lights (HIRL), threshold lights, runway centerline lights (RCLS), runway visual range (RVR), visual approach slope indicator (VASI), a medium intensity approach lighting system with runway alignment indicators (MALSR) and an instrument landing system (ILS).

The ILS approach to runway 18R transmits on a frequency of 111.3 Megahertz (Mhz). The localizer course is 181 degrees; the touchdown zone elevation is 743 feet, the decision height (DH) for the approach when all equipment is operational is 200 feet agl, and the minimum visibility at DH is 1/2 mile. The minimum altitude at SOPHE (the final approach fix) and the DH are 3,000 feet and 943 feet msl, respectively. (See figure 2).

1.11 Flight Recorders

The airplane was equipped with a Fairchild model A-100 A cockpit voice recorder (CVR), serial number 52785, and a Loral Fairchild Data Systems model S703-1000-00 (F-1000), solid state flight data recorder (SSFDR),[14] serial

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[14]The SSFDR will be referred to as the FDR throughout the remainder of this report.

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number 00880. The CVR and FDR were removed from the airplane wreckage and transported to the Safety Board's Washington, D.C., laboratory where they were read out and evaluated.

The CVR's outer metal case sustained minor impact damage; however, the interior of the recorder sustained no heat or impact damage. The CVR tape was removed and copied, a time correlation was performed with ATC transmissions, and a transcript containing the last 31 minutes of flight was prepared.

The FDR sustained no impact damage; and the quality of the recording was excellent with no loss of data. The recorded information covered 25 hours of flight, including the 24 minutes of flight from Columbia until the end of the recording. The FDR contained the following 11 parameters: time; pressure altitude; indicated airspeed; heading; roll and pitch attitudes; captain's control column position; vertical and longitudinal acceleration forces (G); left and right engine EPR; and VHF radio keying.

1.12 Wreckage and Impact Information

The airplane initially touched down in a grassy field located within the airport boundary fence, about 2,180 feet southwest of the threshold for runway 18R, on a magnetic heading of 240 degrees. The elevation of the first ground impact mark was 748 feet (the elevation of runway 18R is 743 feet), and a correlation of the ground scars and airplane structure determined it to be consistent with the right main landing gear. The next ground scar, located 18 feet farther in the direction of travel, was determined to be consistent with the left main landing gear. The furrows made by the landing gear were followed by narrow ground scars that were consistent with the right wing flap hinges.

Pieces of airplane wreckage were scattered throughout the debris path, which was oriented along a magnetic heading of 211 degrees. The debris field contained a wooded area of sheared trees between approximately 500 and 800 feet from the initial impact marks.

The airplane tailcone was located approximately midway along the debris field and in close proximity to the remnants of a small brick structure where the nose landing gear was found. The majority of the right wing was found 90 feet beyond the tailcone, and several trees had been discolored by fuel from the ruptured tanks. Two large sections of the forward fuselage, including seats from the forward passenger cabin, were crushed against three large oak trees located east of Wallace Neel Road and across the street from the private residence. This section of the fuselage contained portions of the left side skin that mated with the cockpit section of the fuselage.

An approximate 40-foot section of the forward fuselage, consisting of the cockpit, the forward galley, and the left side of the passenger cabin and forward cargo compartment, came to rest on Wallace Neel Road, oriented in a southerly direction. The aft portion of the fuselage, including the empennage and the two engines, was the last major section of the airplane in the debris field. This section had come to rest embedded in the carport of a two-bedroom house located across Wallace Neel Road, which was 1,063 feet from the initial impact ground scars.

The first large section of wreckage beyond the right wing was comprised of portions of the first class and coach cabin flooring and seats from both sides of the aircraft. Seat rows 1 through 8, from the right side of the airplane; and seat rows 3 through 8 on the left side of the airplane were found in the wreckage that had impacted two large hardwood trees.

The second section of wreckage consisted of the cockpit, forward flight attendant jumpseat, forward galley, four first class seats from the left side of the airplane. and approximately 12 feet of the cabin floor, aft of the coach cabin divider. There was no evidence of postcrash fire in this portion of the wreckage.

The cockpit sustained substantial deformation. The captain, first officer and observer seats were partially detached from their anchor points. The right side cockpit floor was crushed upward and aft, and both the captain and first officer seats were resting against the lower instrument panel. Examination of the flight controls, switches, handles and instruments was conducted, and the findings were documented. Some of the findings included the position of the captain and first officer's flight directors, which were in the off position. The first officer's heading selector was positioned on 181 degrees, and the captain's heading selector indicated 220 degrees. Additionally, the autopilot servo engage/disengage was in a position that corresponded to being disengaged; and the engine ignitor switches were in the off position.

The third section of wreckage, at rest in the front yard of the residence, was comprised of the left wing and overwing fuselage area, and included the seats from rows 9 through 14. The wing box structure was found relatively intact, but the cabin area over the top of the wingbox had been destroyed by fire.

The large section of the left wing, wing box, and the fuselage section over the center wing section were destroyed by impact damage and postaccident fire. The left main landing gear was found separated from the wing and embedded between the side of the house structure and fuselage; and the right main landing gear was found between the empennage and Wallace Neel Road.

The aft section of airplane consisted of the fuselage from station 870 (between the third and fourth aft-most windows) to the attachment point of the tailcone. The empennage sustained postaccident fire damage. Powerlines and poles that were in the path of the debris were broken and/or destroyed by impact or fire. The aft section of the airplane, found embedded in the carport of the residence, included the passenger cabin area and seat rows 17 through 21. The seats in rows 17 through 19 had separated from their respective floor track mounts and were found under the seats in rows 20 and 21 (which were intact). The fuselage tailcone area sustained impact damage along the floor, and the cabin flooring was deformed upward. The deformation prevented the tailcone door from opening. The interior area of the empennage section was not burned, although the exterior did sustain fire damage.

A large portion of the left horizontal stabilizer and elevator were consumed by fire; however, they remained in their normal mounted position on the vertical stabilizer. The right horizontal stabilizer and right elevator also sustained fire damage, as did the rudder, aft of the hinge line. The postaccident fire consumed the upper portion of the leading edge and in-spar areas of the vertical stabilizer.

Examination of the aforementioned portions of the wreckage did not disclose any evidence of preimpact separation or failure.

The majority of the left wing leading edge (slats), and a portion of the spar and wing tip were separated from the remains of the left wing. The center and inboard sections of the left wing were consumed by the postaccident fire. Approximately 2/3 of the wing flap structure was found attached to the left wing, as were the ailerons and spoilers. Examination of these flight controls revealed that the spoilers were down and that the aileron was streamlined with the wing structure. The right wing was found separated from the fuselage and had sustained fire damage. The flaps, slats and spoilers were found separated from the wing structure.

Examination of the landing gear fittings revealed that the gear was in the down and locked position at the time of impact. The recovered sections of the flaps and flap actuators revealed that the right flaps were in a position that corresponded to 14 degrees extended, and the left flap was in a position that corresponded to 16 degrees extended. The cockpit-mounted flap selector handle was examined, and "smeared" metal was found along the forward edge of the 15-degree detent. The leading edge slats were also examined and found to have been in a position that corresponds to the fully extended position at impact.

1.12.1 Powerplants

Both engines were found with the aft fuselage. The left and right engine inlets had large amounts of wood branches and foliage packed against the inlet guide vanes. The first stage fan blades of both engines had evidence of "hard object" damage to the tips and leading edges. Large amounts of shredded wood and vegetation were found in the bleed air ducts.

Left Engine.--The left engine was attached to its mounts with the inlet, cowl doors and thrust reverser assembly in their normal mounted position. The thrust reverser was found stowed and latched. The reverser latch had been modified for hydraulic operation in accordance with Douglas Service Bulletin 78-38.

Examination of the rotating components indicated that at the time of impact, the engine was capable of producing power.

Right Engine.--The right engine was separated from its mounts and was on the ground next to the fuselage. The forward mount assembly was intact and attached to the engine. However, the forward portion of the pylon structure was fractured and separated from the fuselage. The rear mount assembly and cone bolts were found intact and attached to the pylon structure.

The thrust reverser was found in the fully deployed position. The manually operated reverser latch, located at the 6 o'clock position, was found in the unlatched position. The latch on the right engine had not been modified for hydraulic operation per Douglas Service Bulletin 78-38. Further examination of the reverser system revealed that the reverser buckets extended during the impact sequence and that, upon lifting of the engine for removal from the accident site, the buckets moved to the stowed position.

Examination of the rotating components revealed that at the time of impact, the engine was capable of producing power. Although the thrust reverser was found fully deployed, evidence indicates that it was in the stowed position at the time of impact.

1.13 Medical and Pathological Information

The two flightcrew members survived the accident and both of them were admitted to the hospital after the accident. The captain and first officer submitted to the required drug testing of the Department of Transportation (DOT) and voluntarily submitted to ethyl alcohol testing. The results of both the drug and alcohol tests, as reported by the Civil Aeromedical Institute (CAMI), were negative for both tests for the captain and first officer.

1.14 Fire

The postaccident fire consumed the portions of the aircraft wreckage in which fuel was present. There was also evidence of flashover fire in the immediate vicinity of the debris area. The crewmembers, passengers and ground witnesses stated that they observed fire after the aircraft came to rest in various locations around the accident site. The large portion of the empennage that had separated and contained numerous survivors was heavily damaged by fire on the exterior, but the interior cabin was not adversely affected by heat or flames.

1.15 Survival Aspects

The passenger cabin contained 21 rows of seats and was configured with 12 first class and 91 coach seats. There were 52 passengers on board flight 1016: 27 males, 23 females, and 2 female in-lap infants (younger than 24 months) who were not listed on the passenger manifest.

Of the 37 passengers who received fatal injuries, 32 were the result of blunt force trauma, 4 were due to thermal injuries, and 1 was the result of carbon monoxide inhalation. Passengers seated in rows 3 through 10 sustained nonsurvivable blunt force trauma; and 10 passengers seated aft of row 14 sustained fatal blunt force injuries. The passengers who received fatal thermal or carbon monoxide-related injuries were seated in the area directly over the wing or in very close proximity to it.

Surviving passengers occupied seats 11A, 14F, 15C, and 17E and seats in rows 18 through 21. Some of the passengers in seat rows 17 through 19 were trapped in the wreckage until they were extricated by rescue personnel, while other passengers in those rows were able to escape unassisted. Due to the destruction of the fuselage, none of the emergency exits were used during the evacuation. Occupants escaped through breaks in the fuselage.

The "A" flight attendant lifted the "C" flight attendant (who sustained an open fracture to her kneecap) from the forward jumpseat and pulled her away from the wreckage. The "A" flight attendant then ran to the tail section and further assisted in the evacuation by pulling two passengers and an 18-month-old infant from the wreckage near the right engine.

The "B" flight attendant, seated on the aft jumpseat, opened the tailcone exit door slightly; however, due to cabin deformation, the exit could not be opened fully. Further, the "B" flight attendant closed the tailcone exit door when she observed smoke in the tailcone. The flight attendant then led some passengers out of the wreckage through breaks in the left side of the fuselage.

A 9-month-old infant, who was unrestrained in her mother's lap in seat 21C, sustained fatal injuries. The mother was unable to hold onto her daughter during the impact sequence. Seat 21C was intact and the surrounding cabin structure sustained minor deformation. Additionally, the impact forces in this area were calculated to have been within human tolerances. According to passengers, a flash fire swept through the inside of the cabin during the impact sequence; examination found no evidence of either fire or smoke impingement in this area of the cabin. (See figure 3.)

1.15.1 USAir Passenger Manifest Procedures

The passenger manifest for flight 1016 listed 50 passenger names, but it did not include the names of the two "in-lap" infants. The tickets issued to the adults traveling with the in-lap infants were reviewed. One passenger's ticket had the marking "+ infant" handwritten on the face of the ticket. The second passenger's ticket had no identifying information to document the carriage of the in-lap infant. 14 CFR Part 121.693 requires that children, regardless of their age or whether they are the sole occupant of a seat, must be listed by name on the passenger manifest.

In accordance with USAir's procedures, the "Flight Attendant Manifest" is generated by the Customer Service Agent about 10 minutes prior to departure and is presented to the flight attendants after the last passenger has boarded the airplane. According to the information in the USAir Passenger Service Manual, which was current at the time of the accident, the passengers who were traveling with the infants should have had the words "Plus Infant" written in the name field of the flight coupon (passenger ticket). Additionally, two "Non-Seat Assigned Infant Boarding Pass" stickers were also required to be completed. In accordance with the Service Manual, one Non-Seat Assigned Infant Boarding Pass is required to be attached to the accompanying parent/adult boarding pass; and the second pass is to be attached to the accompanying parent/adult flight coupon retained by the Customer Service Agent.

The current USAir procedures regarding the Advanced Boarding Control II (ABC II) system specifies that the "final" passenger count is to be determined by adding the total number of passenger tickets retained at the gate to the number of passengers remaining on board the airplane (if any) from the previous flight. The total number of passengers is then relayed to the dispatcher and is transmitted to the cockpit prior to takeoff.

The two lap children were seated in 18F and 21C. The 18-month-old female infant was lying across seats 18E and 18F. This infant sustained serious injuries, and her mother sustained minor injuries. The other lap child, a 9-month-old female infant, was being held by her mother in 21C and sustained fatal injuries. According to the mother, she was unable to maintain a secure hold on her child during the impact sequence.

Following the DC-10 accident in Sioux City, Iowa, on July 19, 1989, the Safety Board issued Safety Recommendation A-90-78 to the FAA to revise 14 CFR Parts 91, 121, and 135 to require that all occupants be restrained during takeoff, landing, and turbulent conditions and that all infants and small children below the weight of 40 pounds and under the height of 40 inches be restrained in an approved child restraint system appropriate to their height and weight. Additionally, the Safety Board issued Safety Recommendation A-90-79 urging the FAA to conduct research to determine the adequacy of aircraft seat belts to restrain children.

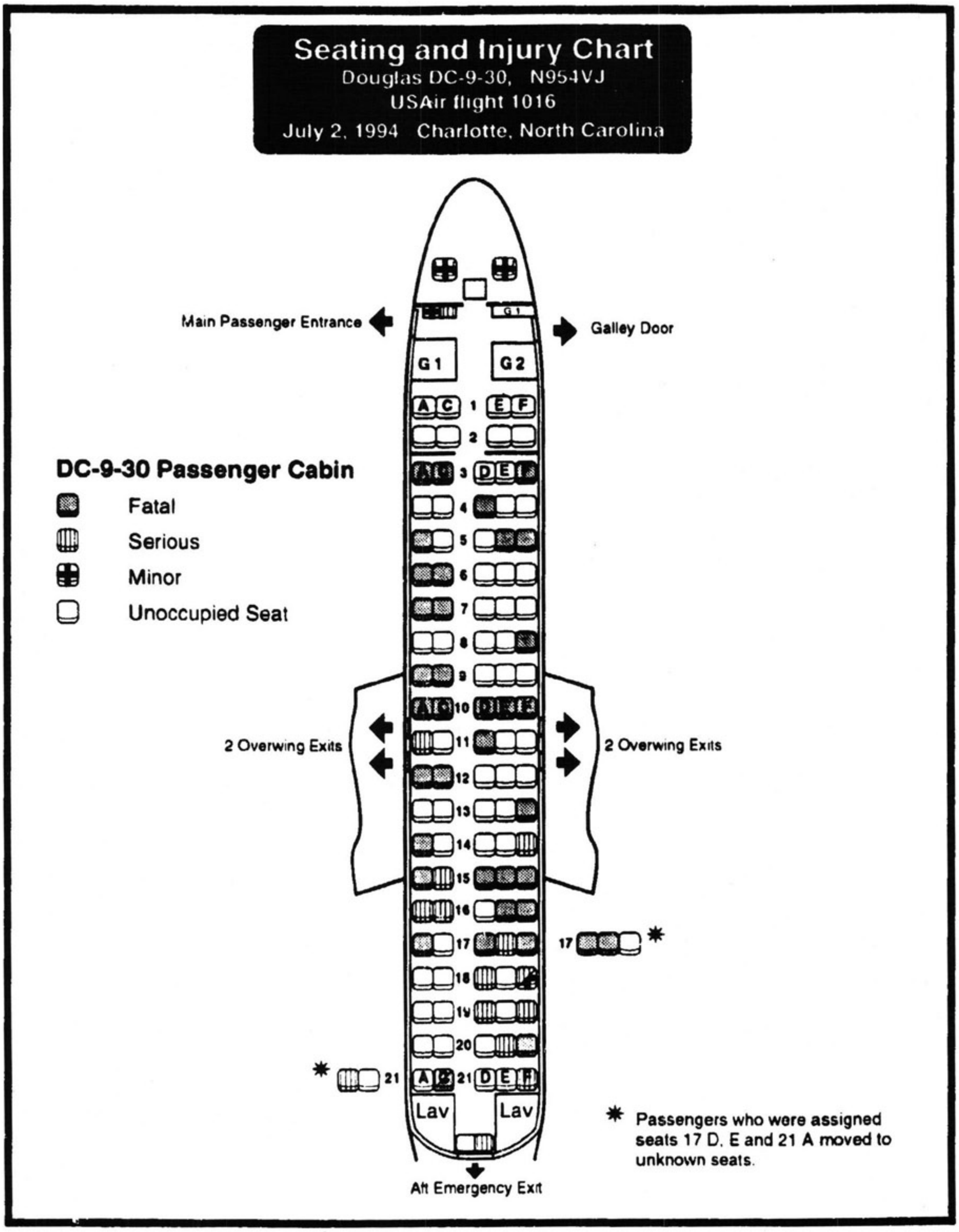

Figure 3.--Cabin diagram.

The FAA conducted research into child restraint devices, and, in September 1994, released a report produced by the Office of Aviation Medicine, Civil Aeromedical Institute (CAMI). The report, entitled "The Performance of Child Restraint Devices in Transport Airplane Passenger Seats," states, in part, that children 2 years of age and currently required to be restrained by an adult lap belt, are not provided an adequate level of protection. The report also states that test results indicated that an anthropomorphic test dummy (ATD), representing a child 3 years of age and restrained by a lap belt, would be afforded adequate protection. However, a 24-month-old child similarly restrained by an in-lap belt was "marginal" because the lap belt tension was not considered to be a "snug fit" when the belt was adjusted to its maximum length.

Further, CAMI conducted a series of dynamic tests on various types of child restraint systems (CRSs), including booster seats, forward-facing carriers, aft-facing carriers, harness systems, belly belts, and normal seat belts. The report concluded that some of the CRSs "may not meet the expected levels of performance in an accident." The tests indicated that "normal lap belts provided acceptable restraint for children of a size represented by a 3-year-old anthropomorphic test dummy."

1.15.2 Emergency Response

At approximately 1845, the Charlotte ATC tower activated the "crash phone" linked to the airport fire station (Station 17) and indicated that "we lost a plane on radar - 5 SOB [Souls on Board]." Eight fire fighters responded with three aircraft rescue and fire fighting (ARFF) trucks (Blaze 1, 2, and 7), and one quick response and command truck (Blaze 5) from the fire station located near the base of the ATC tower. Several fire fighters stated that at the time the equipment was dispatched, "it was raining very hard."

The initial notification to the fire station by the control tower did not identify any particular location of the downed aircraft because of the restricted visibility; thus, the fire equipment traversed the airport via taxiway "A" searching for evidence of an accident. At 1846:09, the ATC ground controller notified the crew in Blaze 5 "we have a large area of smoke visible from the tower, now it appears to be approximately a quarter mile north of the old hangar that CCAir is using...." Simultaneous to the ground controller's transmission, the crew of Blaze 5 heard over their public communications radio a transmission from the City Alarm Room indicating that there was a "possible plane crash in the vicinity of Wallace Neel and

Old Dowd." The ATC ground controller contacted the crew of Blaze 5 and stated that there were "five zero souls, plus five crew on board." The fire equipment crossed the airport, and two of the vehicles exited the airport property through a security gate (gate 36) operated by a magnetic key card. The two remaining vehicles, delayed because they could not open gate 36, eventually drove through the unopened gate and continued their response to the scene.

About 4 minutes after the Charlotte ARFF units arrived on scene, the Charlotte Fire Department (CFD) units arrived at the accident site. The fire fighting efforts proceeded for approximately 5 minutes, using water and aqueous film-forming foam (AFFF) as the extinguishing agents.

The response from all fire departments totaled five alarms, and the Charlotte ARFF used a total of 187 gallons of AFFF. Despite a brief period of heavy rain and high winds, the fires were extinguished quickly, and the rescue of trapped and injured persons commenced immediately.

At 1845, MEDIC dispatched 4 Advanced Life Support (ALS) units, 1 operational supervisory unit, and 25 ambulances from surrounding communities. The first units arrived on scene at 1852, but their response was hampered by debris blocking the roadway. During the treatment process of the injured passengers and crewmembers, paramedics requested manpower assistance; however, additional personnel were either slow to respond or did not arrive.

The transport of the injured victims commenced about 1930, and the first arrivals at three nearby hospitals, Carolina Medical Center, Presbyterian, and Mercy, began at 1938, 2005 and 2018, respectively.

The Charlotte/Douglas International Airport is certified at ARFF index D, and has an FAA-approved emergency plan in accordance with 14 CFR Part 139. The last disaster exercise was conducted on November 6, 1993, near Old Dowd Road, in close proximity to the Berry Hill Baptist Church, and within 1/4 mile of the accident site.

1.16 Tests and Research

1.16.1 Heavy Rain Effect on Airplane Performance

The effect of heavy rain on airplane aerodynamics has been an area of technical interest for the past several years. The Safety Board discussed the effects of heavy rain in the factual report of its investigation of the accident involving a Pan Am World Airways Boeing 727, at Kenner, Louisiana.[15] The Safety Board's report stated, in part, the following:

> ...Essentially, the theory states that heavy rain impacting an airplane can penalize performance three ways: 1) some amount of rain adheres to the airplane and increases the airplane's weight; 2) the rain drops striking an airplane must take on the velocity of the airplane and the resulting exchange of momentum retards the velocity of the airplane; 3) the rain forms a water film on the wing, roughens the wing's surface, and reduces the aerodynamic efficiency of the wing.

The Safety Board has investigated several windshear accidents that were known to have heavy rain occurrences at the time of the accident. In a joint project aimed at studying windshear, the FAA and the National Aeronautics and Space Administration (NASA) also examined the effects of heavy rain as part of the overall windshear phenomenon.

During the course of the study, numerous wind tunnel tests were conducted over a 10-year period using several different wing shapes, including two that were equipped with trailing edge flaps and leading edge slats. These wind tunnel tests simulated the effects of heavy rain to scientifically measure the performance degradation, if any, that heavy rain had on the lifting characteristics of an airfoil.

The tests revealed that there was a measurable reduction in the maximum lifting capability of an airfoil in extreme heavy rain, and some increase in aerodynamic drag. However, these penalties were only predominant when the wing was at a high angle of attack (AOA) during the heavy rain encounter.

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[15] See Aircraft Accident Report--"Pan American World Airways, Inc., Clipper 759, Boeing 727-235, N4737, New Orleans International Airport, Kenner, Louisiana, July 9, 1982" (NTSB/AAR-83/02)

An example of the effects of heavy rain was documented in testing and the results revealed that for a transport category airplane wing design, a 15 percent loss in maximum lift and a 6 degree decrease in the stall AOA occurred when the wing was exposed to an "extreme" rainfall rate of 40 inches per hour. The NASA data indicated that very large amounts of rain were necessary to appreciably affect the aerodynamic performance of the wings commonly found on transport category airplanes. Further, NASA also conducted tests to determine the effects of heavy rain on the AOA vane located on either side of the aircraft. These tests revealed that during extreme rainfall rates, as high as 30 to 40 inches per hour, there was a less than 1 percent error in the AOA vane readings. The rainfall rate in the Charlotte area at the time USAir flight 1016 encountered the "heavy rain" was determined to be approximately 10 inches per hour. In testimony at the Safety Board's public hearing, a NASA researcher stated that the rainfall rate encountered by flight 1016 would not have affected the performance of the airplane.

A performance engineer from Pratt & Whitney Aircraft Engines testified at the public hearing regarding the effects of heavy rainfall rates on the performance of the JT8D engine. The engineer stated that the engines from flight 1016 were tested in simulated extreme rainfall rates equivalent to a 4 percent water to air ratio by weight. The test revealed that the rainfall encounter at Charlotte was not considered to be extreme and that there was no evidence of thrust degradation over that of a "dry" engine.

1.16.2 Airplane Flight Profile and Event Study

The study of aircraft performance examined the motion of the accident airplane relative to time. Recorded radar data, meteorological data, CVR comments and sounds, and FDR data were used to develop a time history of USAir flight 1016's performance. The recorded information from the FDR contained, in addition to airplane performance data, the control column inputs that enabled the Safety Board to compare the response of the airplane to the pitch commands input by the pilot(s).[16]

The performance data indicated that flight 1016 proceeded uneventfully until the final seconds of the flight. At 1839:43, the crew extended the landing gear, followed 38 seconds later by the repositioning of flaps to 40 degrees. The first

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[16]Refer to the Appendix section of this report for graphs of the flightpath of the airplane.

officer had the airplane established on the ILS glideslope, descending through 1,000 feet msl (250 feet agl) at 147 knots indicated airspeed (KIAS).

At 1841:54, the captain stated "here comes the wipers," followed 3 seconds later by a sound recorded on the CVR that was similar to heavy rain. At 1841:58, the first officer commented "there's ooh, ten knots right there," followed shortly thereafter by the captain's remark "OK you're plus twenty." At 1842:14, the captain commanded the first officer to "take it around, go to the right," and the FDR recorded a significant increase in the engine pressure ratio (EPR) indication of both engines. At the time that the missed approach was initiated, the airplane was at a speed of 147 KIAS, on a magnetic heading of 170 degrees, and at an altitude of about 200 feet agl. Airplane pitch attitude began increasing, and roll attitude moved gradually right wing down.

At 1842:19, the first officer stated "flaps to fifteen." Airplane pitch attitude continued to increase, and a positive climb indication and heading change to the right were recorded by the FDR. A sound similar to the flap handle being repositioned was recorded on the CVR at 1842:21. Concurrent with the flap retraction process, the airplane encountered a 35 knot headwind and 30 feet per second (fps) down vertical wind. The CVR recorded the captain state "down, push it down," and the FDR recorded forward movement of the control column.

At 1842:23, the FDR recorded both engine EPR values stabilized at approximately 1.82, about 9 percent less thrust than the target EPR of 1.93, used for the go-around. The EPRs remained steady for about the next 8 seconds. Also, during this time, the FDR recorded the maximum airplane roll attitude of 17° right wing down at 1842:23 and the maximum pitch attitude of 15° nose up at 1842:25.

Between 1842:21 and 1842:25, the airspeed decreased at a rate of about 4.5 knots per second, from an initial speed of 138 KIAS to 120 KIAS. About this same time, the vertical climb rate increased to a recorded maximum of 1,500 feet per minute.

The airplane transitioned from a nose-high attitude and a positive rate of climb to a nose-down attitude and descending flight. At 1842:26, the pitch attitude was decreased through 7 degrees nose up as the captain radioed "up to three we're takin a right turn here." At this point, the airplane leveled momentarily, approximately 350 feet above the ground, and the airspeed decreased to less than 120 KIAS. Also during this same period, the headwind experienced by the airplane was approximately 20 knots; however, the headwind was decreasing at a rate of about 4.4 knots per second. The normal acceleration values recorded by the FDR reached a minimum value of 0.4 G.

At 1842:28, the CVR recorded the "whoop, whoop terrain" sound of the ground proximity warning system (GPWS), and the FDR recorded the airspeed at 116 KIAS. The pitch attitude was decreasing through 2 degrees nose up, while the altitude above the ground decreased to below 330 feet.

About 1842:29, the CVR recorded a flightcrew member state "**power." The captain testified that he commanded "firewall power" in response to the GPWS activation. In concert with the captain's command for firewall power, the FDR recorded an increase in engine EPR values to above 1.82, and an airspeed increase. At 1842:30, control column position moved abruptly aft, and the airplane pitch attitude began increasing about 1 second later. However, at 1842:31, the FDR recorded the airplane's pitch attitude to be 5 degrees nose down and the rate of descent to be in excess of 2,000 feet per minute down.

Engine EPR values revealed a maximum of 2.09 and 1.99 for the left and right engines, respectively, which correspond to an 8 percent increase in the net thrust over the target EPR of 1.93. At 1842:33, the FDR recorded the airspeed at 132 KIAS and the normal acceleration value at 1.4 G. Simultaneously, the CVR recorded the sound of the airplane's stick shaker (stall warning system) activating, followed by the first sound of ground impact at 1842:35.6. The FDR recorded the following parameters at the time the airplane impacted the ground: pitch and roll attitude was about 5 degrees nose up and 4 degrees right wing down, the airspeed was 142 KIAS, the magnetic heading was 214,° and the normal acceleration value was 3.1 G.

1.16.3 FDR/Radar Wind Field Study

The Safety Board conducted several studies of various data to define the horizontal components of the wind field acting on the airplane during the last 2 minutes of flight. In addition, Douglas Aircraft Company (DAC) and Honeywell Inc., conducted similar studies and achieved similar results. DAC subsequently conducted a more rigorous study to determine the vertical components of the wind field. The derived 2-axes and 3-axes components are considered valid for the positions along the actual airplane flightpath.

The first method compared position data derived from an integration of FDR heading, airspeed, and altitude data, to position data defined by recorded automatic radar terminal system (ARTS) data. Differences in position are used to define the horizontal components of the wind field. The results indicated that the airplane encountered a 70 knot change in horizontal winds along the flightpath within a 16 second period of time, which yielded a windshear of about 4.4 knots per second. Using this method, the wind change that flight 1016 would have traversed began as a 40 knot headwind and ended as a 30 knot tailwind.

The second method compared the airplane's ground speed, derived from the integration of FDR longitudinal/normal acceleration values, to the FDR-derived true airspeed. The results indicated that the airplane encountered a 51 knot change in horizontal winds along the flightpath within the last 15 seconds of flight, yielding a windshear of about 3.4 knots per second. Using this method, the wind change that flight 1016 would have traversed would have begun as a 33 knot headwind and ended as an 18 knot tailwind.

DAC used a combination of both the aforementioned methods, as well as pitch, roll and thrust data from the FDR to comprehensively define the 3-axes wind field along the flightpath. The headwind encountered by flight 1016 between 1840:40 and 1842:00 was calculated at between 10 and 20 knots. The initial wind component, a headwind, increased from approximately 30 knots at 1842:00 to 35 knots at 1842:15. The maximum calculated headwind occurred at 1842:17, and was calculated at about 39 knots.

The airplane struck the ground after transitioning from a headwind of approximately 35 knots, at 1842:21, to a tailwind of 26 knots (a change of 61 knots), over a 14 second period. The magnitude of the windshear was determined to be approximately 4.4 knots per second.

The airplane's AOA was not recorded on the FDR, thus increasing the work effort to calculate the vertical winds. On February 22, 1995, the Safety Board recommended that more data parameters be recorded on airplanes like the DC-9-30.[17] The vertical wind calculations performed by DAC revealed that the vertical wind component increased from a relatively low value to 10 fps down at 1842:15. The velocity of the vertical wind component further increased to 25 to

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[17]Safety Board Safety Recommendations A-95-25 through A-95-27.

30 fps down between 1842:20 and 1842:30. About 4 to 6 seconds before ground impact, the altitude was approximately 200 to 250 feet agl, and the vertical wind component had changed to about 5 to 10 fps down.

1.16.4 NASA Atmospheric Study of Derived Winds

At the request of the Safety Board, a Research Meteorologist from the NASA Langley Research Center, Flight Dynamics and Control Division, produced a computer simulation of the environmental conditions that affected USAir Flight 1016. An advanced computer program, known as the Terminal Area Simulation System (TASS), was used to model the simulated atmospheric cloud and microscale phenomena. The model was applied and validated against a wide range of atmospheric phenomena and is currently used by the FAA in windshear system certification.

The simulation model was used to reconstruct several previous windshear-related accidents, including the Delta Air Lines flight 191 accident that occurred on August 2, 1985. The meteorologist who performed the simulation for the Safety Board stated in his presentation to the Safety Board at the public hearing that the results of the simulation revealed USAir 1016 encountered a microburst windshear while on approach for landing on runway 18R. Additionally, flight 1016 most "probably" encountered the microburst that was centered about 1.85 kilometers east of the accident site, during the early stages of development. The microburst was characterized as approximately 3.5 kilometers in diameter, with a peak low level gust of about 53 knots, and a maximum velocity change along a north to south axis of about 86 knots. The windshear was determined to have a maximum (1 kilometer average) north to south F-Factor[18] of about 0.3. The peak rainfall rate was estimated to be as high as 10 inches per hour, and the maximum liquid water content (LWC) was calculated to be about 4.5 grams per cubic meter, but may have been as high as 9 grams per cubic meter. (Wind vector plots are contained in appendix C).

The windshear profile indicated that a downward vertical wind velocity of about 23 fps was estimated to have occurred along the flightpath, about 2,600 feet from the impact point. The microburst was generated from a

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[18] F-Factor is a nondimensional value used to quantify the effects of a microburst on aircraft performance. F-Factor is a function of horizontal shear, vertical wind velocity, and aircraft velocity. The FAA considers an F-Factor of 0.1 to be hazardous. A positive F-Factor is a detriment to the airplane's flightpath gradient.

thunderstorm with maximum cloud top height of less than 30,000 feet. The peak radar reflectivity was recorded at 65 dBZ (extreme echo intensity) at 3 to 4 kilometers above the ground.

According to the meteorologist, the microburst at Charlotte produced the most "severe F-Factor" of any case numerically simulated. When he was asked at the public hearing about the validity of the simulation he stated "...I think overall I would have very good confidence, although I wouldn't have confidence in every little detail of the structure. In other words, a divergence center being located at such and such position off runway 18 or that sort of thing."

1.16.5 Douglas Aircraft Company Flight Simulations

The Safety Board received a mathematical DC-9 flight performance simulation conducted by DAC, with assistance from NASA, which developed a theoretical model of the microburst that was encountered.

The DC-9 simulations were performed using two types of wind field models. The first simulation used the actual time-based winds that were derived from the FDR and FAA radar data for the accident flight. An inherent limitation to this particular simulation is that the FDR-derived winds are only valid for the accident flightpath, and the theoretical flightpath winds could not be determined from those data. Therefore, a second simulation was performed using the NASA-developed wind field model. The NASA model simulated the wind conditions at all points as a function of time and location in three dimensional space. Thus, the NASA-developed wind field provides an infinite variety of flightpaths to be evaluated by the simulation.

Both wind models were validated by executing the DC-9 simulation with FDR-derived parameters and comparing the resulting flightpath against that of the accident flight. The simulated flight, using only the accident parameters and the FDR-derived wind field, was consistent with the actual flightpath of flight 1016, which, in turn, validated the DC-9 simulation model used in this case. The NASA-derived winds also compared favorably with the actual FDR-derived winds within the microburst. However, they were of a lesser magnitude during the early portion of the approach.

The NASA model defined a uniform flow field for the microburst and did not depict precisely the dynamic nature of the leading edge winds of the microburst. However, the comparison did prove satisfactory when it was started at 1842:15, or 15 seconds before the end of the flight.

The simulation used the NASA windshear profile and data from the FDR as a starting point, and the following assumptions were included:

(1) the landing gear was retracted after the sustained positive climb rate, beginning at 1842:20,

(2) engine power was trimmed to the target setting of 1.93 EPR by 1842:22.5,

(3) pitch attitude was maintained at or near 15° nose up while respecting stick shaker, and

(4) engine power was increased to firewall setting after airspeed decreased below 120 knots at 1842:25.

These conditions were consistent with the normal missed approach procedure, until the extreme airspeed loss required "firewall" power. The simulation never exceeded stick shaker AOA; therefore, the pitch attitude was maintained at 15 nose up during the recovery. Also, the airspeed reached a minimum of 115 KIAS compared to the predicted [flaps 15°] stick shaker speed of 109 KIAS. The simulation revealed that the maximum altitude loss during the recovery resulted in the airplane descending to about 325 feet agl, which was followed by an increase in airspeed and altitude.

1.16.6 Control Forces During the Attempted Go-Around

The mathematical DC-9 simulation used by DAC did not recognize and account for pitch control forces. The Safety Board examined the pitch control forces to determine if a pilot could reasonably be expected to achieve the pitch attitudes used in the DC-9 simulations. Both simulations assumed the engine thrust was at or near the takeoff value, the pitch attitude began and remained at or very near the target of 15° nose up, and the flaps were retracted from 40° to 15°.

Assuming the pilot had been exerting minimal or no pitch control forces just prior to the missed approach, the FDR data indicate that flight 1016 was trimmed for about 144 knots. Pitch trim was not recorded by the FDR; thus, the

144 knot trim speed was approximated. The stability and trim data supplied by DAC revealed that the airplane would have been controllable with normal inputs to a speed in excess of 47 knots below the trim airspeed. The data also indicate that a "pull" force of about 24 pounds would have been required to hold the airspeed 47 knots below the trim airspeed. Also, given these conditions, the use of stabilizer trim would have reduced the pull forces to less than 24 pounds.

1.17 USAir Organizational and Management Information

USAir is a wholly owned subsidiary of the USAir Group, Inc., a publicly held corporation. The company was founded by Richard C. Dupont in Delaware in 1929 under the name of All American Aviation. Over the past 50 plus years, the company has undergone several mergers with other airlines. In the late 1980s, USAir merged with Pacific Southwest Airlines (PSA) of San Diego, California, and Piedmont Airlines of Winston-Salem, North Carolina.

USAir employs over 44,000 persons, of whom more than 6,000 are pilots. At the time of the accident, USAir operated 74 Douglas DC-9 airplanes with 674 pilots.

The accident involving flight 1016 was the fourth major accident for USAir in the previous 5 years. The following is a chronology of the previous accidents:

September 20, 1989	Boeing 737-300, Flushing, New York
February 1, 1991	Boeing 737-300, Los Angeles, California
March 22, 1992	Fokker F-28, Flushing, New York

1.17.1 Flight Training Department Personnel

Flight training at USAir is the responsibility of the Director of Flight Training and Standards. The Director is responsible for the administration of pilot and flight engineer qualification and training, and he ensures the continuing competency of the pilots, check pilots and instructors. He reports to the Vice President of Flight Operations and oversees a staff of approximately 300.

The Director in place at the time of the accident was hired by USAir (previously Allegheny Airlines) in January 1978, and he has held several training and management positions within the company. He joined the training department in 1986 as a check airman and was elevated to Flight Manager for the F-100 when the airplane joined the fleet in 1989. In 1991, he was assigned to implement the Crew Resource Management (CRM) and Total Quality Management (TQM) Programs at USAir.

The current Director assumed the position in the latter part of June 1994. Since assuming the position, the Director has made numerous changes to the training department, including the reduction in the number of days that a check pilot conducts training activities, and policy and procedure standardization for the training department and individual aircraft.

The Director stated in testimony that the total pilot training failure rate is approximately 2 percent. He also stated that "2 percent is a healthy failure rate...anything less than 2 percent would be that we're not challenging enough...anything more than 2 percent means that we have a faulty program in place." The results of the USAir rate for unsatisfactory pilot checks was discussed with USAir training personnel, the FAA principal operations inspector (POI), and other management staff. The training personnel acknowledged that the results indicated additional training was being accomplished during proficiency checks, but they stated that this practice was approved by the FAA and was permitted by the company, so long as it was accomplished during the specific time period allotted for the proficiency check.

The reference text in the FAA Inspector's Handbook, FAA Order 8400.10, dated July 28, 1992, states, in part:

> Repeating events. FAR 121.441(e) authorizes check airman to give additional training to airman who fails to satisfactorily complete an event on a check. The additional training must be given prior to repeating the event. Problems have occurred in instances where check airman has merely repeated events until the airman performed these events within tolerances. This practice is not acceptable and is an abuse of training to proficiency.

Additionally, the Inspector's Handbook discusses "Training to Proficiency," and states, in part:

> Training to Proficiency. When a check airman determines that an event is unsatisfactory, the check airman may conduct training and

> repeat the testing of that event. This provision has been made in the interest of fairness and to avoid undue hardship and expense for the airman and operations. Training may not be conducted, however, without recording the failure of these events. The quality control of a training program is accomplished, among other means, by identifying those events on checks which crewmembers fail....
>
> 1. Training and checking cannot be conducted simultaneously. When training is required, the check must be temporarily suspended, training conducted, and then the check resumed.
>
> 2. When training to proficiency is required, the check airman must record the events which were initially failed and in which training was given.
>
> 3. When training to proficiency is conducted and the check is subsequently completed within the original session, the overall grade for the check may be recorded as satisfactory....

The Safety Board interviewed three USAir check airmen in an attempt to gain insight into the training department. The interviews revealed a disparity among the check airmen regarding operational procedures and guidance given to pilots in the various reference manuals.

Two of the three check airmen stated that they "expect" the crew to brief both the visual and ILS approaches. The third check airman stated that "there was nothing in the manual that would require a visual approach to be briefed." He did say, however, that if the pilot had briefed for a visual approach and the weather conditions changed resulting in an ILS approach, he believes the crew would need to conduct an additional briefing.

The three check airmen agreed that in any given situation where the "pilot flying" (PF) was the first officer, he (the first officer) would remain the PF, including a go-around or a missed approach. They did state, however, that this type of information does not exist in writing in any of the pilot reference manuals.

With regard to windshear training and operational procedures in the Douglas DC-9, one check airman stated that he "prefers that the pilot use the flight director" for guidance information during a windshear escape maneuver. According to the USAir DC-9 Pilot Handbook, the use of the flight director for windshear escape guidance is not authorized. Additionally, a second check airman stated that there is no published definition of "maximum power" in any of the pilot reference manuals.

1.17.2 Flight Safety Department

At the time of the accident USAir had a full-time flight safety department that was formally identified as Quality Assurance/Flight Safety. The Director of the office was directly accountable to the Vice President of Flight Operations. The department was comprised of the Director, two full-time check pilots and an administrative support staff.

Through this department, USAir formed a "partnership" with the FAA, the Air Line Pilots Association (ALPA), and USAir management in a "proactive" effort to foster a working relationship and open lines of communication to remedy either current or anticipated problems.

The safety department disseminated safety-related information to pilots through various means, including "Important" information that was communicated directly to pilots via an "E Mail" system, bulletin boards, attachments to flight dispatch papers, and printed safety notices distributed to each pilot's mailbox by the chief pilot's staff. Additional methods of communication with the line pilots are the flight training department and the USAir *Flight Crew View* publication.

As the result of events that were related to this accident and other accidents involving USAir, including the September 8, 1994, B-737 accident near Pittsburgh, Pennsylvania, USAir created a senior level position for safety that reports directly to the Chief Executive Officer of the airline. The responsibilities of this position include oversight of the entire flight safety program at USAir.

1.18 Additional Information

1.18.1 USAir Training and Operating Procedures

1.18.1.1 USAir Flightcrew Training

USAir conducts flightcrew training at its facilities in Pittsburgh, Pennsylvania, Los Angeles, California, and Charlotte, North Carolina. The training programs and facilities encompass all aircraft flown by USAir, to include the B-727, B-737-200, -300, -400, -500, B-757/767, DC-9, MD-80, Fokker F-28, and F-100. The training programs are outlined in the USAir Flight Operations Training Manual (FOTM).

The flight training for USAir pilots is conducted at the simulator facility either in Pittsburgh or Charlotte. The Pittsburgh facility houses DC-9, MD-80, B-727, B-737-200,-300, B-757/767, and F-100 simulators. The Charlotte facility houses the B-727, B-737-200,-300,-400, and F-28 simulators.

The task of standardizing the different pilot groups as a result of the mergers was conducted by a method that was described as "mirror imaging." This method involved selecting a team of check pilots from each of the airlines to develop and implement standardized procedures for the fleet of airplanes. These new procedures were "mirrored" from the airplane procedures that were in use by USAir, and then applied to the fleet. All airplane checklists, flight operations manuals and pilot handbooks were rewritten, and all training sessions, simulator periods, and special meetings were changed to reflect the standardization.

In addition, as part of the standardization process, the pilots from each of the different airlines were not integrated (paired) to fly in the same airplane for approximately 8 months after the mergers, and until the first phase of the mirror imaging program had been completed.

1.18.1.2 USAir Flightcrew Training System

Various training syllabuses have been incorporated into the USAir pilot training program. USAir's FAA-approved training program requires captains to receive, within the preceding 12 months, a proficiency check; and within the preceding 6 months, either a proficiency check or simulator training. First officers are required to receive, within the preceding 24 months, a proficiency check; and within the preceding 12 months, either a proficiency check or simulator training. In addition, first officers may be summoned frequently to participate in Line-Oriented Flight Training (LOFT) provided to the captains.

1.18.1.3 USAir Windshear Training Program

Based on several previous incident/accident investigations, the Safety Board issued safety recommendations to the FAA regarding windshear training information for air carriers. In 1989, the FAA issued an advisory circular (AC) containing a windshear training aid, developed specifically for operators to assist them in the design and implementation of a windshear program. By November of 1989, USAir had flight simulators programmed with FAA-approved windshear profiles. The program was revised in 1990, based on input from the FAA POI.

Windshear training is provided by USAir during basic indoctrination, and in initial and recurrent ground school. The flight portion of the windshear training is conducted during initial, upgrade, transition and recurrent flight training. First officers may only receive one opportunity every 24 months to fly a windshear profile in the simulator.

The ground training focuses on the meteorology of windshear and emphasizes avoidance as a standard practice. This portion of the training uses video tape presentations and written tests to teach recognition, avoidance and recovery techniques. The simulator teaches the pilot to recognize windshear environments using cues from turbulence, airspeed anomalies, simulated air traffic controller reports and the on-board aircraft windshear alerting system.

USAir also uses its pilot-oriented safety publication, *Flight Crew View*, to supplement training on various topics, particularly seasonal topics such as windshear and icing. The edition of *Flight Crew View* that was current at the time of the accident contained a 51 page article regarding windshear, recognition, avoidance and recovery. The article provided specific information regarding cues that would indicate the presence of windshear/microburst activity, such as a "rapid or large airspeed increase, particularly near convective weather conditions...," turbulence, and heavy rain. In addition, the article included a table that charted "Microburst Windshear Probability Guidelines" for use by pilots as a reference guide in determining the presence of windshear. The table indicates, in part, the following:

Presence of Convective Weather Activity Near Intended Flightpath:

Observation	Windshear Probability
Strong wind, blowing dust, tornado features	HIGH
Heavy Precipitation - Observed or Radar	HIGH
Rainshowers	MEDIUM
Onboard Windshear Detection System Alert	HIGH

PIREP of Airspeed Loss or Gain - 15 knots or Greater	HIGH
LLWAS Alert/Wind Velocity Change - 20 knots or Greater	HIGH

The captain testified that he had received his copy of the *Flight Crew View* on the morning of the accident, but that he had not yet had the opportunity to read the publication. However, he also stated that he had read similar articles on the subject of windshear.

The FAA-approved windshear profiles that have been in use at USAir's DC-9 simulator facility in Pittsburgh depict windshear events that occur during various phases of flight. The Safety Board reviewed the profiles and found that at the time of the accident, one scenario, a windshear encounter at 100 feet during the takeoff/climb phase from Charlotte, was most frequently introduced during training. Several pilots characterized the windshear profiles used in the simulator training as readily identifiable and said that they knew when the windshear encounter was about to occur because it always happened during the initial takeoff or final approach phase of flight, and that all of the profiles were preceded by turbulence. The first officer from flight 1016 corroborated this characterization during his testimony and stated that "typically in a simulator you have turbulence associated with an event...and with regard to the accident, we encountered a smooth ride all the way."

The captain and first officer described their perceptions of the windshear training they had received with the company. They stated that they had the opportunity to perform the duties of both the flying and nonflying pilot. However, the Director of Training and Standards stated in his testimony that "right now with the recurrent LOFT program that is almost the captain's ride...so as of this year, it was the captain that was the sole manipulator of the controls...the first officer was doing the seat task function, meaning, in this case, calling out sink rate and altitude." However, he also stated that "during the first officer's proficiency training period [which occurs every 24 months] he [the first officer] is the manipulator [of the controls] in the windshear maneuver."

The Safety Board's review of the USAir Check Airman Handbook revealed that windshear training must be completed at all proficiency training sessions and on all proficiency checks administered in lieu of proficiency training.

1.18.1.4 Windshear Guidance Information

The training section of the USAir DC-9 Pilot's Handbook provides the following information on windshear recognition and recovery:

> Windshear recognition is crucial to making a timely recovery decision. The recommended procedure shall be initiated any time the flightpath is threatened below 1,000 feet agl on takeoff or approach or when a "windshear" or "pull-up" warning occurs. The windshear lights on the panel can aid in early detection of windshear on airplanes so equipped.
>
> NOTE: The following flight procedures must be adhered to when an alert by the windshear detection system is actuated:
>
> An aural windshear warning in conjunction with the flashing red lamp will require a go-around except in the situation when at the pilots' discretion it would be safer to complete the landing; i.e., warning activated close to the runway with flare started and throttles closed.
>
> A flashing amber caution (increasing performance) or steady amber caution (temperature lapse rate) should alert the pilot to the possibility of windshear and should be prepared to execute a G/A if a flashing red should occur.
>
> The guidelines for unacceptable flightpath degradation are as follows:
>
> TAKEOFF/APPROACH: plus/minus 15 knots indicated airspeed
plus/minus 500 FPM vertical speed
plus/minus 5° pitch attitude
>
> APPROACH: plus/minus 1 dot glideslope displacement
Unusual throttle position for a significant period of time.
>
> Again these should be considered as guidelines since exact criteria cannot be established. In every case, it is the responsibility of the pilots flying to assess the situation and use sound judgment in

determining the safest course of action. In certain instances where significant rates of change occur, it may be necessary to initiate recovery before any of the above are exceeded.

If windshear is inadvertently encountered after liftoff or during approach, immediately initiate the recommended recovery technique. If on approach, do not attempt to land. However, if on approach and an increasing performance shear is encountered, a normal go-around, rather than recovery maneuver may be accomplished.

The technique for recovery from a windshear encounter after liftoff or during approach is the same in both cases. This technique is described as follows:

THRUST - Aggressively apply necessary thrust (FIREWALL POWER) to ensure adequate airplane performance. Disengage the autothrottle if necessary. When airplane safety has been ensured, adjust thrust to maintain engine parameters within specified limits.

PITCH - The pitch control technique or recovery from a windshear encounter after liftoff or on approach is as follows:

At a normal pitch rate, increase or decrease pitch attitude as necessary toward an initial target attitude of 15 degrees. The autopilot/flight director should be turned OFF, unless specifically designed for operations in windshear.

Always respect the stick shaker. Use intermittent stick shaker as the upper pitch limit. In severe shear, stick shaker may occur below 15 degrees of pitch attitude.

CAUTION: Continued operation at stick shaker speeds may result in a stalled condition. (emphasis added by company)

If attitude has been limited to less than 15 degrees to stop stick shaker, increase attitude toward 15 degrees as soon as stick shaker stops.

If vertical flightpath or altitude loss is still unacceptable after reaching 15 degrees; further increase pitch attitude smoothly in smali increments.

Control pitch in a smooth, steady manner (in approximately 2 degrees increments) to avoid excessive overshoot/undershoot of desired attitude.

Once the airplane is climbing and ground contact is no longer an immediate concern, airspeed should be increased by cautious reductions in pitch attitude.

CONFIGURATION - Maintain flap and gear position until terrain clearance is assured. Although a small performance increase is available after landing gear retraction, initial performance degradation may occur when landing gear doors open or retraction....

ADDITIONAL CONSIDERATIONS - If the flight director and/or auto-flight systems are not specifically designed for operation in windshear, they may command a pitch attitude change to follow target airspeeds or a fixed pitch attitude regardless of flightpath degradation. This guidance may be in conflict with the proper procedures for windshear recovery. These systems must be disregarded if recovery is required and, time permitting, switched OFF.

Avoid stabilizer trim changes in response to short term windshear-produced airspeed/stick force changes. However, stabilizer trim should be used to trim out stick force due to thrust application.

Throughout the recovery, the pilot not flying should call out vertical flightpath deviations using the barometric altimeter, radio altimeter, or vertical speed indicator, as appropriate.

Rapidly changing winds may cause rapid excursions in pitch and roll with little or no pilot input as well as varying the attitude for stick shaker activation.

Additional information regarding the definition of a windshear, the types of windshear, and the typical weather phenomenon that is associated with windshear is also addressed in the USAir DC-9 Pilot's Handbook, Section 3-51-1.

Also addressed in Section 3-41-1 of the handbook are the operational characteristics and techniques for using the on-board weather radar for detection of weather phenomena and severe turbulence. The handbook states, in part:

> The WXR-700X radar does not have a contour mode; however, red returns are displaying the same level of rainfall as contour. The system is also equipped with turbulence detection that will show areas of rainfall movement which is usually associated with turbulence, and will be depicted in magenta. This will be annunciated as WX+T and is enabled only in the 50 or 25 NM ranges....
>
> While the X-band radar is excellent for detecting storm areas, the radar energy is attenuated by rainfall, the degree of degradation increasing rapidly when precipitation between the storm cell and the radar antenna increases from moderate to heavy. When the aircraft is in an area free of precipitation, the radar is excellent for detecting and evading turbulence, but once in rainfall, its usefulness is diminished.
>
> The PAC Alert annunciation identifies areas of severe attenuation. Should the intervening precipitation be so intense that the signal is attenuated below the minimum discernible signal level, a yellow arc (PAC Alert Bar) is painted at the outermost range marks to indicate azimuth direction where heavy precipitation is encountered [The PAC Alert feature is disabled on USAir's DC-9 fleet].

1.18.1.5 USAir Operating Procedures

The section entitled "Normal Operating Procedures, Landings," in the USAir DC-9 Pilot's Handbook, provides the following guidance to the pilot for the computation of approach speed components:

> ...unless actual conditions are known, i.e., reported windshears or known terrain induced turbulence, it can be considered reasonable

for convenience of operation and reduction of crev· workload to adjust the approach speed by the "1/2 steady-state wind above 20 knots plus all of the gust" values as reported by the tower. Headwind corrections are made for any steady state winds above 20 knots in the forward 180 arc (+ 90 degrees on each side of the runway heading)....The minimum additive to V_{ref} (1.3 V_s) is 5 knots; the maximum additive is 20 knots.

The crew of flight 1016 received several wind reports while on final approach, ranging in value between 8 knots[19] and 21 knots. Using the calculated V_{ref} speed of 121 knots at 40 degrees of flaps, and the maximum reported wind condition of 21 knots (steady-state wind, no reported gusts), the minimum approach speed would have been 126 knots and the maximum 141 knots.

The Safety Board reviewed the operational procedures contained in the USAir DC-9 Pilot's Handbook. The handbook provides the following guidance to the pilot for flight in "severe precipitation:"

With regard to severe precipitation, flightcrews should carefully evaluate all available weather information for the purpose of avoiding unusually severe storms with extreme precipitation. Avoidance of these severe storms is the only measure assured to be effective in preventing exposure to multiple engine damage.

The Safety Board also reviewed the USAir Flight Operations Manual. The manual provided the following guidance to the pilot regarding approach briefings:

An approach briefing shall be completed prior to each approach and landing.

The approach briefing shall consist of the following items, except when conducting visual approaches:

Name of approach
Inbound course and frequency

---

[19]Reported on ATIS information "Yankee."

FAF [final approach fix] altitude
Minimums/Missed Approach Point (MAP) (if applicable)
Initial altitude and heading of missed approach (if applicable)

Additionally, the following shall be briefed for all approaches (if applicable) and special consideration given, such as, but not limited to:

Airport advisory page information
Braking action
Windshear

The guidance to pilots in the DC-9 Pilot's Handbook states that when an ILS approach is being executed, the flightcrew will:

> select the appropriate ILS frequency well in advance of its intended use...the appropriate approach plate should be referred to and all applicable supplementary aids tuned and identified. Outbound procedure turn, and inbound headings and altitudes should be studied. The appropriate minimums and missed approach procedure should be noted....
>
> prior to starting the approach, the "preliminary landing" checklist shall be accomplished and the airplane slowed to the approach speed...also, for a "normal two-engine ILS approach and landing," the pilot will establish V_{ref} plus 5 knots plus wind additives as necessary. Stabilize final approach speed by 800 to 500 feet above the field elevation....
>
> In addition, the nonflying pilot (NFP), regardless of the type of approach being flown, will make audible call-outs of the altitude commencing at 1,000 feet above the airport. The NFP call-out at 500 feet above the airport will include airspeed and sink rate; followed by the "100 feet above minimums" call-out.

The Director of Training and Standards testified regarding flightcrew briefings and said that "the briefing is mandatory," and that standard phraseology should be used.

1.18.1.6 USAir Crew Resource Management (CRM) Program

In 1990, USAir redeveloped its existing CRM program following the issuance of FAA AC-120-51. The previous program was conducted through the Captain Development Program, which was a 2 1/2 day training session that prepared first officers for the process of upgrading to captain.

In 1992, the company altered its flight training and implemented a revised CRM program that was specifically designed to involve both captains and first officers. This change was also performed to facilitate the company's transition to the advanced qualification program (AQP) training.

Under the previous flight training and pilot checking schedule, CRM was accomplished during the captain's annual pilot checking and 6-month proficiency training, while the first officers performed separate biennial proficiency training and checking exercises.

The new training and checking schedule requires that the captain complete CRM training at the time of his/her pilot checking; and the first officer at the time of his/her proficiency training. Six months after both crewmembers have received the aforementioned training, they receive a recurrent LOFT session. This cycle then continues through the remainder of the crewmember's employment.

The USAir CRM program consists of three phases and is administered to all crewmembers, regardless of their participation in the previous program. The first phase is 8.5 hours and introduces the concepts and philosophy of CRM and its importance to flight safety. Among the objectives is the introduction of critical "markers" that have been designated as enhancing flight safety. The absence of any one of these could detract from safety. These "markers" are as follows:

Briefing of Crewmember
Feedback
Inquiry and Assertiveness
Leadership/Followership
Communications/Decision Making
Preparation/Plans/Vigilance
Interpersonal Relationship/Cockpit Climate
Workload/Distraction Avoidance/Situation Awareness
Technical Proficiency and Overall Crew Effectiveness

Also included are the methods of implementation in all phases of flight and active role playing. These sessions were in pilot groups ranging from 12 to 40 participants.

The second phase was designed around the LOFT program and is performed by captains annually and by first officers every 24 months. Each check pilot is trained in the CRM skills by other check pilots (identified as CRM facilitators), who have received special training. The check pilots are trained in both the classroom and in the simulator. Each USAir simulator is equipped with a high resolution video camera, and the entire simulator training session is video taped, including all crewmember conversations. The training session is then debriefed and critiqued by the check pilot and crewmembers.

The third phase is a 1-hour segment devoted to specific topics within the CRM syllabus, and is accomplished during the annual 2-day recurrent training. This phase of the training stresses the importance of all crewmembers, including flight attendants, of participating in the conduct of the flight.

1.18.2 FAA Oversight

The POI assigned to USAir has been in the position for approximately 3 1/2 years. He testified at the Safety Board's public hearing and characterized his relationship with USAir as a proactive partnership, where both parties assist each other and share information. The POI also believed that he had established a "good" working relationship with the Airline Pilots Association (ALPA), the union that represents the USAir pilots.

The POI testified that prior to the accident, he conducted regular surveillance activities at USAir and attempted to educate them regarding FAA issues. He also stated that the company has a "self disclosure" program which has aided his efforts in the identification of areas of noncompliance. The POI said that he believed his responsibility was to "help" USAir comply with the regulations, and to promote aviation safety.

The POI also testified that USAir's previous management structure had "acted as a barrier to standardization." However, because of a new management structure and new personnel, he believes that the standardization issue was no longer an area of concern.

A National Aviation Safety Inspection Program (NASIP) inspection was conducted by a team of 14 FAA inspectors from seven different FAA regions between February 22 and March 19, 1993.

The report summarized the findings of the inspection and identified deficiencies in the various aspects of the company operation. The NASIP identified issues in the area of "Operations," and the following are a summary of those findings:

> The training (Section 1.3) contained seven findings. Several of these relate to inter/intradepartmental lack of communication, such as a lack of understanding of what is contained in the approved training program. Five additional findings, all related to the currency of manuals, were found in the dangerous goods/HAZMAT area and were attributed to inadequate coordination between affected departments.
>
> Crew Qualification (Section 1.4) contained seven findings. These findings were primarily due to a lack of communications between the training department and the recordkeeping department.
>
> Section 1.3.6 - On March 12, 1993, a team member observed a simulator proficiency training period with two captains receiving training. Only one captain was given windshear training, contrary to FOTM 2-4-112, FARs §121.404(b) and §121.427(a)(d)(1). The training was indicated as complete on USAir form OF-32.

USAir acted on this finding and provided the requisite training to the other captain. Also, the check airman that conducted the training was removed from check airman status.

> Section 1.4.1 - A review of the past 90-day source documents revealed that the USAir pilot records' system did not properly document the accomplishment of recurrent windshear training for 51 pilot crewmembers. Reference: FAR §121.427(d)(1), §121.683(a)(1), §121.683(c), §121.433(e).

USAir responded to this finding on April 23, 1993, and stated in a letter to the POI that "there is no requirement by this office to list windshear on the source document in question. Our investigation revealed that windshear is listed as a part of recurrent training and is being documented in accordance with the USAir approved automated recordkeeping system."

1.18.3 Pilot Decision Making

The principal investigator for the human factors research group, based at NASA's Ames Research Center, testified at the Board's public hearing regarding the decision making process by flightcrews. Decision making by a flightcrew member, either individually or collectively, can be a very complex and time consuming process. The NASA investigator stated in her testimony:

> Traditionally decision making has been considered a choice from among a set of [many different] options in whatever kind of environment....The more recent views consider decision making to really include two major components, one being the situation assessment. Before you make a decision in a natural environment, you have to recognize that a problem, a situation exists before a decision is required. So it is up to the participants to notice cues to define what the problem is and identify the options available to them and then make the decision....
>
> Decision making in the cockpit is frequently fraught with time pressure, especially decisions that need to be made close to takeoff or landing. There is a high risk associated with many of those decisions...in the cockpit the crew is doing another task while they are making decisions. They have to fly the plane, they have to perform the standard procedures, the communications, the checklist, and make decisions on top of these other activities...so it's a much higher workload kind of decision making than we usually find in the laboratory....
>
> Another important difference is that decision making in the cockpit is very much supported by guidance. Crews aren't figuring out from scratch what they ought to do in most situations. There are either regulations or procedures or guidelines for what to do under a variety of circumstances.

In the cockpit environment, the decisions of the pilots can be categorized. The captain, while the ultimate authority, is also a member of the team working to identify the problem so that the proper decision can be made and the appropriate action can be taken. According to the NASA investigator:

> Some decisions can be categorized as rule-based decisions. These are cases in which there is very little question about what should be done, but rather it's a matter of whether something should be done. So there's usually a rule that says if condition X occurs, then you carry out response Y....
>
> A case of going around would be clearly a rule base type decision. It's really a go/no go kind of decision in which you've got a bifurcation, you proceed with your general plan. If the conditions are not safe, then you take plan B, which is clearly specified in advance...and what the crew has to do is discern what the conditions are and whether they should take plan A or plan B.

1.18.4 Sensory Illusions

In December of 1990, the Transportation Safety Board of Canada cited spatial disorientation as a probable factor in an accident involving a Fairchild SA-227.[20] The Safety Board also discussed the subject of spatial disorientation in the factual report of its investigation of a DC-8 accident in Swanton, Ohio.[21] The Safety Board stated, in part:

> Errors in the perception of attitude can occur when aircrews are exposed to force environments that differ significantly from those experienced during normal activity on the surface of the earth where the force of gravity is a stable reference and is regarded as the vertical. The acceleration of gravity is the same physical phenomenon as an imposed acceleration, and hence, in certain circumstances, one may not be easily distinguishable from the other. When the imposed acceleration is of short duration, such as the

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[20] Aviation Occurrence Report, Skylink Airlines, Ltd., Fairchild Aircraft Corporation SA227 Metro III C-GSLB, Terrance Airport, British Columbia, 26 September, 1989. Report Number 89H007.

[21] See Aircraft Accident Report--"Air Transport International, Inc., Flight 805, Douglas DC-8-63, N794AL, Loss of Control and Crash, Swanton, Ohio, February 15, 1992" (NTSB/AAR-92/05)

bounce of a car or the motion of a swing, one can separate perceptually the imposed motion from that of gravity. When the imposed acceleration is sustained, however, such as the prolonged acceleration of an aircraft along its flightpath, the human perceptual mechanism is unable to distinguish the imposed acceleration from that of gravity.... Illusions of attitude occur almost exclusively when there are no outside visual references to provide a true horizon....

Additionally, an article entitled "In-flight Spatial Disorientation" in the January/February 1992 issue of *Human Factors and Aviation Medicine* discussed spatial disorientation as follows:

> Maintaining spatial orientation during flight when the outside horizon visual reference is lost requires either orientation instrument displays or automatic stabilization systems. Pilot exposure to linear and angular accelerative forces during loss-of-outside-reference flight produces confusing vestibular and proprioceptor stimulations that result in motion illusions which impair spatial orientation. In-flight sensory spatial orientation cannot be maintained after loss of outside visual horizon references without flight instruments. For orientation in this situation, the pilot must utilize attitude information provided by the cockpit flight displays.[22]
>
> Remember that a high level of flight experience does not produce immunity to spatial disorientation. A pilot can become adapted to in-flight motion conditions, but can still experience sensory illusions that can result in spatial disorientation.[23]

The Safety Board also recognizes that information regarding illusions and spatial disorientation is available to U.S.-certificated pilots in the *Airman's Information Manual* (AIM), AC-61-23B ("Pilot's Handbook of Aeronautical Knowledge") and AC-61-27C ("Instrument Flying Handbook"). The "Instrument Flying Handbook" states, in part:

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[22] Antunano, Melchor J., M. D., and Mohler, Stanley R., M. D., "In-flight Spatial Disorientation." in *Human Factors and Aviation Medicine*, Flight Safety Foundations, Arlington, Virginia, January/February, 1992, p. 2.

[23] Antunano and Mohler, p. 5.

In flight, our motion sensing system may be stimulated by motion of the aircraft alone, or in combination with head and body movement. Unfortunately, the system is not capable of detecting a constant velocity or small changes in velocity. Nor is it capable of distinguishing between centrifugal force and gravity. In addition, the motion sensing system, functioning normally in flight, can produce false sensations. For example, deceleration while turning in one direction, an illusion which can be corrected only by overriding the sensation from the inner ear by adequate outside visual references or by proper reading of flight instruments.[24]

Somatogravic illusion - A rapid acceleration during takeoff excessively stimulates the sensory organs for gravity and linear acceleration, and so creates the illusion of being in a nose-up attitude. The disoriented pilot may push the aircraft into a nose-low or dive attitude....[25]

1.18.5 Air Traffic Control Procedures and Equipment

FAA Order 7110.65H, Air Traffic Control, (hereinafter referred to as the Controller Handbook) contains procedures to be followed by ATC controllers. Paragraph 1.1 of the Controller Handbook states:

This order prescribes air traffic control procedures and phraseology for use by personnel providing air traffic control services. Controllers are required to be familiar with the provisions of this handbook that pertain to their operational responsibilities and to exercise their best judgment if they encounter situations that are not covered in it.

The Controller Handbook also establishes duty priorities for the controller. Paragraph 2-2 states:

a. Give first priority to separating aircraft and issuing safety advisories as required in this handbook. Good judgment shall

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[24]Instrument Flying Handbook, AC 60-27C, U.S. Department of Transportation, Federal Aviation Administration, U.S. Government Printing Office, Washington, D.C. 1980 Page 9.

[25]Instrument Flying Handbook, AC 60-27C, Page 10.

be used in prioritizing all other provisions of this handbook, based on the requirements of the situation a' hand.

b. Provide additional services to the extent possible, contingent only upon higher priority duties and other factors, including limitations of radar, volume of traffic, frequency congestion, and workload.

Paragraph 2-2 is annotated very extensively, and paragraph 2-2a states, in part, that given the variables involved, it is not always possible to develop a list of priorities that would apply uniformly in any given circumstance. However, it urges the controller to use his/her best judgment in prioritizing tasks and states "that action which is most critical from a safety standpoint is performed first."

Paragraph 2-2b states, in part, that the primary purpose of the ATC system is to prevent collisions between aircraft operating in the system and to organize and expedite the flow of traffic. In addition to its primary purpose, the system can provide additional services (with certain limitations) as previously cited. The system is further limited by the pure physical inability to scan and detect the situations under this category. The note concludes "The provision of additional services is not optional on the part of the controller, but rather is required when the work situation permits."

1.18.5.1 Dissemination of Weather Information by ATC Personnel

The three ATC positions that were responsible for providing air traffic services to USAir flight 1016 upon initial contact with the Charlotte ATC tower were: the Arrival Radar West (ARW), the Final Radar West (FRW) and the Local Controller West (LCW). The first two positions are located in the TRACON, and the third one was in the tower. The LCW controller was responsible for the separation of aircraft (arriving and departing) from the final approach fix inbound to runway 18R/36L.

The Safety Board examined the testimony of the FRW and LCW controllers to determine the depth of weather information communicated to the crew of flight 1016. The Safety Board found that the FRW controller had his ASR-9 radar display set for precipitation intensity levels 1 and 3 while he was providing ATC services to USAir flight 1016. The controller testified that when flight 1016 initiated voice contact with him, the only "weather" he observed on his radar display was in the vicinity of the approach end of runway 23. However, the controller also testified that shortly after communications had been established, and flight 1016 was at a point that he characterized as "midfield downwind," he observed additional "weather" developing in the area of 18R, that "just popped up as a level 3." The controller said that the level 3 activity remained in the area for approximately 30 minutes, and he did not report the level of precipitation to the crew of flight 1016, but rather advised them of "some rain."

The LCW controller testified that he observed "three cells" on his ASR-9 radar display shortly before the accident. Two of the cells were south of the airport, and the third appeared to be northeast, between the approach ends of runways 23 and 18L. He also stated that he could not distinguish the level intensity of the cell that was between the two runways because it was over the radar antenna. He also could not recall the VIP levels selected or the altitude filter limits selected on his D-BRITE [digital-bright radar indicator tower equipment] display at the time of the accident.

The Safety Board reviewed the FAA's policies and procedures regarding the issuance of weather information to flightcrews as depicted on ASR-9 radar by controllers. In a written response from the FAA Manager, Air Traffic Investigations staff, ATH-10, the "FAA policy regarding ATC issuance of weather information is in Order 7110.65H, paragraph 2-113...." The manager also stated in his response:

> Order 7110.65H provides for ATC issuance of weather information under certain limited circumstances. When weather information is issued pursuant to the guidance provided in paragraph 2-113, ATC specialists should use certain pre-established phraseology. Examples of scenarios in which the issuance of weather information is recommended are contained in paragraph 2-113. Significantly, the recommendation that weather information be issued and the use of certain prescribed phraseology does not make the issuance of weather information mandatory. Mandatory requirements in Order 7110.65H are preceded by the word "shall."

The Air Traffic Control Handbook, Order 7110.65H, Chapter 2, General Control, Section 6, Weather Information, paragraph 2-113, Weather and Chaff Services, states, in part:

> Issue pertinent information on observed/reported weather of chaff areas. Provide radar navigational guidance and/or approve deviations around weather or chaff areas when requested by pilot...2-113c Example 1. Level five weather echo between eleven o'clock and one o'clock, one zero miles. Moving east at two zero knots, top flight level three niner zero. Example 2. Level four weather echo between ten o'clock and two o'clock one five miles. Weather area is two five miles in diameter....

The automated terminal information service (ATIS) provides pilots of arriving and departing aircraft, via an air traffic controller voice recording that is repeatedly broadcast over a discrete radio frequency, advanced noncontrol airport and terminal area operational and meteorological information. The TRACON flight data controller is responsible for the preparation of the arrival ATIS. ATIS broadcast information "Yankee" that the crew of flight 1016 received upon arrival in the Charlotte area did not indicate that rain, rainshowers or thunderstorms were present in the terminal area. Additionally, ATIS information "Zulu," which included remarks about a thunderstorm and rainshower, was broadcast after the crew of flight 1016 had contacted the LCW controller. The crew would not have been expected to obtain ATIS "Zulu" because they were inside the outer marker (SOPHE) about 2 minutes from touchdown.

Over the course of several minutes, the weather conditions had continued to deteriorate at Charlotte when flight 1016 was inbound on the final approach course. A second special weather observation was taken shortly after ATIS "Zulu" was broadcast, and, at 1840, the tower visibility had decreased to 1 mile, and "heavy" rain was falling on the airport. The inherent limits of the ATIS do not permit timely updated weather information broadcasts, especially in rapidly changing meteorological conditions.

About 1836, the tower supervisor remarked to the Radar Coordinator Arrival (RCA) that the airport was going to "IMC[26] here pretty quickly." The tower supervisor testified that about 1840, he determined that the visibility had decreased to 1 mile, and he announced in a "loud voice" to the controllers in the tower cab his visibility observation. At 1841, the RVR at the touchdown zone of runway 18R had decreased to about 3,500 feet. The information regarding the deteriorating weather

[26] IMC - Instrument Meteorological Conditions.

conditions over the airport, the reduction in visibility, and the decreasing RVR values for runway 18R that had been observed in the 4 minutes prior to the accident had not been transmitted by any ATC personnel to the crew of flight 1016. (See plots of RVR in appendix C).

Paragraph 2-113 of the Controllers Handbook requires the controller to issue pertinent information about observed or reported weather areas, and to provide radar navigational guidance around such areas when requested by pilots. The handbook further states that controllers cannot provide precipitation intensity information unless the intensity level "is determined by NWS radar equipment or ASR-9 radar equipment."

Also, the Controllers Handbook limits the type of weather information a terminal area controller can disseminate. The handbook states, in part, that the controller may disseminate general weather information, such as "large breaks in the overcast," "visibility lowering to the south," or similar statements that do not include specific values. In addition "any elements derived directly from instruments, pilots, or radar may be transmitted to a pilot or other ATC facilities without consulting the weather reporting station." Specific values, such as ceiling and visibility, can be transmitted only if they are obtained from an official observer or from a weather report issued by the weather station or a controller certified to make the observation.

At 1836:55, the FRW controller radioed flight 1016 and said "I'll tell you what USAir ten sixteen they got some rain just south of the field might be a little bit coming off north just expect the ILS now...." The FRW controller stated that his amendment to flight 1016's approach, from a visual to the ILS, was based on his observation of the precipitation detected by the ASR-9.

The tower supervisor testified that he made a visibility observation at the request of the NWS because of heavy rainfall over the airport. He also testified that at the time the visibility decreased to 1 mile, he made an announcement "in a loud voice" in the tower cab to alert the controllers of the reduction in visibility. However, the supervisor stated that although he did not get a specific acknowledgment from any of the controllers, he "fully expected that everyone had heard" his announcement. The LCW controller testified that he did not hear the supervisor's announcement that the visibility had decreased to 1 mile.

1.18.5.2 Charlotte ATC Tower Standard Operating Procedures

On October 12, 1994, the Safety Board deposed several people from the Charlotte ATC tower, including supervisors and managers. In addition, the representative of the National Air Traffic Controllers Association (NATCA) from the Charlotte facility, and an FAA ATC specialist from the Quality Assurance Division, were also deposed regarding the Charlotte ATC tower Order 7220.4, Standard Operating Procedures (SOP). During the investigation, the Board discovered that three different versions of CLT ATC tower Order 7220.4, Section 1, Position Duties and Responsibilities, Chapter 4, Controller-In-Charge/Cab Coordinator, Paragraph 4-10f, were in circulation in the various SOP manuals located in the Charlotte facility.

The plans and procedures specialist (PPS) stated that it was her responsibility to maintain the ATC tower Order 7220.4 manual with approved revisions, to insert the approved revisions in the other copies of the manual located in the facility, and to verify that all applicable personnel were informed of changes made to the manuals. The PPS and other tower personnel who were deposed, with the exception of the NATCA representative, testified that the version of Paragraph 4-10f, dated November 11, 1993, and current at the time of the accident, was as follows:

> Determine the prevailing visibility when required and ensure that visibility is relayed to the National Weather Service.

Changes to this procedure were implemented by the facility management as a result of the accident, and those changes were reflected in the revised version of Paragraph 4-10f, including the words "...and inform each operational position in the tower of the visibility. (NOTE: A "blanket" broadcast is not acceptable)."

During the course of additional investigative activities, the Safety Board was made aware of the revision to Chapter 4 of the Order; however, the revision had not been implemented per the SOP. Further investigation into the policies and procedures revealed that the revised version of Paragraph 4-10f had been implemented and was inserted into the Order manual by management without the facility personnel being briefed about the change, and without the proper method of revising the manual page being used.

The Safety Board obtained copies of the three versions of the procedures and found that a vertical line, typically used to denote the changed information, was not present next to Paragraph 4-10f; and that the new effective date, signifying that the procedure was the new SOP, had not been changed from November 11, 1993. The Safety Board also found that although this document had been reviewed by three individuals, including two managers, the editorial omission and incorrect date were not identified and corrected. The PPS stated that the implementation of this revised procedure was accelerated because the Charlotte facility was being evaluated by an FAA inspection team, and that facility management wanted the procedure in effect prior to the team's arrival.

In her testimony, the PPS stated that the continued maintenance of the Order manual was her responsibility. The Safety Board found, however, that in the absence of the PPS at the Charlotte facility, there were no written procedures for other personnel to reference about the steps necessary to initiate a revision to Order 7220.4, or the levels of supervisory and/or management review to approve the revision for implementation, and no approved methods to verify the notification of facility personnel of the revision. The Safety Board did find that there are some FAA ATC facilities that have developed their own in-house written procedures addressing the maintenance of the facility manual and the dissemination of information, but that there are no standardized procedures in effect for all FAA facilities.

1.18.5.3 Charlotte ATC Tower Equipment

The Charlotte/Douglas ATC tower includes a tower cab and the TRACON. The facility is classified as Level V, and provides ATC service 24 hours a day for CLT and the surrounding metropolitan area.

The ATC facility uses an airport surveillance radar system (ASR-9) that is augmented with automated radar tracking system (ARTS) IIIA computer tracking. Aircraft generate primary or secondary (beacon) targets that are displayed on the plan view display (PVD) by computer-generated symbols and alphanumeric characters depicting aircraft location, identification, ground speed, and flight plan data.

The control tower has eight positions of operation that may be combined to meet daily and hourly traffic demands. The tower cab is equipped with the following equipment: ATIS, two D-BRITE radar systems, which reproduce the

ASR display, two LLWAS display indicators, System Atlanta Information Data (SAID) monitors, integrated communications switching system (ICSS), ILS equipment, field lighting panels, digital altimeter displays, digital clock displays, RVR indicators, and various telephone and status displays.

1.18.5.4 Airport Surveillance Radar-9 (ASR-9)

The ASR-9 radar system at the airport was manufactured by the Westinghouse Electric Corporation and commissioned on May 21, 1991. This ASR-9 radar system is one of the 134 total systems that has either been, or is proposed to be, commissioned at major airports throughout the United States. As of August 10, 1994, there were 85 operational ASR-9 systems.

The ASR-9 radar is capable of displaying precipitation intensities at the equivalent of the NWS VIP levels 1 through 6. The previous radar systems, the ASR-7 and ASR-8, were capable of detecting precipitation but could not accurately determine the intensity levels. The "ASR-9 Weather Channel Test Report," dated May 3, 1989, and prepared by MIT's Lincoln Laboratory for the FAA, states, in part:

> The ASR-9 is a next generation Airport Surveillance Radar...in contrast to earlier FAA radars, the ASR-9 will provide air traffic controllers with quantitative precipitation reflectivity information without the biases introduced by moving target indicator (MTI) circuits or circular polarization. It features robust ground clutter suppression algorithms, spatial and temporal smoothing of the weather maps and range dependent compensation for reflectivity biases introduced by the broad, cosecant-squared elevation antenna pattern of ASRs....The ASR-9 weather channel is designed to provide ATC personnel with an accurate, quantified, clutter-free representation of the precipitation field. Its weather products are generated by either a two-level or six-level weather processor. The ASR-9 weather channel allows ATC personnel to select and display any two of the six NWS levels. The ASR-9 is reliable to within one level as reported by the NWS. The levels are defined in terms of reflectivity. For example: Level 1 indicates "light" precipitation; Level 2 indicates "moderate precipitation; Level 3 indicates "heavy" precipitation; Level 4 indicates "very heavy" precipitation; Level 5

> indicates "intense" precipitation; Level 6 indicates "extreme" precipitation such as hail.
>
> The ASR-9 antenna rotates at 12.5 rotations per minute and utilizes range-azimuth selectable dual receiving beams ("high" and "low")....The wide elevation beam width and rapid scan rate are dictated by the ASR-9's primary function of detecting and resolving rapidly moving aircraft at altitudes up to 35,000 feet, over a coverage area radially of 60 nautical miles.

Maintenance information on the ASR-9, per FAA Order 6310.19, dated July 24, 1991, states, in part:

> The ASR-9 incorporates a dedicated receiver to detect weather returns during heavy weather conditions....The data is then applied to the six-level weather detector where the weather is classified into six levels of reflective intensity. The weather channel utilizes the NWS standard reflectivity levels for the determination of the six levels of weather. The weather processor does not possess processing for determining the exact nature of the meteorological phenomena producing these weather levels. Consequently, any anomalous propagation which produces these same reflectivity levels will be categorized and displayed as weather. To obtain an accurate assessment of its nature the displayed weather should be confirmed with the NWS.

According to the ASR-9 team leader from the FAA's National Data Communications Systems Engineering Division:

> Terminal radar antennas are typically designed to provide a uniform high gain fan beam pattern in a shape that approximates a wedge of a pie turned on its side. There is a loss of radar coverage known as the "cone of silence" over the radar antenna. The cone increases with altitude. Radars do not begin to "listen" for returns right away. For about 1/8 to 3/16 of a mile in radius around the radar site returns are not processed. Hence there is a narrow cylinder, extending vertically above the radar site, which won't process anything. The fan beam pattern does not extend to the full 90 degrees overhead because it would cause an inefficient gain

factor to be built into the antenna and the objects overhead would create a 'ring around' video condition at ranges near the site. Radar systems are placed in the environment at a location selected to look at objects that are required to be detected. The radar site selection is based on the knowledge of the antenna's detection envelope, what needs to be seen, and in what directions. Needing to look directly overhead would indicate a poor site selection and is totally illogical to have such a requirement for one radar site. The FAA's secondary beacon radar systems provide that information for targets equipped with transponders. It should be noted that these pencil beam systems also do not look directly overhead. It is an illogical need.

Conversely, an ASR-9 expert from MIT's Lincoln Laboratory testified at the Safety Board's public hearing on the accident and discussed the ASR-9 radar and its operational limitations. He stated that while there are limitations for any radar system, including the ASR-9, if a weather event with a VIP level of 5 or 6 did occur directly overhead the radar antenna of the ASR-9, the event would overcome the weather filters and it would display precipitation. In addition, Lincoln Laboratory performed a study of the weather events in the Charlotte area at the time of the accident. The results of that study were summarized in testimony at the public hearing, and the following findings were revealed:

> At this time, 12 or 13 minutes prior to the accident, the ASR-9 would have been painting basically a level 1, or at most level 2 cell extending up toward the airport from the south...moving ahead to 1835...our vertical cross-section now along an east-west plane shows this core of red extending down into the ASR-9 beam...beginning at 1841, just prior to the accident, you continue to have the heavy precipitation falling...the ASR-9 should have been painting a level 4 -- level 3 -- level 4 cell, more or less centered on the west side of the airport at this time.

On July 3, 1994, the airport surveillance radar (ASR), including the weather channel, the air traffic control radar beacon system (ATCRB), the multichannel recorder (MCR), the digital altimeter setting indicator (DASI), the ATIS, ARTS, LLWAS, RVR (touchdown, midfield, rollout) systems, the ILS glideslope and localizer equipment, the medium intensity approach lighting system with runway alignment indicator lights (MALSR), and the middle and outer markers, were all recertified in accordance with FAA directives and were determined to be within established standards and tolerances.

1.18.6 Windshear Information

1.18.6.1 General History

Since the first days of flight, rapidly varying winds, especially those near the ground, have plagued aviation. Only in the past 25 years have aviation weather experts been able to perform extensive and comprehensive studies of the meteorological phenomenon known as "windshear." Windshear has been identified as an extreme hazard to flight safety, and is most dangerous to any aircraft, regardless of size or type, during the takeoff and landing phases of flight.

Windshear has been characterized in many different ways; however, the FAA described windshear in its Advisory Circular (AC) 00-50A as "a change in wind direction and/or speed in a very short distance in the atmosphere. Under certain conditions, the atmosphere is capable of producing some dramatic shears very close to the ground...." One of the most recognized sources of intense windshear is the thunderstorm that produces the convective microburst.

A microburst is defined as a "precipitation-induced downdraft, which, in turn, produces an outflow when the downdraft reaches the earth's surface....All microburst outflows have a total horizontal extent less than 2.2 nautical miles; all similar flows that are larger are termed macrobursts."[27]

The hazards inherently dangerous to flight were demonstrated in two major accidents and one incident in the recent past. The first occurred on July 9, 1982, at Kenner, Louisiana, when a Pan American World Airways B-727 crashed after encountering a microburst shortly after takeoff. The Safety Board determined that the probable cause of the accident was:

> the airplane's encounter during liftoff and initial climb phase of flight with a microburst-induced windshear which imposed a downdraft and decreasing headwind, the effects of which the pilot

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[27]*Windshear Training Aid*, Department of Transportation/FAA, Volume 2, Feb. 1987.

would have had difficulty recognizing and reacting to in time for the airplane's descent to be arrested before its impact with trees.[28]

The incident occurred on May 31, 1984, at Denver, Colorado, when a United Airlines B-727 struck the localizer antenna 1,074 feet beyond the departure end of runway 35L after encountering a microburst during takeoff. The Safety Board determined that the probable cause of the accident was:

> an encounter with severe windshear from microburst activity following the captain's decision to takeoff under meteorological conditions conducive to severe windshear. Factors which influenced his decision making include: 1) the limitations of the low level windshear alert system to provide readily usable shear information, and the incorrect terminology used by the controller in reporting this information; 2) the captain's erroneous assessment of a windshear report from a turboprop airplane and the fact that he did not receive a windshear report from a departing airplane similar to his airplane because of congestion on the air traffic control radio frequency; 3) successful takeoffs made by several other air carrier airplanes in sequence; 4) the captain's previous experience operating successfully at Denver under windshear conditions.[29]

The second accident occurred on August 2, 1985, at Dallas/Ft. Worth International Airport, Texas, when a Delta Air Lines Lockheed L-1011 with 163 persons aboard crashed on approach to 17L, after passing through the rain shaft beneath a thunderstorm and encountering a microburst. The Safety Board determined that the probable causes of that accident were:

> the flightcrew's decision to initiate and continue the approach into a cumulonimbus cloud which they observed to contain visible lightning; the lack of specific guidelines, procedures, and training for avoiding and escaping from low-altitude windshear; and the lack of definitive, real-time windshear hazard information. This resulted in the aircraft's encounter at low altitude with a microburst-induced,

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[28] See footnote Number 15.

[29] Aircraft Accident Report--"United Airlines Flight 663, Boeing 727-222, N7647U, Denver, Colorado, May 31, 1984" (NTSB/AAR-85/05)

> severe windshear from a rapidly developing thunderstorm located on the final approach course.[30]

The investigation of the aforementioned windshear-related accidents and incident, and the study of numerous other windshear-related events previous to these, prompted the FAA and other government and industry organizations to continue extensive research and development into operational procedures and detection equipment that could be used by meteorologists, air traffic controllers, and pilots to detect and avoid areas of windshear. Since the research into windshear began, several positive actions have occurred: 1) air carrier pilot training programs have been developed and updated to enhance flightcrew awareness and recognition of the hazard; 2) simulator-based training programs have been improved to effectively demonstrate and evaluate flightcrew performance; and 3) operational techniques have been developed and improved to provide flightcrews with methods of escaping from encounters with windshear.

In 1985, the FAA contracted with the Boeing Commercial Airplane Company to develop a universal training aid that specifically addressed flight in windshear conditions. The research conducted, and the methods demonstrated and recommended, were based on input from several aircraft manufacturers, commercial air carriers, and meteorological consultants. Thus, in February 1987, the *Windshear Training Aid* was published and distributed throughout the aviation industry; and it eventually became the foundation for many of the windshear training programs currently in use at the commercial air carriers in the United States

The following information about windshear is excerpted from various sections of the *Windshear Training Aid*:

> In most windshear situations, the vertical component is usually small, especially near the ground, because it is constrained by the presence of the earth's surface. However, the vertical component can be extreme at higher altitudes, such as in the center of a severe thunderstorm near 25,000 feet agl, where the updraft/downdraft component can sometimes exceed 100 mph. One exception to this general rule occurs in rather complex flows associated with convective microbursts, where horizontal roll vortices (which

[30] See footnote Number 12.

appear as a circular, doughnut shaped tornado) may result in strong, short-lived, small-scale downdrafts and updrafts.

The lateral variation of the wind along the flightpath may be quite significant....The headwind/tailwind component is the most serious problem in windshear. Rapid variations in the headwind/tailwind componenis results in serious performance changes for the aircraft....

Another important aspect of windshear pertains to the space/time scale length in which the wind change occurs. If the changing wind happens over a distance of 10 miles, the change is so gradual that the rate of change of the wind is small...when the wind changes over a very short distance, say 300 feet, the abrupt change can cause turbulence or bumpiness....

Windshear...is a changing wind along the flightpath of the aircraft, on a space/time scale of approximately 5,000 to 12,000 feet (20 to 40 seconds of flight time). Formally, any change of airspeed equal to or greater than 15 knots is considered a severe windshear....

The air mass thunderstorm develops from localized heating at the earth's surface....Air mass thunderstorms can produce strong outflows. The structure of a typical thunderstorm cell produces a gust front cold outflow. This additional feature is a direct consequence of the outrush of rain-cooled air associated with the mature and dissipating stages of the thunderstorm cell....

Most thunderstorms are about 5 to 10 miles in diameter at the earth's surface, with some of the more severe storms nearly 30 miles in diameter. The updraft/downdraft diameters range from 1 to 5 miles, in extremely severe thunderstorm cases. In addition to the scale of the vertical flows, the gust front may extend up to or more than 30 N. M. from the thunderstorm, and in some circumstances, may have an along-front length of 50 to 100 miles....In the terminal area, avoid thunderstorms by no less than 3 nautical miles.

...horizontal vortices [associated with microbursts] may contain powerful updrafts in addition to downdrafts, which may have the potential to cause very rapid airspeed and angle-of-attack changes to penetrating aircraft...if an aircraft passes from a downdraft to an updraft, it will experience an increase in the angle of attack. If a high angle of attack exists prior to encountering the updraft, the stall angle of attack conceivably can be exceeded as the aircraft enters the vortex-induced updraft...another important aspect for an airplane which penetrates a microburst is an airspeed increase as the aircraft first encounters the headwind outflow. This is then followed by a downdraft, and finally a tailwind, as the aircraft exits the microburst. The airspeed increase upon entry into the microburst can be very misleading, perhaps causing the pilot to believe he/she is in an energy-increasing shear. This false sense of security may lead the pilot to pitch down and power back to regain the glideslope, thus creating a serious situation when the pilot subsequently enters the downdraft and tailwind to follow. This headwind increase situation is particularly prevalent in approach-to-landing cases....

Years of research indicate that microbursts can occur in both heavy rain associated with thunderstorms and in much lighter precipitation. All microbursts are directly related to the precipitation process in some way. When a thunderstorm begins to form precipitation in the mid levels of the storm (20,000 feet agl), the loading of this precipitation (or simply the weight of the water mass) is too much to hold, and ice, snow crystals, hail, and rain suddenly rush downward. The associated cold air causes cooling of the precipitation shaft. This air is colder than its environment and it sinks toward the ground, thus forming the downdraft...microbursts imbedded in heavy rain associated with thunderstorms may be more common than previously thought. There is some indication that perhaps one in 20 thunderstorms (5 percent) may produce a microburst...pilots must use extreme caution in penetrating heavy rain in thunderstorm conditions during approach and takeoff....

Airspeed variations develop more slowly with a vertical shear than a headwind/tailwind shear. Airspeed changes in a vertical shear arise indirectly through change in aerodynamic forces.

The research and development that has been underway for more than 25 years has resulted in many tangible benefits, but there are still more to be achieved. Currently, the only operational windshear detection system in use on a large scale is the LLWAS. The limitations of the LLWAS system were acknowledged during the early stages of its development and use; thus, the system was recognized as an interim measure until more sophisticated equipment could be developed and made operational. Today more elaborate equipment has been developed (Doppler NEXRAD) to provide both the meteorologists and the controllers (Terminal Doppler Weather Radar, ASR-9) with the ability to forecast and identify, with almost 100 percent accuracy, areas of microburst windshear activity. Unfortunately, due to several problems, including the inability to acquire land for radar sites, funding, and substandard equipment that affects reliability, the process of installing and commissioning the TDWR and ASR-9 equipment has been slow and, in some cases, nonexistent.

1.18.6.2 Terminal Doppler Weather Radar (TDWR)

TDWR is one of the next "microburst detection" systems scheduled to be installed at airports around the United States. The radar utilizes a highly focused beam and Doppler technology to map the winds and precipitation reflectivity of the surrounding atmosphere. The system will update the near-surface winds once per minute and will perform a full-scale vertical scan of the area in 5 minutes. The TDWR is considered to be "almost" 100 percent reliable in its detection capabilities.

Currently, the FAA plans to install the TDWR system at 47 airports, including CLT. Originally, the installation of these systems was to have been completed by December 1995, but acquisition of land by the FAA has been difficult, thus prolonging the process. The Safety Board found that CLT was the fifth U.S. airport selected to be equipped with the TDWR and that the installation was to be completed by March 1993. However, the FAA was unable to acquire the original land site selected due to a dispute with the owner regarding the cost of the property. This resulted in the delay of the installation; thus, at the time of the accident, CLT had been moved down the schedule to the 38th position.

The accident identified the problems and issues that have plagued the FAA and the TDWR project. An FAA representative testified at the Safety Board's public hearing that they were unable to resolve the problems and acquire the necessary land; thus, the U.S. Congress became involved in the process. In

September 1994, the FAA was mandated by the Congress to have the TDWR system installed and operational at CLT by the end of 1995.

1.18.6.3 Future Windshear Detection Equipment

Ground-Based "Look Ahead" Radar.--Over the past decade, numerous enhancements to ground-based radar technology (Doppler Radar) have made it possible to detect, with a very high confidence level, microburst and windshear activity. Also, the development of airborne windshear detection equipment has provided flightcrews with a "real time" alerting system that detects and alerts a flightcrew of an impending encounter with a windshear. While this equipment has proven valuable in reducing the potentially disastrous effects of a windshear, research and development are currently underway on a new radar system that can "look ahead" and predict when and where a microburst event will occur.

The ability of the current ground-based system (TDWR) has been proven to protect against low altitude windshear encounters; however, the system is dependent on the surface outflow of the moisture-laden downdraft typically associated with the microburst. The newly developed "look-ahead" radar system is designed to detect, locate and measure the movement of microburst downdrafts several hundred feet above the ground, before the outflow winds (which produce windshear) occur. The radar system determines the downdraft velocity by measuring the radial wind velocity aloft, using six antenna beam pairs that "look" at six different elevations of the weather event. The velocity measurements are determined at a minimum of two separate altitudes, When a microburst downdraft region is identified, the velocity gradients are used to predict ground level microburst windshear velocities, the time of the outflow winds, and the location of the event. Unlike the conventional radar systems that need the moisture all the way to the ground in the downdraft for reflectivity, the new look-ahead systems are able to detect "dry" microbursts by detecting the moisture at a higher elevation, measuring the velocity and predicting the area of the microburst event. This type of system is capable of providing an alert of between 2 and 5 minutes before the microburst event occurs. Thus, pilots are able to redirect their flightpath away from the microburst area before an encounter.

Airborne Systems.--The FAA and NASA are engaged in a joint project that has identified a predictive windshear sensor system that can provide flightcrews with a warning up to 30 seconds before they encounter a windshear event.

NASA installed and flight tested three types of sensor systems and found that a modified weather Doppler provided the most consistent windshear detection with a longer range capability. This system consistently provided a 20-to 40-second warning before the airplane encountered the windshear condition. Conventional windshear warning systems currently installed on transport category airplanes are reactive by design and only detect windshear after the airplane has encountered the event. The airborne look-ahead system only scans an area within approximately 3 miles of the airplane, and it detects movement of the moisture in the descending shaft of air in a microburst.

This type of windshear warning system would alert the pilot that a meteorological condition exists ahead of the airplane that is capable of producing a windshear. The system would also provide the pilot with sufficient time to execute a windshear escape maneuver.

2. ANALYSIS

2.1 General

The flightcrew was properly certificated, and each crewmember had received the training and off-duty time prescribed by FAA regulations. There was no evidence of any preexisting medical or physiological condition that might have affected the flightcrew's performance.

The air traffic controllers on duty in the CLT tower at the time of the accident were properly certificated as full performance level controllers. Their performance is discussed later in this report.

The airplane was certificated, equipped and maintained in accordance with Federal regulations and approved procedures. There was no evidence of mechanical malfunctions or failures of the airplane structures, flight control systems, or powerplants that contributed to the accident.

However, the on-board windshear warning system that is designed to alert the flightcrew that they are encountering a microburst windshear did not activate during the accident sequence for some unknown reason(s). A study of the windshear warning system and data from flight 1016 revealed that the warning should have activated 3 to 4 seconds before impact. Possible reasons for the nonactivation include an anomaly in the input parameter calibrations and/or the dynamics of the air mass. The study also revealed that the warning system should have activated even earlier had it not been for a design feature in the software that desensitizes the warning system whenever the flaps are in transition, thus reducing nuisance warnings. Data revealed that the wing flaps were retracting from 40 degrees to 15 degrees (about a 12-second cycle) when the windshear was encountered. It was determined that if the desensitizing feature had not been incorporated, the warning system would have activated approximately 8 to 9 seconds prior to ground impact. The significance of the lack of windshear warning to the flightcrew will be discussed in the operational factors portion of this report. Additionally, the Safety Board addressed the nonactivation of the windshear warning system in several safety recommendations issued to the FAA in November 1994.

The accident occurred when the airplane descended into the ground after the flightcrew attempted a go-around on final approach to runway 18R at CLT.

Based on the evidence, the analysis of this accident is directed at the meteorological conditions, airplane performance, air traffic control services, and the flightcrew performance. Additionally, the analysis examined the management and oversight factors related to the circumstances of the accident.

2.2 Meteorological Factors

2.2.1 General

The Weather Service Specialist (weather observer) at the Charlotte NWS office made and disseminated, both locally and via telephone, surface weather observations in a timely and appropriate manner. As far as can be determined, the actions of the Weather Service Specialist during the afternoon and evening of the accident were substantially in compliance with NWS procedures and guidelines.

The actions of the Center Weather Service Unit (CWSU) meteorologist during the afternoon and evening of July 2 were adequate. He was attentive to the significant weather conditions occurring in the Atlanta airspace and made the appropriate issuances to FAA facilities. However, the Safety Board believes that the meteorologist may have been at a disadvantage in his efforts to Met Watch the northern area of the Atlanta airspace because of the unavailability of the CAE WSR-88D data for the Charlotte area.

The Safety Board believes that if the meteorologist had been able to access the CAE WSR-88D data, it would have provided a high resolution depiction of the weather conditions in the Charlotte area. The data, if available, would have shown the development of the weather cell near the airport about 19 minutes before the accident, and could have been transmitted to the Charlotte TRACON, ATC tower, and flightcrews.

Testimony by the Charlotte tower supervisor indicated that verbal issuances regarding thunderstorms received from the Atlanta CWSU meteorologist are typically noted on ATIS and forwarded to pilots in this manner. The Safety Board is concerned that there are no requirements for a controller to provide CWSU information directly to pilots. While it is not possible for the Safety Board to know what actions the crew of USAir 1016 would have taken given an advisory of a Video Integrator Processor (VIP) level 3, 5 or 6 echo near the airport, the Board does believe that this critical weather information might have influenced the flightcrew's decision regarding the approach at Charlotte.

Additionally, the Safety Board believes that the CWSU is a valuable program and a necessary part of the National Airspace System. However, the FAA and NWS must reevaluate the total program to improve the reporting system. The Safety Board is concerned that, in the case of the Atlanta CWSU meteorologist, it may not be possible for one person to monitor 100,000 square miles of airspace for significant weather phenomena and to make timely issuances to the affected ATC facilities. Given that the CWSU meteorologist is required to make the appropriate advisories whenever a thunderstorm is detected as defined by the Service NWS, thunderstorms imply severe or greater turbulence, severe icing, and low level windshear, thus every thunderstorm can be considered potentially hazardous. The Safety Board believes that the constant attention necessary to monitor a very severe thunderstorm could possibly overwhelm the CWSU meteorologist, especially on days when numerous thunderstorms are occurring in the airspace. As the CWSU meteorologist stated at the Safety Board's public hearing on this accident, "it's more than one person can handle."

The Safety Board examined the performance capabilities of the LLWAS at Charlotte and the possible effect it had on the accident. While the Safety Board realizes the system configuration at the time of the accident may have been susceptible to degraded performance due to sheltering of the LLWAS wind sensors by obstructions, the Safety Board believes there was no degradation in the performance during the windshear event of July 2, 1994. However, because of the siting problems identified in this accident, the Safety Board believes that the FAA should review all LLWAS installations to ensure that all wind sensor sites are located for optimum LLWAS performance.

The Safety Board also examined the usefulness of aviation advisories issued to airports using the WSR-88D. The Board believes that the advisories, while an important tool for identifying hazardous weather, can be compromised because the radar display may depict an incorrect airport location, runway configuration or city location, thus compromising the value of the advisory.

2.2.2 The Environment

The meteorological evidence relevant to this accident included weather conditions at the airport at the time of flight 1016's approach, the weather information provided by the NWS to ATC, the weather information provided by ATC to the flightcrew of flight 1016, and their use of the airplane's weather radar system.

The weather conditions at the airport during the arrival of USAir flight 1016 were essentially as forecast. The forecast and reported weather included convective thunderstorm activity with the associated low clouds, reduced visibility, and rain. Any time that convective activity is forecast, there is a potential for microburst windshear in the vicinity of thunderstorms.

USAir flight 1016 encountered a microburst windshear while on a missed approach from runway 18R. The microburst was the result of convective activity that was centered near the east side of runway 18R and that had cloud tops measured to an altitude of 30,000 feet. The microburst was determined to be approximately 3.5 kilometers in diameter and was capable of producing a rainfall rate of about 10 inches per hour. The total wind change near the ground was determined to be about 75 knots (at approximately 300 feet the winds were 86 knots), with the strongest downward vertical winds below 300 feet agl calculated to be 10 to 20 fps. The outflow winds most likely exhibited asymmetry with stronger winds on the west side of the microburst.

Witnesses to the accident reported localized heavy rain and gusty winds near the approach end of runway 18R. Several witnesses reported that the winds were gusty with wind speeds of 20 to 35 knots, while one witness under the flightpath of flight 1016 reported wind speeds of up to 50 to 60 miles per hour. The wind directions reported suggest the center of an area of divergence located east of runway 18R.

Pilots, both on the ground and in the air, reported that the thunderstorm appeared as a small echo approximately 3 miles in diameter and indicated "mostly red" on the radar. About 1832, the first officer of USAir Flight 806 noticed two strikes of cloud-to-ground lightning about 15 seconds apart to the east-southeast of the field. The crew of flight 806 also stated that as they taxied on taxiway E-12, they saw a wall of water approaching from the south. They said that the "visibility through the precipitation was nonexistent."

2.2.3 Wind Field Analysis

An area of VIP level 6 echo returns was centered near the approach end of runway 18R about the time of the accident. These storm areas were capable of producing microburst activity and peak rainfall rates of 10 inches per hour or higher.

All available data were used to compute the horizontal winds encountered by flight 1016 during the last moments of flight. The airplane encountered a windshear 7 to 8 seconds after the missed approach was initiated. Computations indicate that during the initial climb, after the missed approach was initiated and during the final descent (to within 2 to 3 seconds of ground impact), the wind along the flightpath changed significantly. The computations revealed that the wind shifted from a headwind of about 35 knots to a tailwind of about 26 knots in 15 seconds. The vertical velocity component of the wind field was also examined and it was determined that the vertical wind velocity increased from about 10 fps down to about 25 fps down, and increased further to 30 fps down as the airplane attained its maximum altitude and transitioned into a descent. It was during the latter portions of the descent, approximately 2 to 3 seconds before ground impact, that the vertical velocity component of the wind field decreased to about 5 to 10 fps down.

NASA's meteorological numerical model revealed that the microburst was centered about 1 nautical mile east of the accident site (about 900 feet west of the runway 18R threshold). The peak low level gust was calculated to be about 53 knots with a maximum north to south velocity change of about 86 knots.

2.2.4 Air Traffic Control Weather Dissemination

The primary air traffic control issue examined by the Safety Board was the controllers' failure to disseminate pertinent weather information to the crew of flight 1016. The radar and tower controllers had indications that the weather was deteriorating when flight 1016 was 16 miles from the runway, on the downwind leg of the visual approach. The Safety Board also believes that the combination of air traffic control procedures and a breakdown in communications within the Charlotte ATC tower prevented the flightcrew of flight 1016 from being provided critical information about adverse weather that developed over the airport and along the approach path to the runway. The Safety Board believes that if the flightcrew had been provided information regarding the severe weather in the terminal area, they might have abandoned the approach to runway 18R sooner or they might not have initiated the approach.

The TRACON FRW did not provide the pilots of flight 1016 with critical information about precipitation that was identified and depicted on the ASR-9 radar. The FRW controller stated in his testimony at the Safety Board's public hearing that the ASR-9 depicted precipitation at a level 3 intensity, which the

NWS classifies as "heavy precipitation." At 1836:59, the controller advised the crew of flight 1016 that they "may get some rain just south of the field, might be a little bit comin' off north." This simple statement was the controller's interpretation of precipitation that was depicted as a NWS VIP level 3 and was not the proper phraseology that was in the ATC Handbook.

In his testimony, the manager of the Advanced System Branch of the FAA's Air Traffic Division stated that controllers in general are "absolutely not" taught to interpret information detected by the ASR-9 radar. The Safety Board is concerned that controllers are not required to either display precipitation or issue to flightcrews the precipitation levels depicted on their radar.

The ASR-9 radar was developed specifically for depicting precipitation echoes accurately in the form of six standard VIP intensity levels. Although the controller is bound by the ATC Handbook, which states, in part, "issue pertinent information on observed/reported weather or chaff areas...," the determination of "pertinent information" by the individual controller is very subjective and is not defined in the ATC Handbook. Therefore, one controller may regard a VIP level 2 return to be pertinent, whereas a second controller may only report VIP level 5 precipitation information. Also, since the issuance of weather information is considered to be an additional duty for the controller, such information may not be reported.

In 1989, the General Accounting Office (GAO) conducted a study of the FAA's use of new radar and identified a lack of formal procedures for the issuance of ASR-9 weather information to pilots. In 1994, the manager of Air Traffic Investigations stated, in part:

> FAA policy regarding ATC issuance of weather information is contained in Order 7110.65...when weather information is issued pursuant to the guidance...ATC specialists should use certain pre-established phraseology...Significantly, the recommendation that weather information be issued and the use of certain prescribed phraseology does not make the issuance of weather information mandatory.

The FRW controller stated that his workload was "light" and that the complexity was "light to none." He also stated that because of the light workload, he was able to perform additional duties, including the issuance of weather information. The guidance provided in the ATC Handbook for the issuance of weather information specifically states that certain phraseology will be used when the information is issued. An example of this phraseology is as follows: "Level five weather echo between eleven o'clock and one o'clock, one zero miles...."

The Safety Board is concerned by the subjective nature of the guidance to controllers regarding the issuance of weather information, especially when that information is generated from the ASR-9 radar.

The Safety Board believes that despite the FRW controller's intentions, his use of the words "some rain" might have been interpreted by the flightcrew as a description of the amount or intensity of the rainfall. This characterization might have led the crew to believe that the rainfall was insignificant and did not pose a threat to the completion of the flight. The recommended phraseology was intended to standardize weather condition reports to pilots and to make pilots aware of the location and intensity of precipitation depicted on radar. While the Board believes that the FRW controller's choice of words to describe the weather event were improper, all other aspects of the handling of flight 1016 were satisfactory.

At 1839:12, while flight 1016 was approximately 7.5 miles from the runway, the crew of a departing USAir flight contacted the local west controller (LCW) and stated "there's a storm right on top of us." The LCW controller responded "affirmative." The controller testified that he did not relay this information to the crew of flight 1016 because "the weather was not impacting runway 18R and another airplane had circled from runway 23 and landed on runway 18R in front of USAir 1016." While this may be the controller exercising his discretion not to disseminate weather information, the Safety Board believes that it would have been prudent for the controller to issue the information regarding the deteriorating weather conditions to the pilots of flight 1016.

The Safety Board examined the issue of windshear information dissemination by the LCW controller and found that he did not issue the windshear alert to flight 1016 in a timely manner. The LLWAS centerfield sensor indicated an alert at 1840:27, when flight 1016 was about 4.5 miles from the runway. Each of the controllers (local east, local west and ground control) stated that they issued the wind as indicated by the centerfield sensor. Considering the fact that the LLWAS was alerting, the wind was issued by the controllers as a wind gust, from 100 degrees at 19 knots gusting to 21 knots, rather than as a windshear. However, the Safety Board determined that the data measured by the centerfield sensor was, in fact, the result of a windshear and not a wind gust as reported.

The ATC communications transcript of the ground control position indicates that the ground controller was aware of low level windshear activity about 1840. Additionally, examination of the sensor data information revealed that, not only did the northeast quadrant sensor alarm, both the centerfield and southeast sensors also displayed an alert. However, this information was not relayed to the crew of flight 1016, as required by the ATC Handbook. The Safety Board believes that because all three control positions received the same information from the various, sensors and the LLWAS system indicated a windshear condition in various quadrants of the airport, the controllers chose to ignore the alarm and not to issue an alert.

The Safety Board concludes that the LCW controller should have recognized the rapidly deteriorating weather conditions, including lightning in the vicinity of the airport and the decrease in tower visibility from 6 miles to 1 mile, especially since he stated that he could not see the approach end of runway 18R. However, he did not activate the RVR equipment because he did not recognize conditions on his own, and he was not directly made aware of the reduction in visibility. Additionally, he was not aware of the centerfield windshear alert or the multiple sensor alerts.

The Safety Board believes that it was the LCW controller's responsibility to provide the flightcrew with the most accurate and timely information possible. While the separate pieces of weather information would not have provided a complete description of the weather event, collectively they would have provided the crew with a more accurate depiction of the weather environment. Also, if the controller had issued all of this weather information, the flightcrew's decision to continue the approach might have been influenced enough for them to abandon the approach sooner. Therefore, the Safety Board concludes that the performance of the LCW controller was a contributing factor to this accident.

The Safety Board found that the tower supervisor did not correctly perform his duties when he determined that the prevailing visibility had decreased to 1 mile, and he did not relay this information to the other controllers. Also, he did not activate the RVR equipment or ensure that the controllers issued RVR information to pilots.

The tower supervisor is responsible for providing general supervision in the ATC facility. Although he does not directly control traffic, he must ensure the safe and efficient operation of the facility. This is accomplished by a multitude of tasks, including the assignment of controller positions, ensuring that the appropriate equipment is activated and operational, and determining the prevailing visibility. The supervisor must also oversee control positions to monitor the quality of the controller's performance and ensure that they receive all available information.

The supervisor testified at the public hearing that he was aware of the requirement to notify each controller individually of the prevailing visibility, and that notification by means of a "blanket broadcast" was not acceptable. Although it was later determined that this procedure was not in effect at the time of the accident, it still remains the responsibility of the supervisor to ensure that, like pilots, the controllers have all available information regardless of SOPs. The supervisor's failure to communicate the visibility information relates directly to the local controller who stated that he was unaware that the prevailing visibility had decreased to 1 mile and that the RVR should have been activated and reported to pilots.

The ATC Handbook provides specific guidance that any time the prevailing visibility is determined to be 1 mile or less; or when the RVR indicates a reportable value of 6,000 feet or less, regardless of visibility, this information will be reported to pilots. The supervisor determined the prevailing visibility had decreased to 1 mile; however, he did not ensure that all of the equipment necessary to determine RVR was activated. At 1840, the RVR indicated a reportable value of 2,400 feet, which was the USAir minimum value permissible to execute the ILS approach. The RVR value was not reported to the crew of flight 1016 because the RVR display located in the tower cab was not activated. Currently, there are no standardized procedures to ensure that controllers are aware of a reportable RVR value when the system is not in an operational mode in the tower.

In conclusion, the Safety Board believes that the failure of the controllers to report ASR-9 radar data and other pertinent weather information to the crew of flight 1016, and the supervisor's failure to ensure that each controller was aware of the decreased visibility and that all necessary RVR equipment was activated and displaying reportable information, were contributing factors to the accident. As the result of these findings, the Safety Board believes that the FAA should amend the ATC Handbook and take other actions to correct the deficiencies identified in this accident.

2.3 Aircraft Performance

An analysis of the airplane's performance was conducted to determine if the effects of heavy rain were a factor in the accident. Tests conducted during previous heavy rain studies revealed that there is a measurable reduction in the maximum lifting capability of an airfoil in extreme heavy rain, and some increase in aerodynamic drag. However, these penalties were significant only when the wing is at high AOA during the heavy rain encounter. Based on the FDR data, the various AOAs recorded during the last minute of flight were not considered to be high. Thus, the Safety Board concludes that the effects of heavy rain on the engines and wings were insignificant and did not contribute to the events that resulted in the accident.

The Safety Board believes that based on the weather conditions and their adverse effect on aircraft performance, the flightcrew should have completely avoided the convective activity (storm cell). However, because they did not abandon the approach earlier, the performance of the airplane during the windshear encounter was analyzed to determine if it was capable of successfully flying through the windshear encounter, assuming optimum piloting technique. Simulations revealed that given the NASA wind flow field, the airplane could have escaped the windshear encounter if several crew actions had been performed: First, the power was advanced by the first officer to an EPR setting of approximately 1.82; however, the captain did not trim to the target EPR of 1.93; second, the FDR indicated that a positive rate of climb had been established; however, the landing gear was not retracted; and lastly, the pitch attitude of the airplane was not maintained at or near the target of 15° nose up.

The simulations indicate that lowering the nose to 5° below the horizon was the most significant factor that prevented the escape from the windshear encounter. Based on these simulations, the Safety Board concludes that flight 1016 could have successfully flown through the windshear encountered if the flightcrew had executed an optimum missed approach procedure, and if "firewall" thrust had been applied as the airspeed decreased below 120 knots. The combination of the crew's failure to use maximum go-around thrust, and the reduction of pitch attitude at a critical phase of flight, resulted in the airplane descending to the ground. The data also support the conclusion that flight 1016 could have overcome the windshear encounter if the flightcrew had executed the windshear escape maneuver (maximum effective pitch attitude and maximum "firewall" power) immediately after the initial airspeed decay.

The Safety Board also examined the control column forces that the first officer most likely experienced during the missed approach. The evidence indicates that the pitch trim had not been changed subsequent to the initiation of the missed approach. Given this condition, the first officer would have had to continue to increase back pressure on the control column as the airplane slowed to maintain a constant pitch attitude. At 115 knots, the airplane was most probably 29 knots below the trim speed. The force required to maintain this attitude would have been less than 24 pounds, which was well within the capabilities of the pilot. Therefore, control column forces might also have affected subsequent events during the missed approach maneuver. Specifically, when the captain directed the first officer "down, push it down," the first officer did not have to push forward on the control column. He merely had to release some of the back pressure on the control column to achieve the desired effect of lowering the nose. While it is possible that the first officer intentionally released the pressure to comply with the directive, this action might also have been instinctive because pilots are unlikely to ignore an out-of-trim condition.

2.4 Operational Factors

The Safety Board examined the flightcrew's operating procedures and practices, USAir's windshear and CRM training programs, the flightcrew's decision making process and actions taken, and the oversight of flight operations and pilot training program by USAir and the FAA.

The circumstances of the accident prompted the Safety Board to examine the decisions made by the flightcrew during the final minutes of flight. Based on the information that was available to the flightcrew, it was evident that they did not immediately recognize the microburst encounter, and they did not initiate immediate corrective actions. This can be attributed, in part, to the limitations of the information processing in the human brain. An expert in the field of Engineering Psychology and Human Performance believes that reaction time varies as a function of such factors as the complexity of the stimulus (the event), and the intensity of the stimulus.[31] Also, it is believed that the degree to which the respondent has practiced the response also affects reaction time. The Safety Board believes that the flightcrew initiated the approach into an area of convective activity that, based on information from other sources, was not considered to be threatening.

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[31] Wickens, C. D., *Engineering Psychology and Human Performance*. Columbus, Ohio, Charles E. Merrill, 1984.

The crew's decision to continue the approach, even though the weather conditions were rapidly deteriorating, might have been influenced by the lack of significant weather information, or reported information, that led the crew to believe that the weather conditions still did not pose a threat to the safe completion of the flight. The decisions made by the flightcrew, and their actions based on those decisions, are discussed in subsequent sections of this report.

2.4.1 Flightcrew Actions

The recorded conversations on the CVR and testimony provided by the flightcrew revealed that the flightcrew did not adhere to standard operating procedures (SOP) set forth in the USAir pilot operating handbook during the flight from Columbia to Charlotte. Several examples of this include: an incomplete predeparture briefing by the first officer; the nonessential conversation between the crewmembers below 10,000 feet (sterile cockpit); and the captain's failure to make the required "1,000 foot above the airport" and the "100 feet above minimums" altitude callouts. While the lack of strict adherence to procedures did not have an adverse affect on the en route portion of the flight, the nonstandard operating practices during the final phase of flight might have caused the pilots to lose situational awareness[32] during the approach.

The captain testified at the public hearing that they had briefed the ILS approach procedures after receiving the revised clearance from the air traffic controller. However, the "standard ILS approach briefing" for the ILS approach to runway 18R recited by the first officer during his testimony at the public hearing was not evident on the CVR.

The Director of Training testified that the briefing recited by the first officer during his testimony was accomplished "perfectly." The Director of Training added that it was "mandatory" and that standard "phraseology set out in the manual is required" for every ILS approach. The Director of Training further stated that the reason for the standardized briefing was to ensure situational awareness, as defined in AC 60-22.

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[32]Situational awareness is defined by the FAA in Advisory Circular (AC) 60-22, Aeronautical Decision Making, as follows: "The accurate perception and understanding of all of the factors and conditions affecting the pilot, the flight environment and type operation that affect safety before, during, and after the flight."

The CVR recording did reveal that the pilots had discussed selected items typically included in the approach briefing; however, these items were identified and verified in a nonstandard manner. The recording indicates that at 1825:27, the first officer said "all right that's one eleven uh, three and uh, one eighty one." The required information to be briefed by the crew was expected to be provided in a standard format with specific phraseology. The information about the approach, which included the localizer frequency and the inbound course heading (181 degrees) to runway 18R, did correspond to the first officer's remarks recorded on the CVR. About 10 minutes later, the first officer, in response to the checklist item "approach brief," said "visual back up ILS." Approximately 12 minutes later, the captain commented "if we have to bail out, it looks like we bail out to the right," followed about 13 seconds later with the remark "chance of shear."

The Safety Board acknowledges that the first officer did respond to the checklist item "approach brief" and that he had identified selected features, such as the localizer radio frequency and the final approach heading, prior to the performance of the checklist. However, since the flightcrew did not acknowledge the air traffic controller's issuance of the ILS approach, the Safety Board believes that the crew still had visual contact with the runway at that point in time and that they expected to complete the approach in visual conditions. The Safety Board also believes that, had the pilots performed the required approach briefing for the ILS, which would have included the airport field elevation, final approach fix altitude, decision height, and missed approach procedure and altitudes, they would have increased their situational awareness for the approach.

Shortly after encountering the intense rain on final approach, and apparently without realizing that they were either in a windshear or could possibly encounter a shear, the captain commanded the first officer to "take it around, go to the right." The first officer executed a normal missed approach rather than the windshear escape maneuver, with the exception of altering the heading to the right about 45°, and applied "full power" and pitched the airplane to the standard 15 degrees nose-up attitude. This was contrary to both the controller's instruction to "fly runway heading, climb and maintain three thousand" and the published missed approach procedure. While this course of action was deemed necessary by the captain to avoid the adverse weather along the approach path, the altered heading could have compromised traffic separation afforded aircraft under direct ATC control.

About 8 seconds after the first officer pitched the airplane up to 15° (the maximum recommended pitch attitude specified in the pilot operating handbook for the normal go-around procedure) and rolled into a 17° banked turn to the right, the CVR recorded the captain as saying "down, push it down." Although the captain and first officer testified that they did not recall making the comment or hearing the comment, the Safety Board examined the CVR and FDR data and correlated the timing of the statement to the control yoke position and pitch attitude. Comparing the captain's statement of "down, push it down" which occurred at 1842:22.0, the FDR recorded movement of the control yoke that changed proportionally as the attitude of the airplane transitioned from 15° nose up to 5° nose down. Three seconds after giving the command, the captain responded to a previous radio transmission from the controller and acknowledged that they were climbing to 3,000 feet and altering their course to the right of the runway heading. At 1842:28, the CVR recorded the sounds of the ground proximity warning system (GPWS) aural warning, followed 4 seconds later by the sound of stick shaker activation, and ending with the sound of ground impact at 1842:36.

The captain testified that upon the initiation of the missed approach, the airplane was at an altitude of 1,200 feet, or about 450 feet above the ground. The FDR recorded altitude of flight 1016 at the time the missed approach was initiated was 950 feet, or approximately 200 feet above the ground. Also, at the time the captain said "down, push it down," neither he (performing the nonflying pilot duties) nor the first officer (using instrument reference for the execution of the missed approach) could see the ground because of the intense rain. The Safety Board believes that the first officer had initially performed the required procedures to reconfigure the airplane for the normal missed approach and began its execution. However, the Safety Board also believes that the performance of the nonflying duties by the captain might have seriously affected his awareness of altitude; thus, he issued the command without realizing their close proximity to the ground. Also, once the command was given, the captain did not monitor the first officer's actions or the performance of the airplane.

The Safety Board studied the captain's remark to the first officer of "down, push it down" to understand why a command such as this would have been issued when the airplane was in very close proximity to the ground and traversing an area of unfavorable weather. The captain testified that he did not recall issuing the command; thus, the basis for this remark cannot be fully known with certainty. However, when the FDR data were examined and compared to various elements of the flight, one possible explanation for the captain's command became apparent.

Examination of the circumstances during the last minute of flight strongly suggested that the captain, upon losing his visual cues instantaneously when the airplane encountered the heavy rain, could have experienced a form of spatial disorientation. The disorientation might have led him to believe that the aircraft was climbing at an excessively high rate and that the pitch attitude should be lowered to prevent an aerodynamic stall. Additionally, when the airplane encountered the heavy rain, the flightcrew would have lost their outside horizon visual reference. Also, it may not have been possible for the captain to regain situational focus on the primary flight instruments because he was performing other tasks. Further, because the flightcrew was initiating the missed approach, which involved a large increase in engine thrust, a pronounced increase in pitch attitude, and a banked turn to the right, the crew would have been exposed to significant linear and angular accelerative forces. These forces could have stimulated the flightcrew's vestibular and proprioceptive sensory systems and produced a form of spatial disorientation known as somatogravic illusion.

The Safety Board believes that since the captain was not the pilot flying the airplane, he was a prime candidate for the effects of a somatogravic illusion for the following reasons: his visual and mental focus was outside the airplane during the majority of the approach to runway 18R; he was not using the primary flight instruments for spatial orientation; his visual cues were no longer available during the encounter with the heavy rain; and the accelerative forces resulting from the power application and the "G" forces associated with the pitch to 15 degrees nose up and a roll to 17 degrees right wing down, in combination, produced physiological sensations that the captain might have misinterpreted as excessive during the transition from a relatively level flight attitude to 15 degrees nose up during the missed approach.

The Safety Board recognizes that the captain has many hours of flight experience in transport category aircraft, as well as in high performance military aircraft. However, the Safety Board is also aware that while neither the captain nor the first officer recall the command being issued or pitch change being introduced, the CVR recorded the captain saying "down, push it down," at 1842:22, and, approximately 1 second later, the airplane's pitch attitude transitioned from 15 degrees nose up to 5 degrees nose down over a 7-second period. The captain testified at the public hearing that he did not recall being disoriented during the missed approach. Nevertheless, the Safety Board believes that since neither crewmember reported seeing the airspeed decreasing prior to the command, the captain might have been adversely affected by the sensory illusion, which, in turn, could have prompted his ordering the first officer to lower the nose to correct for the perceived excessive nose-high sensation. Therefore, the Safety Board believes that the captain's improper command resulted in the first officer's significant lowering of the airplane's pitch attitude. The resulting change in pitch caused the airplane to descend, thus eliminating the altitude margin that would have been necessary to escape the windshear.

The Safety Board also examined the actions of the first officer regarding the captain's remark. As the flying pilot, the first officer would have maintained a scan of several instruments that would have given him the best situational awareness by providing essential information about airspeed, altitude, and aircraft attitude. However, as the FDR data indicate, it is believed that during the course of performing the missed approach procedure, the first officer acted, without challenge, to a command from the captain to "down, push it down." One of the principles in the practice of CRM is the uninhibited challenge of the captain by the first officer when an unsafe condition exists or an inappropriate command has been issued. The Safety Board believes that the first officer should have been fully aware of the airplane's proximity to the ground (approximately 200 feet agl) when the captain commanded the missed approach, as well as their altitude (350 feet agl) when the captain commanded "down, push it down." Thus, the first officer's immediate reaction should have been to challenge the impropriety of the command rather than reacting first.

2.4.2 CRM Training

CRM training was developed because investigations into the causes of many air carrier accidents and incidents have shown that human error is a contributing factor in 60 to 80 percent of them.[33] The principles of CRM use the concept of team management in the flight deck environment with the crewmembers acting in harmony together rather than as technically competent people acting independently.

USAir's CRM program incorporates training modules that include: communications processes, decision behaviors, team building, team maintenance, and workload management/situational awareness. The Director of Training testified at the public hearing that USAir's CRM program trained teams rather than individuals. Additionally, CRM encourages crewmembers to use all of the resources at hand, which also includes SOP. SOP gives flight crewmembers a baseline with which to compare observations and effect change as necessary.

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[33] Advisory Circular (AC) 120-51A, Crew Resource Management Training, February 10, 1993.

Standardized procedures also enhance communications between crewmembers and facilitate a collective decision.

A study commissioned by the Boeing Commercial Airplane Group examined "crew-caused" accidents and identified the following deficiencies in standardization and discipline in companies operating the aircraft involved in the study:

> A strong check airman program acts as a continuous quality control check on the training department. Standards for check airman candidates exist in writing, and the highest level of flight operations management participates in the evaluation and selection process. Methods exist for assuring the uniformity of check pilot techniques and instruction, usually accomplished during periodic (monthly) meetings of all check pilots. There is a special system of recurrent checks for check pilots that is independent of the line pilot recurrent training program. An effort is made to assure the uniformity of checkir -chniques by correlating reported nonstandard behavior in students check pilots where possible. (Emphasis added).
>
> There is a firm requirement for in-depth takeoff and approach briefings for each segment. This provides the entire crew with knowledge of precisely how the event is to be performed....
>
> The approach briefing is usually done at the top of descent before workload increases. It covers the navigation, communication and procedural details of the approach for the specific runway involved, including missed approach details.
>
> Cockpit procedural language is tightly controlled to maintain consistency and to avoid confusion from nonstandard callouts that can result from crewmembers using differing phraseology. Callouts and responses are made verbatim. The recurrent training program and check pilot system rigidly enforce this requirement.

The Safety Board found that the check airmen interviewed after the accident indicated that individual pilots have different methods of accomplishing checklists. The Safety Board notes with concern that in a department where standardization is promoted and enforced, there is an apparent lack of standardization among the company check airmen. One check airman was unaware that there was a company requirement for flight crewmembers to brief visual approaches, while another check airman believed that crewmembers were required to brief the visual approach.

The Safety Board has addressed the subject of CRM in previous accident investigations and continues to advocate that the principles of CRM be employed and practiced by flight crewmembers at all times. Adherence to SOP for both the routine and nonroutine flight operations can have a strong positive effect on how well individuals function during times of high workload or high stress. SOP fosters good communication and team building because the team members know what to expect from each other as well as themselves.

The Safety Board believes that the crew of flight 1016 appeared to be comfortable with each other in the cockpit. However, their actions, especially during the final phase of flight, were those of individuals rather than as members of the same team. This was evident from their nonadherence to "sterile cockpit" procedures, inadequate checklist responses, and their abbreviated, personally stylized, and/or nonstandard briefings. The Safety Board is concerned with the crew's behavior because it suggests that they, as well as other pilots, do not adhere to procedures during "routine" flights and phases of flight. One such example demonstrated during the accident flight was the violation of the sterile cockpit rule. The Safety Board found that the required approach briefing was not accomplished completely, and that nonessential conversation below 10,000 feet msl was allowed to continue. The sterile cockpit rule was implemented to reduce flightcrew distractions when situational awareness is most needed, such as during flight phases in close proximity to the ground. Regardless of the nature of the flight, the Safety Board believes that the flightcrew must devote full attention to the operation of the airplane. Literature on the study of human factors further underscores the importance of flightcrew attention to the environment. One noted expert stated:

> Attention serves as an important constraint on situational awareness. Direct attention is needed for not only perception and working memory processing, but also for decision making and forming response executions.[34]

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[34]Endsley, M. R., (1995) "Situation Awareness in Dynamic Human Decision Making: Theory." In R. D. Gilson, D. J. Garland, and J. M. Koonce (Eds.) *Situational Awareness in Complex Systems*. Santa Monica, California. Human Factors and Ergonomics Society.

Thus, the Safety Board believes that less than full attention can degrade a pilot's situational awareness, as evidenced in this accident, and even the most routine of flights can unexpectedly demand the highest levels of pilot attention, skill and proficiency.

Additionally, the CVR recording of the crew's conversations revealed that neither the captain nor the first officer contributed to an atmosphere that encouraged the use of standard operating procedures. The Safety Board has long been an advocate of CRM training for captains and assertiveness training for first officers. The exchange of information between the captain and first officer was satisfactory. However, the Safety Board believes that as a result of a casual atmosphere, tasks were either not performed or were accomplished in such a manner that their effectiveness as a team was reduced. Specifically, the crew's situational awareness was inadequate, and the first officer failed to challenge the captain's inappropriate command of "down, push it down."

2.4.3 Windshear Training and Airborne Weather Radar

Automation and technology developed by the aviation industry have advanced to such a level that the precise location and moment of a microburst can be predicted with a fairly high level of accuracy. While such technology is not currently available for widespread use, forecasting techniques have been developed that permit meteorologists to predict, with a high degree of accuracy, the type of day or weather pattern from which microburst activity is likely to occur. Since microbursts are a product of convective activity, the best way to avoid the microburst windshear is to avoid flight either under or in close proximity to convective activity, such as cumulonimbus clouds or, in particular, thunderstorms.

The Safety Board's examination of the USAir windshear training program revealed that the curriculum discussed the necessity of avoiding windshear and emphasized that crewmembers should be able to recognize cues that either indicate the possibility of a windshear or an actual encounter. The program at USAir was comparable to industry standards contained in the *Windshear Training Aid*, and the crew of flight 1016 had received the training.

The USAir windshear training program provides crewmembers with a table of microburst windshear probabilities based on different cues. These cues include: (1) precipitation that is depicted as red on airborne weather radar has a high probability of microburst activity; (2) an LLWAS alert of less than 20 knots has a medium probability; and (3) an airspeed gain of greater than 15 knots has a high probability of microburst activity. These guidelines apply to operations in the airport vicinity, within 5 miles of the point of takeoff or landing along the intended flightpath and below 1,000 feet agl. The cues should be considered cumulative and if more than one is observed, the probability weighing should be increased.

The Safety Board believes that the crew of flight 1016 was exposed to at least three windshear probability cues, two of which were rated as high. They were the combination of convective weather conditions that existed at the airport; the flightcrew's visual observations and decision to make the missed approach to the right; and the subsequent intracockpit discussions about the location of the rain. Finally, the flightpath that would have resulted from following the prescribed ILS approach procedure offered a strong likelihood of an encounter with microburst windshear activity.

The observation of the microburst cues was further validated by the CVR recording when the captain commented about 4 minutes before the accident that the rain activity "looks like it's sitting right on the [unintelligible]," to which the first officer replied "yep, [the edge of the rain is] laying right there this side of the airport, isn't it." This information, combined with the previous knowledge gained from the airborne weather radar about the weather cell, should have been a clear indication that a microburst was very possible.

Based on the guidance and training provided by USAir to this crew, the Safety Board believes that there were sufficient microburst windshear cues presented to the flightcrew that warranted abandoning the approach earlier. However, perhaps because of incomplete or misleading weather information from other sources (the "smooth ride" report from another flight and visual contact with the runway), the flightcrew's perception of the weather was interpreted as nonthreatening. Thus, they continued the approach beyond the final approach fix. Nonetheless, based upon their simulator training, the Safety Board believes that once the pilots observed the increased airspeed upon entry into the rain, they should have recognized that a windshear condition existed, and they should have executed a windshear escape maneuver.

The Safety Board is concerned that the windshear training conducted in the simulator may not be totally effective because flightcrews, through repetition, have become accustomed to performing required routine tasks in the training and checking process. These tasks result in: 1) the pilot having a good knowledge of the type of maneuver or abnormal condition that will be simulated; 2) knowledge of the time period that the abnormal condition may be simulated; 3) crew reliance in identifying windshear on the aircraft windshear alert system; and 4) rote knowledge of the "routine" procedure necessary to successfully satisfy the simulated condition. This was found to be evident in the USAir windshear training program to the extent that, typically, the windshear cues always provided to the flightcrews in the simulator occurred in the form of either turbulence immediately before the windshear and/or a fluctuation in airspeed.

The Safety Board believes that the use of repetitive windshear cues, such as turbulence and/or airspeed fluctuation in USAir's windshear training conducted in the simulator, might have led the pilots to associate windshear with those cues. As was evident in this accident, there was no turbulence associated with the entry into the microburst wind field at Charlotte. The lack of turbulence could have contributed to the crew's failure to identify the microburst activity because it was dissimilar to the cues they had been trained to recognize in the simulator.

The Safety Board also examined whether the flightcrew would have been able to escape the windshear if the aircraft warning system had been designed to provide a warning 8 to 9 seconds before the impact. It can be inferred from the Douglas simulation data that if the airplane had been starting upward at a pitch rate of 4 degrees per second, and firewall power had been selected 1 second after the windshear warning, the airplane might have been able to escape. However, it must be noted that the flightcrew received a GPWS warning 7 seconds before the impact, and although they initially reacted properly by pulling back on the stick, they failed to maintain proper corrective action.

The Safety Board concludes that the windshear program in place at USAir met industry standards, and the pilots had received the requisite training. However, the pilots did not apply the principles of this training adequately during the accident flight. Therefore, the Safety Board believes that the FAA should reexamine the circumstances and findings of this accident as a basis for a review and revision, as necessary, of airline industry windshear training programs.

2.5 FAA Oversight

The POI for USAir testified at the Safety Board's public hearing regarding oversight of the air carrier. In his testimony, the POI stated that he examined the Program Tracking and Reporting System (PTRS) data for trends of noncompliance with Federal Aviation Regulations (FAR). He also stated that he examined the training program and the compliance with USAir's operational procedures and did not observe any trends in the area of noncompliance with FAR or company procedures. However, he did observe a trend in noncompliance with company procedures.

The POI testified that he became aware of a situation that developed during a 1993 National Aviation Safety Inspection Program (NASIP) inspection in which an inspector observed a USAir check airman giving windshear training to only one of the two captains that were paired together during a simulator period. The POI said that when the inspector made the check airman aware of this discrepancy, the check airman changed the record to reflect that the training had occurred, rather than bring the other captain back for the required windshear training.

The Safety Board was concerned with this incident because it related to the windshear training provided to flight crewmembers, and it directly related to the circumstances of this accident. The POI stated that the incident that was described was not of concern to him because USAir had complied with the regulation and that, considering the regulations were unclear with regard to falsification of operational records, the aforementioned change to the training records did not constitute noncompliance. However, the regulation does delineate this action as being in noncompliance.

The 1993 NASIP inspection also revealed that 51 USAir pilot training records were lacking entries that would indicate exposure to windshear training. The POI testified that he was notified of this finding; however, he did not interview any of these pilots, and he did not review the records to ascertain whether the deficient pilots had received flight checks by the check airman who had been the subject of noncompliance.

The Safety Board's concern extends to the relationship that has developed between USAir and the POI. The POI testified that his office, which has oversight responsibility, has a unique relationship with the air carrier. He described his relationship with USAir as one of "compliance through partnership," whereby he reports FAA trend information to USAir and they initiate a program to achieve compliance.

The Safety Board believes that the FAA has a responsibility to maintain a vigilant oversight of the carrier and provide guidance when necessary. This appears to have been compromised by the fact that the POI, after having been informed that 51 pilot training records did not indicate the receipt of windshear training, did not take action to validate the information. Instead, the POI relied entirely on USAir to rectify the situation and come into compliance with standard operating procedures. The POI stated that he had only 11 inspectors to oversee a training program that involves 15,000 individuals. He said "I cannot follow up on every noncompliance that we find out there. I have to rely on the carrier to take that responsibility. And so, as far as I'm concerned, compliance through partnership works and we become very innovative in making it work in our office and we've done some very unique things with this."

While the Safety Board encourages the FAA to develop a relationship of trust with the air carrier, there must also be limitations placed on that trust. The Safety Board is concerned that overreliance on the air carrier to carry out its responsibility could limit the POI's ability to maintain an adequate oversight program and monitor the operation for noncompliance.

In addition, the Safety Board is concerned about the findings of either inadequate or abbreviated use of checklists by flightcrews, as well as other procedural deviations that have been identified in many past accident investigations. In its adopted final accident report for the Continental Airlines flight 795, MD-82, that overran the end of the runway at LaGuardia Airport, Flushing, New York, on March 2, 1994, the Safety Board stated, in part:[35]

> The Safety Board has addressed the issue of inadequate checklist procedures by airline pilots several times over the years. Most recently, in a letter dated February 3, 1994, to the FAA Administrator, the Safety Board issued two safety recommendations [A-94-001 and -003] that addressed the issue of flightcrew checklists. The safety recommendations resulted from a safety study of 37 flightcrew-involved major accidents of U.S. airlines from the years 1978 through 1990.[36] In that study, the Safety Board

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[35]See Aircraft Accident Report--"Runway Overrun Following Rejected Takeoff, Continental Airlines Flight 795, McDonnell Douglas MD-82, N18835, LaGuardia Airport, Flushing, New York, March 2, 1994" (NTSB/AAR-95/02)

[36]See "Safety Study, A Review of Flightcrew-Involved, Major Accidents of U. S. Air Carriers, 1978 through 1990" (NTSB/SS-94/01)

> found that six of the eight takeoff accidents studied involved procedural checklist failures on the part of the flightcrews during the taxi phase of operation.

The Safety Board, in its study of flightcrew-involved major accidents, made the following conclusions that are also relevant to the accident involving flight 1016:

> Procedural, tactical decision, and monitoring/challenging errors were the most common types of errors identified in the 37 accidents reviewed for this study; and of the primary errors identified, errors of omission were more frequent than errors of commission.
>
> A pattern common to 17 of the 37 accidents was a tactical decision error by the captain (with more than half constituting a failure to initiate required action), followed by the first officer's failure to challenge the captain's decision.

Also, the Safety Board found during the accident investigation of Continental Airlines flight 795 that pilot procedural deficiencies had been previously noted. FAA inspectors found them during a special inspection of Continental Airlines before the USAir accident in Charlotte. In the final report for Continental Airlines flight 795, the Safety Board stated, in part, "If pilots fail to adhere to procedures during en route inspections by FAA inspectors, they most likely behave in a similar manner when no inspector is present." The Safety Board believes that the failure of the flightcrews to adhere to standards and procedures may reflect a general lack of professionalism that is not being corrected by the training and checking programs at airlines. The findings in this investigation, as well as in many previous investigations, suggest that there may be a systemic problem of complacency and nonstandard conduct that adversely affects the performance of flightcrews during critical phases of flight.

On April 26, 1994, the FAA responded to the Safety Board and stated that it agreed with both recommendations and that it intended to issue an Advisory Circular addressing the issues cited in A-94-001 and A-94-003. On July 6, 1994, the Safety Board classified the FAA's actions "Open--Acceptable Alternate Response." Currently, the Safety Board is awaiting final action by the FAA on this important matter that has been cited as a factor in many previous airline accidents, including USAir flight 1016. The investigation of the accident involving flight 1016 identified issues that were similar to those previously addressed. Therefore, the Safety Board concludes that the actions previously recommended by A-94-001 and A-94-003 are also applicable to USAir.

Additionally, the Safety Board is aware that the aforementioned safety issues, as well as others discussed in this report, are being addressed as the result of the recent FAA-sponsored aviation safety conference held in Washington, D.C., on January 9 and 10, 1995. The Safety Board has examined the Aviation Safety Action Plan issued on February 9, 1995, that resulted from this joint government and industry conference and finds that many of the safety issues discussed during the conference were identified in previous Safety Board reports and were addressed in a number of safety recommendations. The following principles, cited in the Plan, are intended to achieve the stated goal of "zero accidents:"

> Pursuit of the goal of zero accidents is a shared responsibility of all Government, industry, and labor organizations and of each individual member of the aviation community.
>
> The aviation community must change from a mind set that minimizes accidents to one that demands zero accidents.
>
> FAA and industry approaches to safety must be proactive and focus on anticipating safety threats and preventing mishaps.
>
> Safety data and information must be shared freely among members of the aviation community to ensure the greatest safety benefits to the flying public.

As a result of the conference, 173 initiatives were proposed by industry participants from recognized safety issues. Many of these same safety issues were developed, not only during the investigation of flight 1016, but also following numerous other accidents. Several examples include: the human factors aspects of the controller/pilot interface and the need for improved collection and dissemination of weather information to pilots; the establishment of safety departments at all airlines; the need for an approved Flight Operations Quality Assurance (FOQA) program at airlines; and the improvement of pilot training program standards.

The Safety Board strongly urges the FAA to implement timely changes to satisfy the recommendations arising from the conference.

2.6 Survival Factors

Four major sections of wreckage were found. (Refer to Section 1.15 of this report.) Impact damage and forces varied between the four major sections of wreckage. The cockpit, forward flight attendant jumpseats, and four first class seats were in the wreckage located on Wallace Neel Road. No passengers were seated in this section. The impact forces were within human limits, and this area and the pilots' seats and flight attendants' jumpseats remained intact. The "C" flight attendant was struck by an unknown piece of wreckage which caused a fracture of the patella.

Seat rows 3 through 8 were destroyed when that section of fuselage impacted two large hardwood trees. Passengers in this section sustained nonsurvivable blunt trauma injuries. Rows 9 through 14 and the left wing were located in the front yard of a private residence and had extensive fire damage. In this section, some passengers sustained fatal blunt force injuries, some others died of the effects of the fire, while others died from a combination of blunt force injuries and the fire. Two passengers, although injured, were able to escape before the fire intensified. Passengers in rows 15 and 16 sustained blunt force and/or thermal injuries.

The aft section of the airplane, which included seat rows 17 through 21, was found imbedded in the carport of the residence. Occupants of this section sustained blunt force injuries and burns. Some of the blunt force injuries occurred to occupants of seat rows 17 and 18 when those rows rolled under the tail section during the impact sequence. The Safety Board believes that the more serious burn injuries sustained by these survivors occurred as they escaped the left side of the wreckage. Based on their injuries, the Safety Board believes that the passengers who were assigned seats 20E and 20F were not in those seats at the time of the accident.

There were 57 occupants on flight 1016: 52 passengers and 5 crewmembers. The passenger manifest listed 50 names and did not include the names of two in-lap infants. Federal Aviation Regulations specifically address the issue of passenger manifests. 14 CFR 121.693(e) requires that a load manifest contain the names of passengers aboard the airplane. The FAA also issued Action Notice 8340.29 and Air Carrier Operations Bulletin No. 8-91-2 to reaffirm that every occupant, who is not a crewmember with assigned duties, must be listed on the passenger manifest.

The USAir procedures for accounting for in-lap infants requires the gate agent to place an "Infant Boarding Pass-Non Assigned Seat" sticker and the remark "Plus Infant" in the name field of the accompanying adult's flight coupon. Neither of the flight coupons for the adults associated with the two in-lap infants included an "infant boarding pass" sticker. Although one coupon included a handwritten notation "+ infant," the second coupon did not; thus, the infant was not included on the passenger manifest.

The Safety Board identified inaccuracies with passenger manifests in several previous accident investigations and issued Safety Recommendations A-79-65 and A-90-105 that asked the FAA to require standardized reporting by air carriers of passengers on manifests. Both of these recommendations have previously been classified as "Closed--Acceptable Action."

While the FAA has established rules that there be an accurate listing of occupants (14 CFR 121.693(e)) regarding manifests, and USAir has procedures for accounting for in-lap infants, these procedures are not consistently followed. The Safety Board believes that USAir should review its procedures to ensure that manifests have an accurate count of all occupants on each airplane.

The Safety Board believes that the regulation that permits children 2 years of age and younger to sit on an adult's lap contributes to the inaccuracy of the passenger manifests. While USAir does have procedures in place to identify children on the manifest, the reporting is neither consistently practiced by the staff nor enforced by management. Additionally, children under the age of 2 being transported on domestic air carrier flights are not required to be ticketed. Therefore, their names do not appear on the ticket-generated manifest and, as seen in this accident, are not included in the total passenger count.

The Safety Board found that the 9-month-old in-lap infant who was held by her mother in seat 21C sustained fatal injuries during the impact sequence. The child's mother was unable to maintain a secure hold on the child during the impact sequence. The Safety Board believes that if the child had been properly restrained in a child restraint system, she probably would not have sustained fatal injuries.

Because the CAMI research has determined the size of a child who would be adequately restrained by an airplane lap belt, the Safety Board classifies Safety Recommendation A-90-79 "Closed--Acceptable Action."

Also, because the CAMI report found that normal lap belts can provide acceptable restraints for 3-year-old children, as represented by a 36-pound anthropomorphic test dummy, the Safety Board finds that the 40 pounds, 40 inches standard used in Safety Recommendation A-90-78 has been superseded by the findings of the CAMI report. Since the FAA has not taken steps to require that all occupants be restrained during takeoff, the Safety Board now classifies Safety Recommendation A-90-78 "Closed--Unacceptable Action/Superseded."

The Safety Board is disappointed with the FAA's inadequate actions regarding the required use of child restraint systems on transport category, air carrier flights. The Safety Board notes the increased use of integrated child restraint systems in automobiles, as well as the probable introduction of ISOFIX [standard child restraint system attachments that will be incorporated into the design of automobiles]. Therefore, the Safety Board is concerned about possible future problems for parents who may not have the appropriate child restraint systems for aircraft use. Accordingly, the Safety Board believes that the FAA should develop standards for forward-facing, integrated child restraint systems to be used in aircraft. The Safety Board believes that the development of forward-facing, integrated child restraint systems for aircraft could correct some of the problems identified in the CAMI testing. The Safety Board also believes that small children traveling on aircraft should be provided crashworthiness protection that is at least equivalent to that provided to other passengers.

2.7 Previously Issued Safety Recommendations

On August 16, 1987, Northwest Airlines, Inc., flight 255 crashed shortly after takeoff from Detroit Metropolitan/Wayne County Airport, Romulus, Michigan. Of the persons on board flight 255, 148 passengers and 6 crewmembers were killed; one passenger, a 4-year-old child, was injured seriously. On the ground, two persons were killed, one person was injured seriously, and four persons suffered minor injuries.

The Safety Board determined that the probable cause of the accident was the flightcrew's failure to use the taxi checklist to ensure that the flaps and slats were extended for takeoff. As a result of the Northwest Airlines flight 255 accident,[37] on June 27, 1988, the Safety Board issued recommendation A-88-067, urging the FAA to:

> Require that all part 121 and 135 operators and principal operations inspectors emphasize the importance of disciplined application of standard operating procedures and, in particular, emphasize rigorous adherence to prescribed checklist procedures.

An earlier FAA response, on December 20, 1990, concerning Safety Recommendation A-88-067 stated that:

> The FAA ensures that all 14 CFR Parts 121 and 135 Operators and Principal Operations Inspectors emphasize the importance of disciplined application of standard operating procedures and the rigorous adherence to checklist procedures. On December 30, 1988, in response to this safety recommendation, the FAA issued Action Notice A8400.2 Normal Checklist Review, Parts 121 and 135 Operators, which required Principal Operations Inspectors to review the adequacy of checklists and the implementing procedures used by all 14 CFR Parts 121 and 135 operators. On February 22, 1988, the FAA published an NPRM to promulgate an SFAR that would improve air carrier training, evaluation, certification, and qualification requirements for appropriate evaluation. The SFAR was published on October 2, 1990.

The POI for USAir testified that there was a recognized trend in pilot noncompliance regarding standard operating procedures at USAir.

The FAA responded again to the safety recommendation on March 25, 1991, and referenced the Advanced Qualification Program (AQP) that was published on October 2, 1990. This AQP SFAR 58 (Special Federal Aviation Regulation) established an alternative method of traditional training programs and permitted certificate holders that were subject to the training requirements of 14 CFR Parts 121 and 135 to develop innovative training programs that incorporate the most recent advances in training methods and techniques. The SFAR also established training programs for meeting the training, evaluation, certification, and

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[37] See Aviation Accident Report--"Northwest Airlines, Inc., Flight 255, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, August 16, 1987" (NTSB/AAR-88/05)

qualification requirements for flight crewmembers, flight attendants, aircraft dispatchers, instructors, evaluators, and other operations personnel subject to the training requirements of 14 CFR Parts 121 and 135.

Safety Recommendation A-88-067 was classified "Closed--Acceptable Action" on March 27, 1992.

The Safety Board believes that the FAA should reiterate to its POIs the necessity for all carriers to adhere to standard operating procedures and, in particular, to emphasize rigorous compliance to prescribed checklist procedures.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew was properly certificated and had received the requisite training and off-duty time prescribed by Federal Aviation Regulations.

2. There was no evidence of preexisting medical or physiological conditions that would have adversely affected the flightcrew's performance.

3. The air traffic controllers handling the flight were properly certificated and had received the training to be designated as full performance level (FPL) controllers.

4. The airplane was certificated, equipped and maintained in accordance with Federal regulations and approved procedures.

5. There was no evidence of a mechanical malfunction or failure of the airplane structure, flight control systems, or powerplants that would have contributed to the accident.

6. The crew of flight 1016 was not provided the updated weather information broadcast in ATIS information "Zulu," as required by the ATC Handbook. The weather information reflected thunderstorm and rainshower activity.

7. The Terminal Doppler Weather Radar (TDWR) had not been installed at Charlotte/Douglas International Airport as scheduled. The accuracy of the TDWR would have provided the controllers with definitive information about the severity of the weather, and the timely issuance of that information would have been beneficial to the crew of flight 1016.

8. The Phase II low level windshear alert system (LLWAS) at Charlotte performed normally during the microburst event of July 2, 1994, and was not adversely affected by the location of the northwest wind sensor.

9. Inadequate controller procedures and a breakdown in communications in the Charlotte air traffic control tower prevented the crew of flight 1016 from receiving additional critical information about adverse weather conditions over the airport and along the approach path to the runway.

10. The flightcrew's decision to continue the approach into an area of adverse weather may have been influenced by weather information from the crews of preceding flights that had flown the flightpath to runway 18R previously.

11. The thunderstorm over the airport produced a microburst that flight 1016 penetrated while on its approach to runway 18R.

12. The horizontal windshear calculated for the microburst was as much as 86 knots; however, flight 1016 encountered a windshear computed to be 61 knots over a period of 15 seconds.

13. An inadequate computer software design in the airplane's on-board windshear detection system prevented the flightcrew from receiving a more timely windshear alert.

14. Unaware that they had penetrated the first part of the microburst, the captain commanded the first officer to execute a standard missed approach instead of a windshear escape procedure.

15. The first officer initially rotated the airplane to the proper 15° nose-up attitude during the missed approach. However, the thrust was set below the standard go-around EPR limit of 1.93, and the pitch attitude was reduced to 5° nose down before the flightcrew recognized the dangerous situation.

16. According to performance simulations, the airplane could have overcome the windshear encounter if the pitch attitude of 15° nose up had been maintained, the thrust had been set to 1.93, and the landing gear had been retracted on schedule.

17. The FAA's principal operations inspector and USAir's management were aware of inconsistencies in flightcrew adherence to operating procedures within the airline; however, corrective actions had not resolved this problem.

18. The passenger manifest was not prepared in accordance with regulations or USAir procedures; thus, the two lap children aboard were not identified on the manifest.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable causes of the accident were: 1) the flightcrew's decision to continue an approach into severe convective activity that was conducive to a microburst; 2) the flightcrew's failure to recognize a windshear situation in a timely manner; 3) the flightcrew's failure to establish and maintain the proper airplane attitude and thrust setting necessary to escape the windshear; and 4) the lack of real-time adverse weather and windshear hazard information dissemination from air traffic control, all of which led to an encounter with and failure to escape from a microburst-induced windshear that was produced by a rapidly developing thunderstorm located at the approach end of runway 18R.

Contributing to the accident were: 1) the lack of air traffic control procedures that would have required the controller to display and issue ASR-9 radar weather information to the pilots of flight 1016; 2) the Charlotte tower supervisor's failure to properly advise and ensure that all controllers were aware of and reporting the reduction in visibility and the RVR value information, and the low level windshear alerts that had occurred in multiple quadrants; 3) the inadequate remedial actions by USAir to ensure adherence to standard operating procedures; and 4) the inadequate software logic in the airplane's windshear warning system that did not provide an alert upon entry into the windshear.

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:

Amend FAA Order, 7110.65, Air Traffic Control, Chapter 2, General Control, Section 9, Automatic Terminal Information Service (ATIS) Procedures, paragraph 2-141, Operating Procedures, to ensure that broadcasts are promptly updated whenever any conditions conducive to thunderstorms are observed. These conditions would include, but not be limited to, windshear, lightning, and rain. Additionally, require that controllers issue these items until the information is broadcast on the ATIS and the pilots have acknowledged receipt of the information. (Class II, Priority Action) (A-95-40)

Amend FAA Order 7110.65, Air Traffic Control, Chapter 2, General Control, Section 6, Weather Information, paragraph 2-115, Reporting Weather Conditions, to require the tower supervisor to notify tower and radar approach control facility personnel, in addition to the National Weather Service observer, of the deterioration of prevailing visibility to less than 3 miles. Additionally, require the controllers to issue the visibility value to pilots until the information is broadcast on the ATIS and the pilots have acknowledged receipt of the information. (Class II, Priority Action) (A-95-41)

Amend FAA Order 7110.65, Chapter 2, Section 6, paragraph 2-113, to require radar and tower controllers to display (including on BRITE) the highest levels of precipitation, whether it is VIP level 1 or level 6, as depicted by ASR-9 radar, and issue the information to flightcrews. (Class II, Priority Action) (A-95-42)

Provide clear guidance to all air traffic controllers and supervisors that "blanket broadcasts" in the tower cab without receiving acknowledgments are unacceptable methods of communicating information, and require that all advisories, coordination, and pertinent information disseminated to controllers are acknowledged by the individual controller to ensure receipt of the information. (Class II, Priority Action) (A-95-43)

Require that the FAA record the precipitation levels detected by the ASR-9 radar system, and retain the information for use in the reconstruction of events during incident/accident investigations. (Class II, Priority Action) (A-95-44)

Develop and disseminate guidance and definitive standards to FAA inspectors to ensure a clearly identified system of checks and balances for FAA programs, such as "compliance through partnership," and provide the necessary training to ensure the understanding of such programs. (Class II, Priority Action) (A-95-45)

Require that Principal Operations Inspectors (POIs) ensure that their respective air carrier(s) adhere to the company's operating procedures, and emphasize rigorous compliance to checklist procedures. (Class II, Priority Action) (A-95-46)

Review all low level windshear alert system (LLWAS) installations to identify possible deficiencies in performance, similar to those identified by the sheltered wind sensors at the Charlotte/Douglas International Airport, and correct such deficiencies to ensure optimum performance of the LLWAS. (Class II, Priority Action) (A-95-47)

In cooperation with the National Weather Service, re-evaluate the Central Weather Service Unit (CWSU) program and develop procedures to enable meteorologists to disseminate information about rapidly developing hazardous weather conditions, such as thunderstorms and low altitude windshear, to FAA TRACONs and tower facilities immediately upon detection. (Class II, Priority Action) (A-95-48)

Reevaluate the *Windshear Training Aid* based on the facts, conditions, and circumstances of this accident, with the view toward incorporating additional simulator training cues, such as scenarios in which no turbulence is encountered, before the onset of the actual windshear, and to include procedures for using the windshear escape maneuver, in lieu of a missed approach procedure, when the airplane is in the final approach phase (below 1,000 feet) and conditions conducive to windshear are present, regardless of whether the pilot encounters airspeed fluctuations or precipitation. (Class II, Priority Action) (A-95-49)

Develop standards for forward-facing, integrated child safety seats for transport category aircraft. (Class II, Priority Action) (A-95-50)

Revise 14 Code of Federal Regulations Parts 91, 135, and 121 to require that all occupants be restrained during takeoff, landing, and turbulent conditions, and that all infants and small children be restrained in a manner appropriate to their size. (Class II, Priority Action) (A-95-51)

--to the National Weather Service:

Reevaluate, in cooperation with the FAA, the CWSU program, and develop procedures to enable meteorologists to disseminate information about rapidly developing hazardous weather conditions, such as thunderstorms and low altitude windshear, to FAA TRACONs and tower facilities immediately upon detection. (Class II, Priority Action) (A-95-52)

--to USAir:

Conduct periodic check airmen training and flight check reviews to ensure standardization among check airmen with regard to complying with USAir's operating procedures. (Class II, Priority Action) (A-95-53)

Reemphasize the necessity for flightcrews to achieve and maintain diligence in the use of all applicable checklists and operating procedures. (Class II, Priority Action) (A-95-54)

Reemphasize in pilot training and flight checking the cues available for identifying convective activity and recognizing associated microburst windshears; and provide additional guidance to pilots on operational (initiation and continuation of flight) decisions involving flight into terminal areas where convective activity is present. (Class II, Priority Action) (A-95-55)

Review company procedures regarding passenger counts on manifests to ensure their accuracy and accountability of all occupants on the airplane. (Class II Priority Action) (A-95-56)

Additionally, as a result of the design feature in the on-board windshear warning system that prevented nuisance alerts while the airplane's flaps were in transit, on November 28, 1994, the Safety Board issued the following safety recommendations to the Federal Aviation Administration:

A-94-208

Issue a Flight Standards Information Bulletin to operators of aircraft equipped with a Honeywell Standard Windshear System to assure that flightcrew members of those airplanes are advised of the current limitations of the system that delays windshear warnings to flightcrew members when the flaps are in transition.

A-94-209

Conduct a review of the certification of the Honeywell Standard Windshear System, with emphasis on performance while the flaps are in transition. and require that the system be modified to ensure prompt warning activation under those circumstances.

A-94-210

Modify Technical Standard Order C-117 to ensure that windshear warning systems undergo testing with the flaps in transition before granting certification.

On February 13, 1995, the FAA responded to these recommendations and indicated that it will take the following action:

> A-94-208
>
> FAA will issue a flight standards bulletin by March 31, 1995;
>
> A-94-209
>
> FAA is reviewing the Honeywell Standard Windshear Detection System and other systems to determine if these systems delay detection of windshear during flap configuration changes....
>
> A-94-210
>
> FAA is revising the Technical Standard Order (TSO) C-117...to require the applicant show by analysis or other suitable means that the system threshold is above a point at which nuisance warnings would be objectionable under conditions of severe turbulence or aircraft change of configuration; i.e., flaps and/or gear retraction....

The FAA also intends to issue an Airworthiness Directive (AD) to revise the Airplane Flight Manual (AFM) and AFM Supplements for all Honeywell Standard Windshear Detection systems to caution the flightcrew that during flap configuration changes the system is desensitized, and that alerts resulting from windshear encounters will be delayed. Additionally, the FAA will require Honeywell to design a modification to the system that ensures that windshear warning system activation will occur during flap transition.

On March 27, 1995, the Safety Board classified these recommendations "Open--Acceptable Response."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

James E. Hall
Chairman

Robert T. Francis II
Vice Chairman

John Hammerschmidt
Member

April 4, 1995

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified about the accident involving USAir flight 1016 about 1915 on July 2, 1994. A full Go-Team was dispatched to Charlotte later that evening via the FAA's Gulfstream IV. The Investigator-In-Charge (IIC) was Mr. Gregory A. Feith, and Mr. John Hammerschmidt was the Board Member who accompanied the team to Charlotte. The on-scene investigation was conducted over a period of 8 days. Follow-up investigative activities were conducted at various locations and involved extensive operations, airworthiness, air traffic control, and aircraft performance matters.

Investigative groups were convened at the Safety Board's Headquarters in Washington, D. C., to read out the cockpit voice recorder (CVR) and flight data recorder (FDR) after they were recovered from the accident airplane and transported to the Safety Board.

The following were designated as parties to the investigation:

1. The Federal Aviation Administration (FAA)
2. USAir, Inc.
3. Air Line Pilots Association (ALPA)
4. Association of Flight Attendants (AFA)
5. International Association of Machinists (IAM)
6. Douglas Aircraft Company (DAC)
7. National Air Traffic Controllers Association (NATCA)
8. Honeywell, Inc.
9. National Weather Service (NWS)

2. Public Hearing

A public hearing, chaired by Member John Hammerschmidt, was held in Charlotte, North Carolina, from September 19 through 22, 1994.

APPENDIX B

COCKPIT VOICE RECORDER TRANSCRIPT

LEGEND

RDO	Radio transmission from accident aircraft
CAM	Cockpit area microphone voice or sound source
-1	Voice identified as Pilot-in-Command (PIC)
-2	Voice identified as Co-Pilot
CAEGND	Radio transmission from Columbia ground control
CAETWR	Radio transmission from Columbia tower
CAEDEP	Radio transmission from Columbia departure control
CLTATIS	Radio transmission from Charlotte air terminal information service
ATL	Radio transmission from Atlanta Center
APR1	Radio transmission from first Charlotte approach controller
OPS	Radio transmission from USAir flight operations
APR2	Radio transmission from second Charlotte approach controller
TWR	Radio transmission from Charlotte tower
ACFT	Radio transmission from unknown aircraft
US983	Radio transmission from USAir flight 983
US806	Radio transmission from USAir flight 806
5211	Radio transmission from flight 5211
*	Unintelligible word
@	Non pertinent word
#	Expletive
%	Break in continuity
( )	Questionable insertion
[ ]	Editorial insertion
....	Pause

Note: Times are expressed in eastern daylight time (EDT).

As part of the Safety Board's accident investigation process, the Captain, and First Officer were invited to review the CVR group's transcript and provide suggested corrections or additions. This review was conducted on July 29, 1994 and suggested the following changes. The CVR group was subsequently re-convened on August 9, 1994 and all items except numbers three, five, and part of eight were adopted into the final transcript.

1. Statement at time 1841:18, change "folks" to "seven".
2. Statement at time 1816:54, change " * " to "two".
3. Statement at time 1819:00, [pilots suggested this was non-pertinent].
4. Statement at time 1826:00, change to: **CAM-1**
5. Statement at time 1831:03, change to "Karen".
6. Statement at time 1835:32, change "fuel" to "four".
7. Statement at time 1838:38, after ****, add "VOR" .
8. Add statement at time 1842:31.5, **CAM-1** "firewall power".

Albert G. Reitan
Transportation Safety Specialist (CVR)

Attachment:

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
START of RECORDING			
START of TRANSCRIPT			
1811:26 CAM-2	engine instruments?		
1811:27 CAM-1	check.		
1811:27 CAM-2	check.		
1811:28 CAM-2	start valves?		
1811:28 CAM-1	lights out.		
1811:29 CAM-2	ignition?		
1811:30 CAM-1	off.		
1811:30 CAM-2	anti ice?		
1811:31 CAM-1	off.		
1811:32 CAM-2	electrical systems?		
1811:33 CAM-1	checked.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1811:33 **CAM-2**	A/C supply?		
1811:34 **CAM-1**	auto.		
1811:34 **CAM-2**	hydraulics?		
1811:34 **CAM-1**	on high on checked.		
1811:35 **CAM**	[sound of loud click]		
1811:36 **CAM-2**	annunciator panel's checked.		
1811:36 **CAM-1**	checked.		
1811:37 **CAM-2**	(door lights locked) shoulder harness?		
1811:38 **CAM-1**	on left.		
		1811:41 **RDO-2**	and ah ten sixteen taxi now.
		1811:42 **CAEGND**	ten sixteen taxi to runway one one.
		1811:45 **RDO-2**	thank you sir.
1811:47 **CAM**	[sound of loud click]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1811:50 CAM	[three tones similar to those of takeoff warning horn]		
1811:54 CAM	[non pertinent conversation]		
1812:13 CAM	[sound of click]		
1812:24 CAM-2	ah... I'll do this take ..... air conditioning auto shut off?		
1812:27 CAM-1	it's armed.		
1812:27 CAM-2	* horizon * *.		
1812:29 CAM-1	it's checked.		
1812:30 CAM-2	waiting on a "W" ... waiting on a "W" and "B".		
1812:32 CAM-2	ahh.		
1812:34 CAM-?	* * *.		
1812:42 CAM-2	the trip I just got off here .. everybody's ... it's all running together here now.		
1812:51 CAM	[non pertinent conversation]		

INTRA-COCKPIT COMMUNICATION TIME & SOURCE	INTRA-COCKPIT COMMUNICATION CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	AIR-GROUND COMMUNICATION CONTENT
		1814:06 RDO-2	hello there Columbia ten sixteen.
		1814:12 CAEOPS	ten sixteen go ahead sir.
		1814:13 RDO-2	yeah you got the weight and balance?
		1814:18 CAEOPS	yes sir we've got gross weight without fuel seven two three two five gross takeoff eight six three two five .. stabilizer four point seven you've got fifty seven (or possibly "folks") on board.
		1814:29 RDO-2	alright ah got a good copy thank you much.
		1814:32 CAEOPS	have a good one.
1814:38 CAM-1	I thought you said it's gonna be a light one?		
1814:39 CAM-2	well okay ah you got four point seven.		
1814:41 CAM-1	set.		
1814:42 CAM	[three sounds similar to stab. trim warning]		
1814:45 CAM-1	ah [masked] trim set zero zero.		
1814:47 CAM-2	zero zero.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND CC NICATION	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1814:47 CAM-2	that's five blue light.		
1814:48 CAM-1	five five and a blue light.		
1814:55 CAM-2	and ah takeoff data eighty seven thousand is ah, thirty thirty three one forty one.		
1815:00 CAM-1	set.		
1815:01 CAM-2	takeoff warning?		
1815:03 CAM-1	checked.		
1815:04 CAM-2	takeoff briefing ... twenty-five hundred feet .. and ah thirty three four is departure.		
1815:10 CAM-1	okay.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1815:14 **PA-2**	good afternoon folks from the flight deck we'd like to say welcome aboard to you ... ah we're next in line for departure we'll be on our way momentarily to charlotte .. once we're airborne just about twenty minutes of flight time up to ah Charlotte Douglas ah airport ... the weather up there is just about what you see out the window .. partly cloudy skies they have ninety degrees on the last hour .. sit back and enjoy the flight at this time we'd like to ask the flight attendants to please take their seats for departure ... welcome aboard.		
		1815:39 **CAETWR**	USAir ten sixteen Columbia tower ready?
		1815:42 **RDO-1**	you betcha.
		1815:43 **CAETWR**	USAir ten sixteen fly runway heading runway one one cleared for takeoff.
		1815:47 **RDO-1**	alright ah runway heading we're cleared to go USAir ten sixteen.
1815:50 **CAM**	[sound similar to that of increase in engine power]		
1815:52 **CAM-2**	* * (fuel) * set we ready?		
1815:53 **CAM-2**	flight attendants been advised, ignition?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1815:55 **CAM-1**	both.		
1815:56 **CAM-2**	anti-skid?		
1815:57 **CAM-1**	go ahead.		
1815:58 **CAM-2**	no light .. flight controls?		
1815:58 **CAM-1**	bottom.		
1815:59 **CAM-2**	tops all free .. annunciator panel?		
1816:00 **CAM-1**	checked.		
1816:01 **CAM-2**	transponder DME?		
1816:04 **CAM-1**	TA RA TCAS.		
1816:05 **CAM-2**	got ah, fourteen six showing supposed to have ah, thirteen six.		
1816:08 **CAM-1**	that's right.		
1816:10 **CAM-2**	I got your ah, on the inbound radial me on the outbound radial.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1816:13 **CAM-1**	okay ... ready to roll.		
1816:17 **CAM-2**	I'm gonna kick (the parking brake off).		
1816:19 **CAM-1**	you got it.		
1816:20 **CAM**	[sound of loud click similar to that of parking brake being released]		
1816:23 **CAM**	[sound of increase in engine power]		
1816:25 **CAM-1**	spooled.		
1816:30 **CAM-1**	power's set.		
1816:36 **CAM-1**	eighty knots, power check's okay.		
1816:44 **CAM**	[sound similar to that of nose gear on runway]		
1816:48 **CAM-1**	"V" one.		
1816:50 **CAM-1**	"R".		
1816:54 **CAM-1**	two.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1816:59 **CAM-2**	positive rate, gear up.		
1817:03 **CAM**	[sound similar to that of gear handle actuation]		
1817:03 **CAM-1**	your throttles.		
1817:05 **CAM**	[sound similar to that of trim motion warning horn]		
1817:07 **CAM**	[sound similar to that of trim motion warning horn]		
1817:10 **CAM**	[sound similar to that of trim motion warning horn]		
		1817:18 **CAETWR**	USAir ten sixteen contact departure
		1817:20 **RDO-1**	ten sixteen good day.
1817:28 **CAM-2**	flaps slats after takeoff.		
		1817:31 **RDO-1**	USAir ten sixteen is with you climbing * - two point five.
1817:35 **CAM**	[sound similar to that of flap handle actuation]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1817:36 **CAEDEP**	USAir ten sixteen Columbia departure radar contact turn left heading two niner zero .. once you're established on that heading I'll have higher for you .. maintain two thousand five hundred.
		1817:43 **RDO-1**	twenty five hundred left two ninety, USAir ten sixteen.
1817:47 **CAM**	[concurrent with previous transmission sound similar to altitude alert signal]		
1817:58 **CAM-2**	Owens uh, little Owens airport right across the river over there.		
1818:06 **CAM-1**	what stadium is that?		
1818:07 **CAM-2**	that's the University of South Carolina, Gamecocks.		
1818:10 **CAM-1**	uh huh.		
1818:21 **CAM-2**	that's all part of the school right down there.		
		1818:23 **CAEDEP**	USAir ten sixteen, climb and maintain one zero thousand.
		1818:25 **RDO-1**	one zero thousand, USAir ten sixteen.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1818:30 **CAM-1**	ten thousand.		
1818:31 **CAM-2**	** on the right.		
1819:00 **CAM-1**	do you want me to fly while you eat?		
1819:02 **CAM-2**	no, I'm alright.		
1819:03 **CAM-1**	OK.		
1819:03 **CAM-?**	**.		
1819:06 **CAM**	[sound of several clicks]		
		1819:42 **CAEDEP**	USAir ten sixteen, contact Jacksonville center, one two four point seven. good day.
		1819:46 **RDO-1**	twenty four seven, USAir uh, ten sixteen. goodday.
		1819:56 **RDO-1**	USAir ten sixteen's climbing to ten.
		1819:59 **JAX**	USAir ten sixteen good evening, climb and maintain one two thousand, twelve.
		1820:02 **RDO-1**	one two thousand, USAir ten sixteen.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1820:05 **CAM-1**	one two thousand.		
1820:06 **CAM-2**	ten.		
1820:08 **CAM-1**	in the box.		
1820:10 **CAM-2**	they just gave us a heading, they didn't say intercept or do anything.		
		1820:16 **RDO-1**	do you want US ten sixteen to maintain the two ninety heading?
		1820:19 **JAX**	USAir ten sixteen, uh you join Columbia three fourteen radial, as filed.
		1820:26 **RDO-1**	USAir ten sixteen.
1820:29 **CAM-2**	OK, OK.		
		1821:21 **JAX**	USAir seventeen sixty six, keep your speed up for spacing with company into Charlotte and what will your speed be tonight?
		1821:28 **RDO-1**	was that for US ten sixteen?

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1822:25 **JAX**	USAir ten sixteen, contact Atlanta center one three five point three five, good day.
		1822:30 **RDO-1**	thirty five thirty five, US ten sixteen, good day.
		1822:40 **RDO-1**	USAir ten sixteen, one two thousand.
		1822:43 **ATL**	ten sixteen, Atlanta center, current altimeter is three zero zero two. turn thirty degrees right to intercept UNARM arrival.
		1822:50 **RDO-1**	thirty right to the UNARM, thirty oh two for the altimeter, US ten sixteen.
1822:59 **CAM-1**	I'm off.		
		1823:00 **CLTATIS**	one zero weather. visibility six miles haze. temperature eight eight, dew point six seven. wind one five zero at eight. altimeter three zero zero one. ILS approaches runway one eight left, one eight right. localizer back course runway two three approach in use. if unable to comply with speed restrictions, advise. read back all hold short instructions. advise you have information, Yankee. Charlotte International Airport arrival information Yankee, Charlotte two one five one Zulu weather. five thousand scattered. visibility six miles haze.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1823:38 **CAM-1**	five thousand scattered. six in haze. eighty eight degrees, wind's one fifty at eight. three zero zero one. eighteen left right and two three.		
1823:45 **CAM-2**	thank you.		
1824:40 **CAM-2**	how old are you Mike?		
1824:41 **CAM-1**	thirty eight.		
1824:42 **CAM-2**	thirty eight?		
1824:44 **CAM-1**	how about yourself.		
1824:48 **CAM-2**	I'll be, forty two on the twenty sixth of July.		
1824:54 **CAM-1**	is that right? I had you figured about thirty five.		
1824:57 **CAM-2**	did you really?		
1824:57 **CAM-1**	oh yeah.		
1824:59 **CAM-2**	I knew there's something I liked about you.		
1825:05 **CAM-1**	[sound of laughter]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1825:13 **CAM-1**	what kind of airplanes you fly corporate?		
1825:17 **CAM-2**	little Lear and I flew a Citation ** Diamond and a King Air, **.		
1825:28 **CAM-1**	that's nice equipment.		
1825:29 **CAM-2**	yeah, yeah, pretty nice and uh, and a lot of piston bangers, Navajos and all that stuff.		
1825:36 **CAM-1**	yeah. I've got a lot of time in Navajos, Aztecs, Senecas.		
1825:42 **CAM-2**	I got a lot of time in Navajos.		
		1825:44 **ATL**	USAir ten sixteen, fly heading, zero one zero intercept the Charlotte two thirty two UNARM arrival.
		1825:50 **RDO-1**	is that zero one zero for USAir ten sixteen?
		1825:53 **ATL**	correct, zero one zero intercept the Charlotte two thirty two UNARM arrival.
		1825:57 **RDO-1**	USAir ten sixteen.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1826:00 **CAM-1**	I don't have much Cessna. the place I worked I was flying for a Beech and Piper dealer, so I had a lot .... I gave a lot of dual in an Aztec C ** multi-engine rating. ** got about seven hundred hours *** Apache.		
1826:17 **CAM-2**	I got a lot of time in Navajo Chieftain and a lot of time in Cessna four oh twos and uh, four fourteen four twenty ones.		
1826:24 **CAM-1**	** I always thought they were pretty good airplanes.		
1826:25 **CAM-2**	yeah, yeah, it is. I enjoyed flying it.		
1826:30 **CAM-1**	I didn't care much for uh, some of the Cessna four oh twos uh, and stuff. I just didn't think they, they didn't do what they said they'd do.		
1826:37 **CAM-2**	alright. you know, there's a lot of things where you know, there's trade-offs. the Cessna wasn't nearly as good a short field airplane as the Nav, Navajo. is uh, about the same speed, except the Cessna might have been a little bit faster depending on which model *.		
1826:55 **CAM-1**	yeah.		
		1826:57 **ATL**	USAir ten sixteen, contact Charlotte approach one two five point three five, and before you go sir uh, slow back to two hundred and fifty knots, and Charlotte two five three five.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1827:06 **RDO-1**	we'll slow 'er back, twenty five thirty five. US ten sixteen. have a good weekend.
		1827:10 **ATL**	sir.
		1827:14 **RDO-1**	USAir ten sixteen, twelve thousand Yankee.
		1827:17 **APR1**	USAir ten sixteen, Charlotte approach, expect runway one eight right.
		1827:20 **RDO-1**	eighteen right.
1827:27 **CAM-1**	I'll be off.		
		1827:32 **RDO-1**	Charlotte, ten sixteen.
		1827:36 **OPS**	go ahead.
		1827:37 **RDO-1**	we should be in in about fifteen minutes, got one uh, write-up uh, maintenance.
		1827:42 **OPS**	OK, go ahead with your write-up.
		1827:43 **RDO-1**	we got uh, we got some blue fluid leaking out of the uh, out of the lav.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1827:49 **OPS**	** OK blue fluid leaking out of the lav and give me your call sign one more time.
		1827:53 **RDO-1**	USAir ten sixteen aircraft nine five four.
		1827:56 **OPS**	OK, ten sixteen thank you sir inbound to B thirteen. that aircraft turns uh, nine eighty three to Memphis.
		1828:01 **RDO-1**	thank you.
1828:11 **PA-1**	ladies and gentlemen, we're forty miles from Charlotte **** should be on the ground **** safe and happy holiday. at this time we'd like our flight attendants to please prepare the cabin for arrival.		
		1828:20 **APR1**	USAir ten sixteen, descend and maintain one zero thousand.
		1828:29 **RDO-1**	one zero thousand, US ten sixteen.
		1828:32 **APR1**	normal speeds fine right now ten sixteen.
		1828:33 **RDO-1**	ten sixteen.
1828:36 **CAM-1**	care to deviate?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1828:38 **CAM-2**	uh well when we join this radial here, I'm gonna, we're gonna make a little right turn.		
1828:44 **CAM-1**	ah OK, I'm sorry, see I wasn't paying attention. ... see I understand lotta times when I say something I'm not paying attention.		
1828:51 **CAM-2**	uh, OK. ... your trying to understand the things you don't know are you?		
1828:51 **CAM-1**	I'm trying to consider the things I don't know about. and I'm not always doin'a good job of that.		
1829:04 **CAM-1**	B thirteen, she says.		
1829:05 **CAM-2**	B thirteen.		
1829:18 **CAM-1**	my guess is that it just spilled down through the floor, ...so I'm not going to put it in the book until I talk to a mechanic.		
1829:46 **CAM-2**	eleven ten.		
CAM-?	**.		
1829:54 **CAM-2**	there's more rain than I thought there was. it's startin' ** pretty good. a minute ago. now it's held up.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1829:56 **CAM-1**	yeah.		
1829:57 **CAM**	[four beeps similar to altitude alert signal]		
		1830:11 **RDO-1**	Charlotte, US ten sixteen.
		1830:14 **APR1**	USAir ten sixteen, go ahead.
		1830:15 **RDO-1**	we're gonna swing just uh, five degrees to the right here just uh, for about a quarter half mile.
		1830:21 **APR1**	that's fine.
1830:44 **CAM-1**	bumpy in there		
1830:45 **CAM-2**	yeah.		
1831:03 **CAM-2**	I wonder if @ is going to come screaming up here in a minute?		
1831:23 **CAM-2**	my wife was born and raised in a little town, a little town right down here just south of uh, Charlotte.		
1831:28 **CAM-1**	oh, is that right?		
1831:30 **CAM-2**	Rock, Rock Hill, South Carolina.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1831:32 **CAM-1**	Rock Hill.		
		1831:34 **APR1**	and USAir ten sixteen, let's start reducing now, if you would please.
		1831:37 **RDO-1**	USAir ten sixteen.
1832:18 **CAM-1**	looks like that's settin' just off the edge of the airport.		
1832:24 **CAM-2**	this thing starts to swing and then, doesn't come over there.		
1832:27 **CAM-1**	and it just goes to show ya.		
1832:31 **CAM-2**	just can't find a good VOR.		
CAM-1	yeah.		
1833:14 **CAM-2**	let's go right through that hole.		
1833:16 **CAM-1**	yeah.		
		1833:17 **RDO-1**	US. ... uh, approach, US ten sixteen.
		1833:18 **APR1**	ten sixteen, go ahead.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1833:19 **RDO-1**	we're showin' a, little build-up here at uh, looks like it's sittin' on the radial. like to go about five degrees to the left, to the west.
		1833:27 **APR1**	how far ahead are you lookin' ten sixteen?
		1833:30 **RDO-1**	'bout fifteen miles.
		1833:32 **APR1**	I'm goin' to turn you before you get there, I'm goin' to turn you in about five miles northbound.
		1833:35 **RDO-1**	OK.
1833:38 **CAM-2**	good call.		
1833:57 **CAM-1**	we need to sashay around that right side there. you'll have enough.		
		1834:00 **APR1**	USAir ten sixteen turn left heading three six zero.
		1834:04 **RDO-1**	OK, left to three sixty, US uh, ten sixteen.
1834:11 **CAM-2**	that's too far the other way **.		
1834:16 **CAM-1**	and let's go though this saddle here.. it won't be that bad.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1834:17 **CAM-2**	OK.		
1834:37 **CAM-1**	now you ought to be able to come left up here. three sixty.		
1834:44 **CAM-2**	yeah **. *** I apologize ***.		
1834:47 **CAM-1**	I didn't know if you copied that or not.		
1834:51 **CAM-2**	yeah, I'm just trying to give them a little smoother ride than what they've had so far. ha, ha.		
		1835:01 **APR1**	USAir ten sixteen, descend and maintain six thousand.
		1835:04 **RDO-1**	out of ten for six. US ten sixteen.
1835:06 **CAM-2**	what runway did he say?		
1835:07 **CAM-1**	eighteen right.		
		1835:09 **APR1**	USAir ten sixteen contact approach one one niner zero.
		1835:12 **RDO-1**	nineteen zero, US ten sixteen, gooday.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1835:18 **RDO-1**	USAir ten sixteen, ten for six.
		1835:21 **APR2**	USAir ten sixteen Charlotte approach, maintain four thousand runway one eight right.
		1835:25 **RDO-1**	four thousand for the right side.
1835:27 **CAM-2**	alright that's one eleven uh, three and uh, one eighty one.		
1835:32 **CAM-1**	OK, your cabin's down, four pumps on, seat belt sign's on, hydraulics', on high on check, altimeters flight instruments thirty oh one, set.		
1835:41 **CAM-2**	set.		
1835:48 **CAM-1**	landing data EPR, *** (eighty seven) for one twenty two.		
1835:49 **CAM-2**	twenty two.		
1835:50 **CAM-1**	EPR set, shoulder harness?		
1835:51 **CAM-2**	fastened.		
1835:52 **CAM-1**	approach brief?		

INTRA-COCKPIT COMMUNICATION TIME & SOURCE	INTRA-COCKPIT COMMUNICATION CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	AIR-GROUND COMMUNICATION CONTENT
1835:53 CAM-2	visual back up ILS.		
1835:54 CAM-?	***.		
		1835:54 APR2	USAir ten sixteen turn ten degrees right, descend and maintain two thousand three hundred vectors to visual approach to one eight right.
		1836:00 RDO-1	ten right, down to twenty three hundred, USAir ten sixteen.
1836:03 CAM-1	looks like we're number one.		
1836:04 CAM-2	(yeah) right.		
1836:21 CAM-2	slats.		
CAM	[clicks similar to flap handle being moved]		
1836:24 CAM-1	slats out.		
1836:28 CAM	[two one second sounds similar to stabilizer motion warning horn]		
1836:37 CAM-1	this thing just drops like a rock, doesn't it.		
1836:38 CAM-2	boy doesn't it.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1836:40 **CAM**	[another sound similar to stabilizer motion warning horn]		
1836:46 **CAM-2**	better than that # Boeing can do.		
1836:48 **CAM-1**	the, the seven twos come down pretty good.		
1836:50 **CAM-2**	aw, the seven two will, yeah.		
1836:52 **CAM-2**	yeah that three hundred ...		
		1836:59 **APR2**	I'll tell you what, USAir ten sixteen, may get some rain just south of the field. might be a little bit commin' off north, just expect the ILS now. amend your altitude maintain three thousand.
		1837:08 **RDO-1**	OK, we'll maintain three, and uh, we're comin' right down. US ten sixteen.
		1837:13 **APR2**	OK, I'll turn your base as soon as I can get you outside the marker.
		1837:15 **RDO-1**	OK.
1837:18 **CAM-1**	three thousand.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1837:20 **CAM-2**	three thousand.		
1837:34 **CAM-1**	I'm glad we got that sandwich down there because I hate eatin' late. I'd rather eat something nasty early, than		
1837:41 **CAM-2**	something good late, ha ha.		
1837:43 **CAM-1**	something good late within reason.		
		1837:44 **APR2**	USAir ten sixteen, turn right heading zero nine zero.
		1837:47 **RDO-1**	zero nine zero, US ten sixteen.
1837:56 **CAM**	[sound similar to stabilizer motion warning horn]		
1838:22 **CAM-2**	four three.		
1838:26 **CAM**	[four beeps sound similar to altitude alert]		
		1838:27 **APR2**	USAir ten sixteen, turn right heading one seven zero, four from SOPHE, correction four from yeah SOPHE, cross SOPHE at or above three thousand cleared ILS one eight right approach.
		1838:34 **RDO-1**	SOPHE at or above three, cleared the right side. USAir ten sixteen.

TIME & SOURCE	INTRA-COCKPIT COMMUNICATION CONTENT	TIME & SOURCE	AIR-GROUND COMMUNICATION CONTENT
1838:38 CAM-1	looks like it's sittin' right on the [unreadable due to unrelated ATC transmission through cockpit speaker] *****.		
1838:47 CAM-2	flaps to five.		
1838:48 CAM	[sound similar to flap handle being moved]		
1838:49 CAM-1	five.		
1838:50 CAM-2	I'll ding 'em.		
1838:51 CAM-1	OK.		
1838:52 CAM	[sound of three chimes)		
1839:02 CAM-1	if we have to bail out *-		
1839:03 CAM-2	*.		
1839:06 CAM-1	it looks like we bail out to the right.		
1839:09 CAM-2	amen.		
1839:09 CAM-1	ten miles to the VOR which is off the end of the runway. 'bout a mile off the end of the runway.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1839:14 **CAM-2**	yeah.		
1839:16 **CAM-1**	so I think we'll be alright.		
1839:20 **CAM-1**	chance of shear.		
		1839:24 **APR2**	Air ten sixteen, contact tower one two six point four.
		1839:27 **RDO-1**	twenty six four, US ten sixteen. gooday.
		1839:29 **APR2**	so long.
1839:30 **CAM-2**	fifteen.		
1839:31 **CAM**	[sounds similar to flap handle movement]		
		1839:33 **ACFT**	ah that's OK, its probably better off we didn't go anyway.
		1839:38 **RDO-1**	US, USAir ten sixteen for uh, eighteen right.
		1839:42 **TWR**	USAir ten sixteen ...
1839:43 **CAM-2**	gear down.		

INTRA-COCKPIT COMMUNICATION TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
		1839:44 TWR	...Charlotte tower, runway ...
1839:45 CAM	[click and sound of rushing air similar to landing gear being extended]		
		1839:47 TWR	...one eight right. cleared to land. following F one hundred short final. previous arrival reported smooth ride all the way down the final.
		1839:49 RDO-1	USAir ten sixteen, I'd appreciate a pirep from the guy in front of us.
1839:55 CAM-1	ignition's off, gear ?		
1839:57 CAM-2	down.		
1839:59 CAM-1	spoilers.		
1839:59 CAM	[sound of click similar to spoilers being armed]		
1840:00 CAM-2	lights out and armed.		
1840:01 CAM-1	lights out and armed, did you ring 'em?		
1840:02 CAM-2	yes I did.		
CAM-1	OK.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1840:05 **CAM-2**	twenty five.		
1840:06 **CAM-1**	twenty five.		
1840:06 **CAM**	[two clicks similar to flap handle being moved]		
1840:10 **CAM-2**	yep, laying right there this side of the airport, isn't it?		
1840:14 **CAM-1**	well.		
1840:15 **CAM-2**	the edge of the rain is, I'd say.		
1840:15 **CAM-1**	yeah.		
1840:19 **CAM**	[sound similar to stabilizer trim in motion warning horn]		
1840:21 **CAM-2**	flaps forty please.		
1840:22 **CAM-1**	forty flaps.		
1840:22 **CAM**	[two clicks similar to flap handle being moved]		
		1840:29 **TWR**	USAir nine eighty three, turn left the next forward high speed and say your ride uh, how the ride was on final sir?

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1840:35 **US983**	smooth, USAir nine eighty three.
		1840:37 **TWR**	nine eighty three roger, you can make the reverse. contact ground control, point niner.
		1840:40 **US983**	USAir nine eighty three.
		1840:42 **TWR**	USAir ten sixteen, company "FK" one hundred just exited the runway, sir he said smooth ride.
		1840:46 **RDO-1**	thank you uh. what are you showing the winds?
		1840:48 **TWR**	USAir nine sixteen wind is showing one zero zero at one nine.
		1840:53 **RDO-1**	USAir ten sixteen.
1840:56 **CAM-2**	one zero zero at one nine. eh?		
		1840:59 **TWR**	USAir ten sixteen, wind now one one zero at two one.
		1841:02 **RDO-1**	USAir ten sixteen.
1841:05 **CAM-1**	stay heads up.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		1841:06 **TWR**	wind shear alert northeast boundary winds one nine zero at one three.
1841:07 **CAM-?**	**** [concurrent with radio transmission]		
		1841:18 **TWR**	Carolina fifty two eleven Charlotte tower, runway one eight right, cleared to land, wind one zero zero at two zero. wind shear alert, northeast boundary wind one nine zero at one seven.
		1841:29 **5211**	appreciate that, fifty two eleven.
		1841:32 **TWR**	USAir eight zero six, you want to just sit tight for a minute sir?
		1841:35 **US806**	yes sir, we'd like to just sit tight.
		1841:37 **TWR**	USAir seven ninety seven company aircraft in front of you is going to sit and wait a while sir. do you want to go in front of him?
		1841:43 **US797**	no no, it wouldn't sound like a good plan. we'll uh, it didn't look like a whole lot to us on the radar taxiing out so it shouldn't be uh, shouldn't be too many minutes.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1841:54 **CAM-1**	here comes the wipers.		
1841:56 **CAM-2**	alright.		
1841:57.6 **CAM**	[sound similar to rain concurrent with sound similar to windshield wipers starts and continues to impact]		
1841:58.9 **CAM-2**	there's, ooh, ten knots right there.		
1842:06.4 **CAM-1**	OK, you're plus twenty.		
1842:14.0 **CAM-1**	take it around, go to the right.		
		1842:16.1 **RDO-1**	USAir ten sixteen's on the go.
1842:17.7 **CAM-1**	max power.		
1842:18.5 **CAM-2**	yeah max power ...		
		1842:18.5 **TWR**	USAir ten sixteen understand you're on the go sir, fly runway heading. climb and maintain three thousand.
1842:19.4 **CAM-2**	flaps to fifteen.		
1842:20.8 **CAM**	[clicks similar to flap handle being moved]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1842:22.0 **CAM-1**	down, push it down.		
		1842:25.5 **RDO-1**	up to three we're takin' a right turn here.
		1842:27.9 **TWR**	USAir ten sixteen, understand you're turning right?
1842:28.4 **CAM-5**	["whoop whoop terrain" sound begins and continues to first sound of impact]		
1842:28.5 **CAM-?**	** power.		
1842:32.7 **CAM**	[vibrating sound similar to aircraft stick shaker begins]		
1842:33.5 **CAM**	[vibrating sound similar to aircraft stick shaker ends]		
1842:35.3 **CAM**	[one beep similar to trim in motion]		
1842:35.6 **CAM**	[sound of impact]		
1842:36.0 **CAM**	[sound of impact]		
1842:36.5 **CAM**	[sound of impact]		

1842:36.6
END of RECORDING
END of TRANSCRIPT

APPENDIX C

METEOROLOGICAL INFORMATION

The Safety Board has investigated numerous windshear-related incidents/accidents involving air carrier aircraft over the past 20 years. A comprehensive examination of the weather conditions and information available to the flightcrew was conducted, not only to develop the events that led to this accident, but to identify deficiencies that might have existed.

The following weather forecasts and observations were current at the time of the accident, and all information was available to the flightcrew through the appropriate means:

Terminal Forecast (FT)

CLT...1300 to 2100 (CLT FT 021717):

5,000 feet scattered; visibility 5 miles, haze; occasional ceiling 5,000 feet broken; visibility 6 plus miles; slight chance ceiling 2,000 feet broken; visibility 2 miles; thunderstorm, moderate rain showers after 1600.

The FT was issued about 1231 by the NWS Forecast office in Raleigh Durham, North Carolina (RDU). The forecast was amended at 1845, and the following amended forecast was valid from 1845 to 2000:

Ceiling 4,500 feet broken; visibility 6 miles; thunderstorm, light rain showers, haze; winds 200 degrees at 10 knots; occasional ceiling 1,000 feet overcast; visibility 1 mile; thunderstorm, heavy rain showers; wind gusts 25 knots.

Area Forecast (FA)

The following information was retrieved from the NWS FA (MIA FA 021812 AMD) and was valid from 1412 on July 2, until 0200 on July 3.

Thunderstorms imply severe or greater turbulence, severe icing, low level windshear, and IFR conditions.

North Carolina

Piedmont...Clouds 2,500 to 3,500 feet scattered; visibility 4 to 6 miles; haze. 1600...Clouds 3,000 to 3,500 feet scattered to broken; tops 8,000 feet; visibility 4 to 6 miles; haze/isolated thunderstorms, moderate rain showers; cumulonimbus tops to 40,000 feet.

The FA was issued by the National Aviation Weather Advisory Unit (NAWAU) in Kansas City, Missouri.

In-flight Weather Advisories

The following AIRMETs [airman's meteorological information] issued at 1545 were valid at the time of the accident:

AIRMET Sierra Update 3 for IFR valid until 2200...
No widespread IFR expected.

AIRMET Tango Update 3 for Turbulence valid until 2200...
No significant turbulence expected except in the vicinity of convective activity.

AIRMET Zulu Update 3 for Icing valid until 2200...
NOTE: AIRMETs, SIGMETs, and Convective SIGMETS are issued by the NAWAU.

Aviation Weather Watch (AWW)

AWW advisories are issued by the National Severe Storms Forecast Center in Kansas City, Missouri. There were no AWWs (severe thunderstorm and tornado watches) in effect for the Charlotte area at the time of the accident.

Meteorological Impact Statement (MIS)

The following excerpted portions of the MIS were issued by the Atlanta Center Weather Service Unit (ACWSU) Meteorologist:

ZTL MIS 01 valid 0935 to 2135...

Widely scattered level 3 to 5 thunderstorms developing after 1400. Movement from 250 degrees at 10 knots...Maxir ıum tops 45,000 to 50,000 feet.

The area encompassed by this MIS included Charlotte and was transmitted to the Charlotte Terminal Radar Approach Control (TRACON) facility.

Runway Visual Range Information

The runway visual range (RVR) data recorded at Charlotte is determined by transmissometers with a 250 feet baseline. The graphs of transmittance for the runway 05 touchdown zone (TD) and runway 36L TD were obtained from the NWS, and the following RVR values were estimated from the graphs:

Runway 05 TD

Time	Transmittance Percent	RVR (Feet)
1835	95	6,000 plus
1840	87	5,500
1845	86	5,000
1849	95	6,000 plus

During the perioa 1840 to 1845, there was a decrease in transmittance to a value of less than 0 percent (RVR of less than 500 feet).

Runway 36L TD

Time	Transmittance Percent	RVR (Feet)
1835	96	6,000 plus
1840	95	6,000 plus
1845	91	6,000 plus
1849	94	6,000 plus

During the period 1840 to 1845, there was a decrease in transmittance to 5 percent (RVR of less than 500 feet).

Runway 36L Rollout (RO)

Time	Transmittance Percent	RVR (Feet)
1835	96	6,000 plus
1840	85	4,500
1845	76	2,800
1850	89	6,000 plus

During the period 1840 to 1845, there was a decrease in the transmittance to 29 percent (RVR of 800 feet).

The runway 36L RO Transmissometer (18R TD) is located about 112 degrees and 1,447 feet from where flight 1016 initially impacted the ground. The runway 36L Midpoint Transmissometer (18R Midpoint) is located about 160 degrees at 4,573 feet from the initial impact point. The runway 36L TD Transmissometer (18R RO) is located about 166 degrees at 7,520 feet from the initial impact point. A detailed review of the runway 36L RO (18R TD) graph of transmittance revealed the following values for the respective estimated times:

Time	RVR Value
18:37:00	6,000 Plus
18:38:00	6,000 Plus
18:39:00	2,400
18:39:31	2,800
18:40:22	2,200
18:40:37	3,500
18:41:10	3,500
18:41:48	3,500
18:42:13	2,400
18:42:17	2,200
18:42:36	1,600
18:43:00	800

As noted in Federal Meteorologist Handbook No. 1, RVR computer readouts should normally agree to within one reportable value when the RVR is derived from the graphs of transmittance. The CLT ATC tower has RVR computer readouts; thus, the following reportable values of RVR: 6,000, 5,500, 5,000, 4,500, 4,000, 3,500, 3,000, 2,800, 2,600, 2,400, 2,200, 1,800, 1,600, 1,400, 1,200, 1,000, 800, 700, 600, 500.

Weather Radar Data

A WSR-74C weather radar is located at Charlotte/Douglas International Airport. The radar is equipped with a Video Integrated Processor (VIP) which permits the observer to determine objectively the intensities of the weather echoes. Based on this capability, the NWS has classified the following six levels of echo intensity and has assigned a VIP number for each level:

VIP Level	Echo Intensity	WSR-57 dBZ Value	WSR-88D dBZ Value
1	weak	18	20-25
2	moderate	30	30-35
3	strong	41	40
4	very strong	46	45
5	intense	50	50
6	extreme	57	55-75

The Charlotte National Weather Service (NWS) Office

The Charlotte NWS is located approximately 1 mile southeast of the Charlotte ATC tower. The primary function of the office is to conduct and disseminate surface weather observations, and it does not issue aviation weather advisories. However, all public severe weather warnings that occur within 50 miles of Charlotte are disseminated locally on AWIS. The NWS office is equipped with various weather detection systems including a WSR-74C weather radar unit. The data from the radar is used to issue publicly disseminated Severe Weather Warnings and to compose special weather statements. However, due to ground clutter, the weather in the area of the airport is difficult to detect.

The NWS office disseminates its observations by Automation of Field Operations and Services (AFOS) "longline" [telephone lines] to the central NWS computer after entering the data into the Micro Computer Aided Paperless Surface Observation (MAPSO), and the Automatic Weather Information Service (AWIS) local network to ATC and a few airline users. The policy of the Charlotte NWS is to enter the data on MAPSO for dissemination on AFOS and subsequently to retransmit this information on the AWIS. This process typically takes several minutes between the completion of an observation and its transmission on AWIS. It is NWS policy that weather observations be transmitted longline first rather than locally, which can result in a delay of several minutes from the time the observation is completed to the receipt of weather information by local aviation interests.

The Charlotte NWS weather service specialist testified at the Safety Board's public hearing that a severe thunderstorm warning would be issued if the radar identified cloud tops were above 50,000 feet, or a level 5 core was observed above 26,000 feet. Rainfall rates are not a criteria for determining weather severity. The specialist also stated that the NWS office was unaware of the VIP level of the thunderstorm that was over CLT at the time of the accident.

Atlanta Center Weather Service Unit (CWSU)

According to Weather Service Operations Manual Chapter D-25, the purpose of the CWSU is to provide weather consultation and advice to managers and staff within the Air Route Traffic Control Center (ARTCC) and to other supported FAA Facilities. This is done through briefings and products (forecasts and nowcasts) describing actual and forecast adverse weather conditions that may affect air traffic flow or operational safety over the ARTCC's portion of the National Airspace System (NAS). The CWSU meteorologist at the Atlanta ARTCC (ZTL) is responsible for over 100,000 square miles of airspace and 15 ATC towers. The meteorologist can issue both verbal and written issuances detailing significant weather that will impact ZTL's airspace. The written advisories comprise Center Weather Advisories and Meteorological Impact Statements.

The CWSU meteorologist worked the 1400 to 2200 shift the day of the accident. Except for an overlap between about 1400 and 1430, he was the only person on shift. This is normal staffing for the CWSU. During the afternoon and evening of the accident, the meteorologist was "met watching" thunderstorm development throughout the ZTL airspace. The radar data being used for weather evaluations included the Doppler radar data from Maxwell Air Force Base (AFB) displayed on a Next Generation Weather Radar (NEXRAD) Principal User Processor (PUP), Radar Remote Weather Display System (RRWDS) imagery from six individual radars, and a Weather Services Incorporated (WSI) mosaic provided through the Harris Meteorologist Weather Processor. There were questions regarding the reliability of the WSI mosaic since a number of radars were either out of service or had been removed from the mosaic by WSI. The CAE WSR-88D data was not available at the CWSU on July 2, 1994, even though the process to start the installation was begun on February 16, 1994. However, the radar data became available on September 13, 1994; 7 days after the Safety Board's request to FAA-AAI-200 as to the reason the data was not available at the time of the accident.

The CWSU meteorologist briefed the Charlotte Terminal Radar Approach Control (TRACON) regarding the thunderstorm potential at about 1408. A graphic weather bulletin was faxed to the TRACON about 1420, and the forecast, valid until 2100, indicated isolated level 4 to 5 thunderstorms for an area that included Charlotte. The area forecast for Charlotte, valid until 2200, indicated isolated thunderstorms, heavy rain showers, with gusts to 45 knots in the vicinity.

About 1520, the CWSU meteorologist was involved in monitoring weather and briefing FAA facilities by phone in the southern portion of the ZTL airspace regarding thunderstorm activity. According to the CWSU meteorologist, the more significant and organized weather activity was in the southern portion of the airspace being monitored. About the time of the accident, the meteorologist was using the Maxwell AFB Doppler radar to study thunderstorm intensity, tops, and movement in the Columbus, Georgia, airspace. According to testimony of the CWSU meteorologist, the Maxwell AFB WSR-88D Doppler weather radar data was of more value than conventional weather radar data in the development of information regarding the thunderstorm activity. This information was subsequently relayed to various airports. At 1843, the meteorologist contacted the Traffic Management Unit (TMU) at ZTL about thunderstorm development in the Charlotte area. Weather radar data from Athens, Georgia, and Maiden, North Carolina, were used to identify the weather conditions. The Athens radar site, located about 140 nautical miles from Charlotte, indicated a VIP level 1 to 2 (weak to moderate) intensity echo; and the Maiden radar site, located about 35 nautical miles northwest of Charlotte, indicated a small VIP level 3 (strong) echo. This information was provided to the TMU, and, at 1839, the Charlotte Approach Control Traffic Management Coordinator advised the TMU that thunderstorm activity was impacting the arrivals. Based on this information, the TMU lowered the airport acceptance rate.

At 1853, the Charlotte TRACON was briefed on the possibility of a VIP level 3 thunderstorm on the north edge of the airport. There were no Center Weather Advisories in effect for the ZTL airspace from 1400 to 2200, and the CWSU meteorologist stated "based on the information available to me, in my judgment, none of the thunderstorm activity in the Atlanta Center's airspace, which I observed on the 1800 UTC - 0200 UTC shift of July 2, 1994, met criteria for the issuance of a Center Weather Advisory." The meteorologist also testified at the Safety Board's public hearing on the accident that a Center Weather Advisory was not issued for the thunderstorm at Charlotte because he was in the process of briefing the Columbus, Georgia, TRACON about weather developments in their airspace about the time of the accident. Also, the meteorologist said that the weather was a more organized area of weather. He also testified that based on the weather activity that he observed in the Charlotte area at the time of the accident, he would not have issued a Center Weather Advisory for thunderstorm activity "because in my judgment, the activity which I noted on the information which I had available and other -- I had no other information that indicated it met the criteria."

USAir Dispatcher

The dispatcher responsible for the release of flight 1016 stated that prior to the release of flight 1016, he reviewed all meteorological information available at the time. Prior to the departure from Columbia, he reviewed the radar summary chart and the CAE and CLT weather radar sites, and, in his judgment, the majority of the weather activity was in the eastern part of North Carolina between Charlotte and Wilmington, North Carolina. The dispatcher stated that he reviewed the radar data recorded at 1851 (about 9 minutes after the accident) and observed on the CAE weather radar a small VIP level 3 echo approximately the size of a "pencil head" just north of Charlotte. However, he had not been in radio contact with flight 1016 after its departure from CAE.

National Aviation Weather Advisory Unit (NAWAU)

The meteorologist at the NAWAU in Kansas City, Missouri, stated that among his many duties, he was responsible for issuing Convective SIGMETs. He stated that he was working at the Convective SIGMET desk from 1600 to midnight on the day of the accident, and that he was the only person working the desk.

He typically issues hourly Convective SIGMETS for hazardous thunderstorms for the country. The criteria for issuance are contained in Weather Service Operations Manual Chapter D-22. On the day of the accident, there were no Convective SIGMETs in effect for the Charlotte area and "there was nothing in that area that would have met criteria for issuance."

The issuance criteria for Convective SIGMETS are as follows:

a) Severe thunderstorms;

b) Embedded thunderstorms;

c) A line of thunderstorms;

d) An area of active thunderstorms affecting at least 3,000 square miles. Active thunderstorms are defined as thunderstorms having a VIP level (i.e. a reflectivity intensity) of 4 or greater and/or having significant satellite signatures and affecting at least 40 percent of the area outlined.

Additional Weather Equipment at CLT

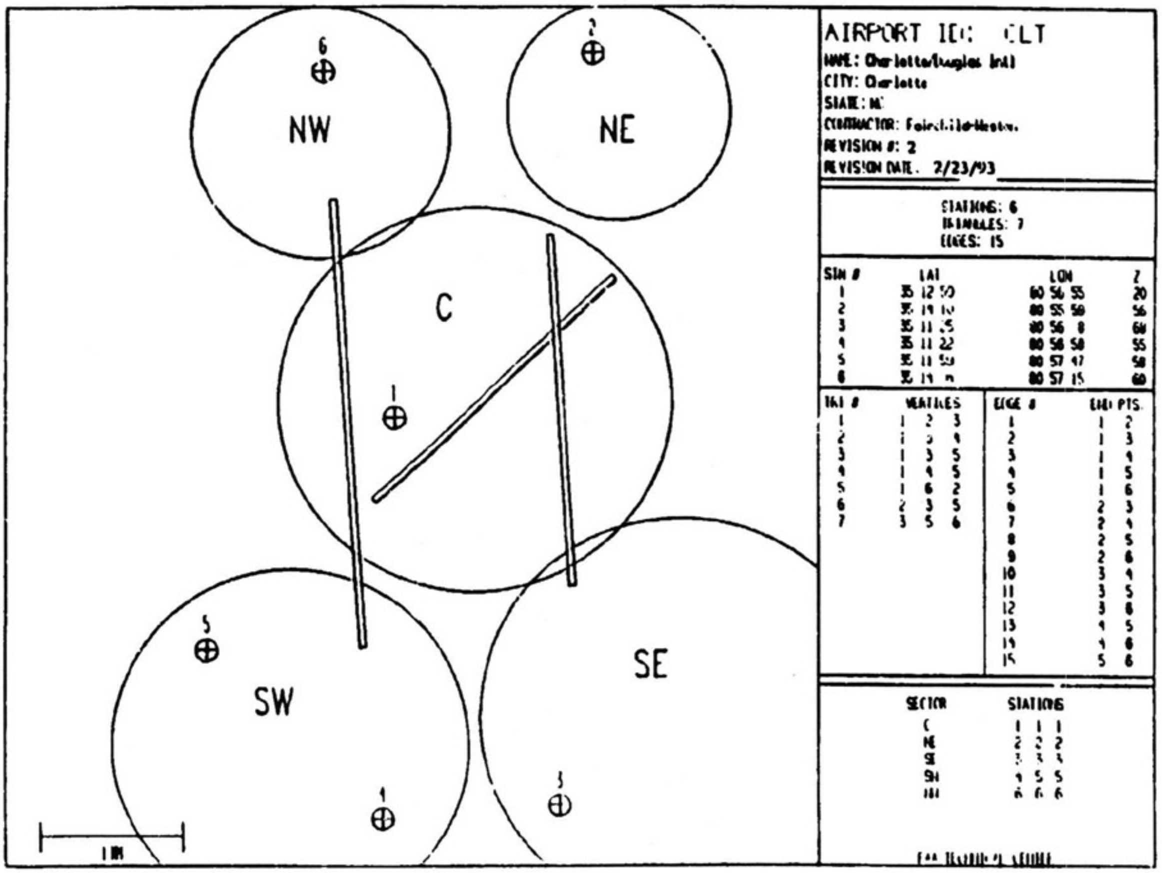
A Lower Atmospheric Doppler Profiler (LAP 3000) was installed and was being used by the State of North Carolina to study air quality in the area of CLT. The instrument measures and records horizontal and vertical wind information from about 300 feet to above 1,000 feet above the ground for the volume of atmosphere above the beam center. The Profiler equipment was located about 700 feet southeast of the approach end of runway 23.

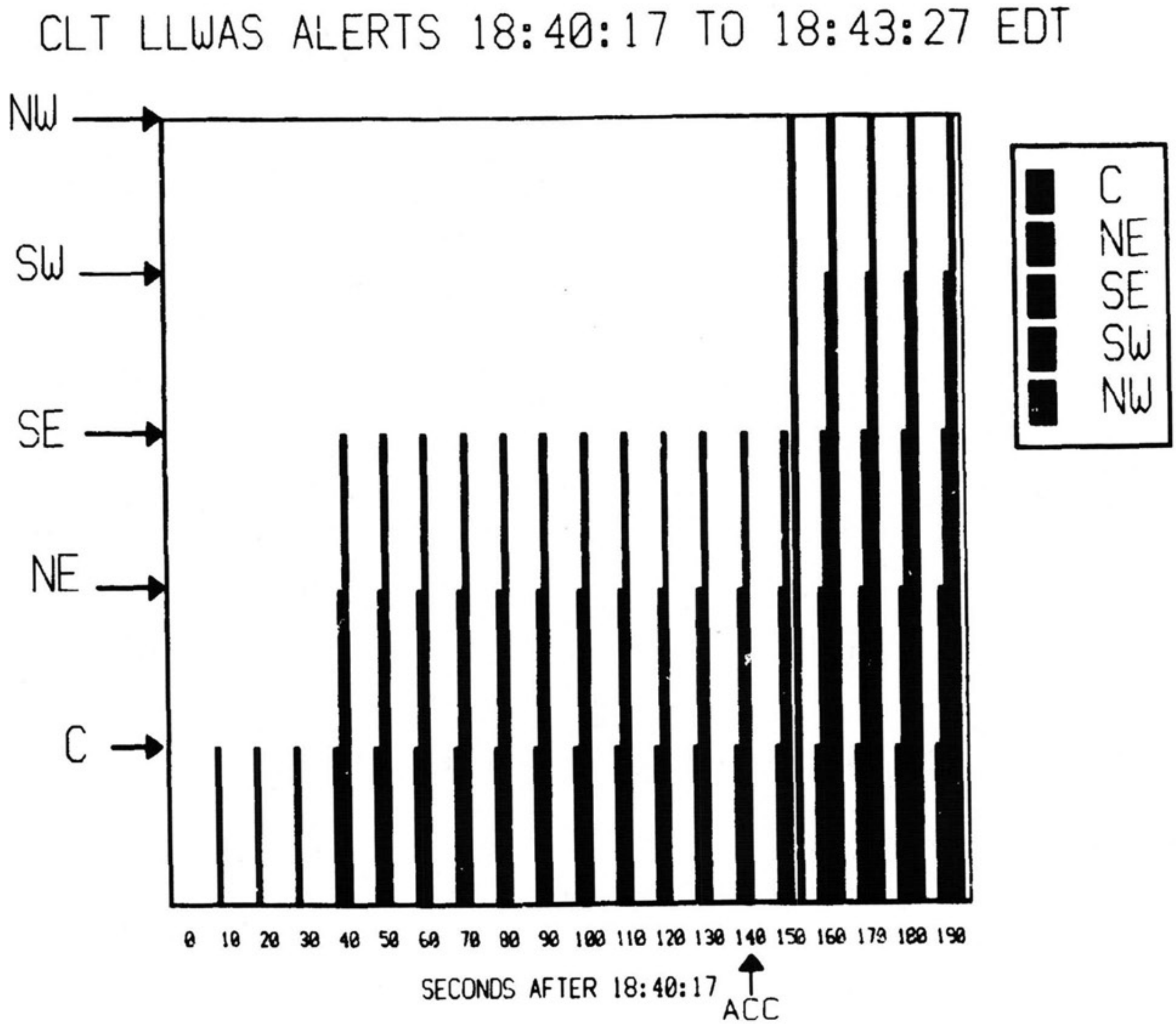
In a report produced by the NOAA [National Oceanic and Atmospheric Administration]/ERL/Environmental Technologies Laboratory, Meteorological Applications and Assessment Division, Boulder, Colorado, the following (excerpted information) was derived from the data recorded by the LAP 3000:

> The radar wind profiler in this case used 3 beam directions; one was vertical and two were 21° off vertical (towards 30° and 120° in azimuth) to measure the atmosphere at 105 m vertical resolution from 0.14 to 4.1 kilometers (km) above ground level (agl). The radar pointed toward each direction for 30 seconds, and thus provided wind profiles every 1.5 minutes that can be used to infer characteristics of precipitation and sometimes vertical air motion above the radar....From examination of 12 hours of data from the vertically pointing beam, it is possible to determine that convective precipitation occurred at the profiler site from about 1730 to

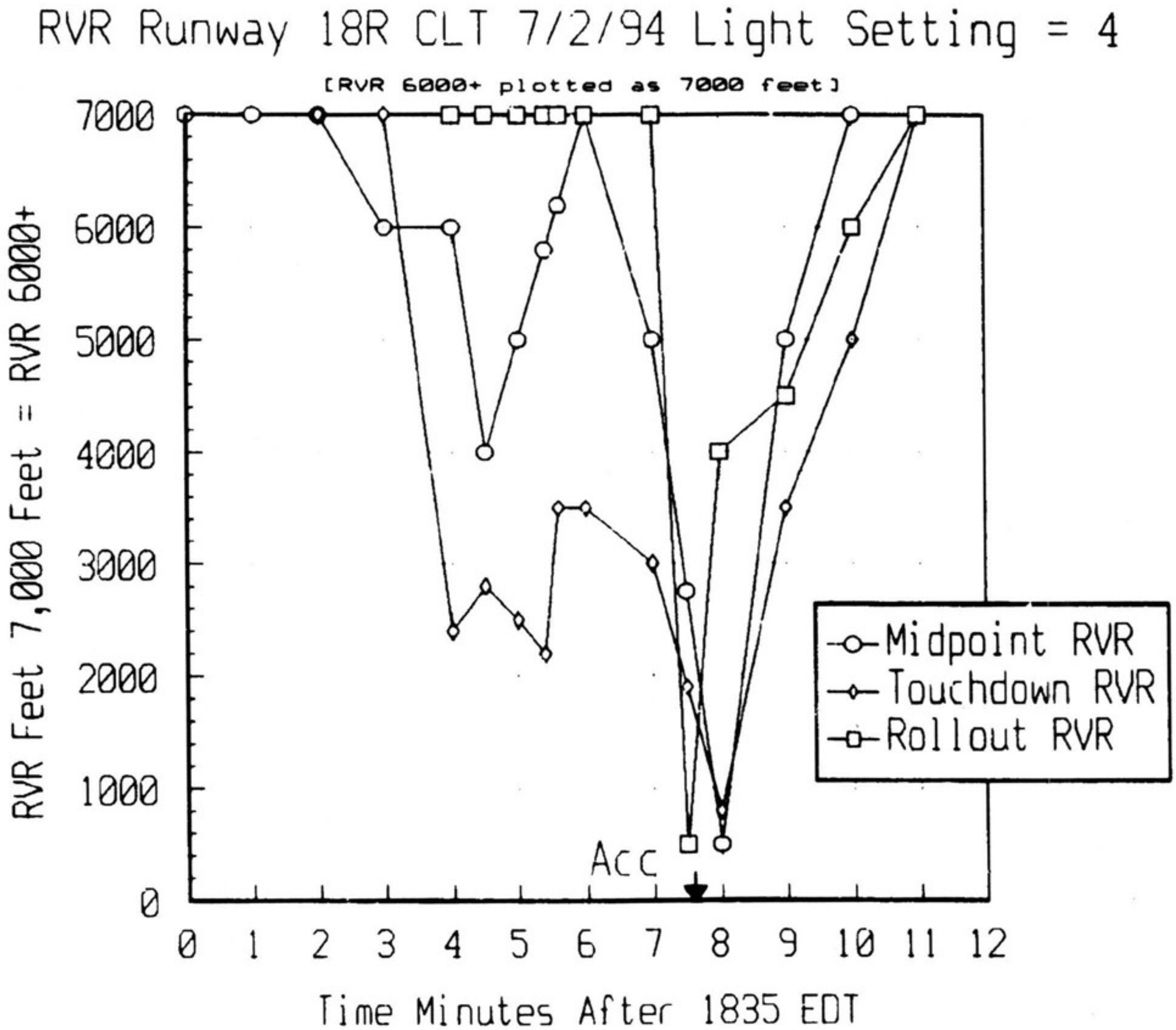
1755....Regions of downward velocities greater than 10 m s^{-1} approximately represent the regions of downward air motion. These were located primarily from 0.8 to 3.0 km agl from 1733 to 1742, and contained downward air motions of about 2 to 4 m s,$^{-1}$ except at the time of the crash (1743), when downward air motion of greater than 1 m s^{-1} could be inferred below 0.5 km agl.... A strong convective storm produced heavy precipitation at the time of the accident; strong vertical motions are likely to have been present very close to where the crash occurred; and the strongest inferred downdraft below 0.5 km agl occurred at the time of the crash.

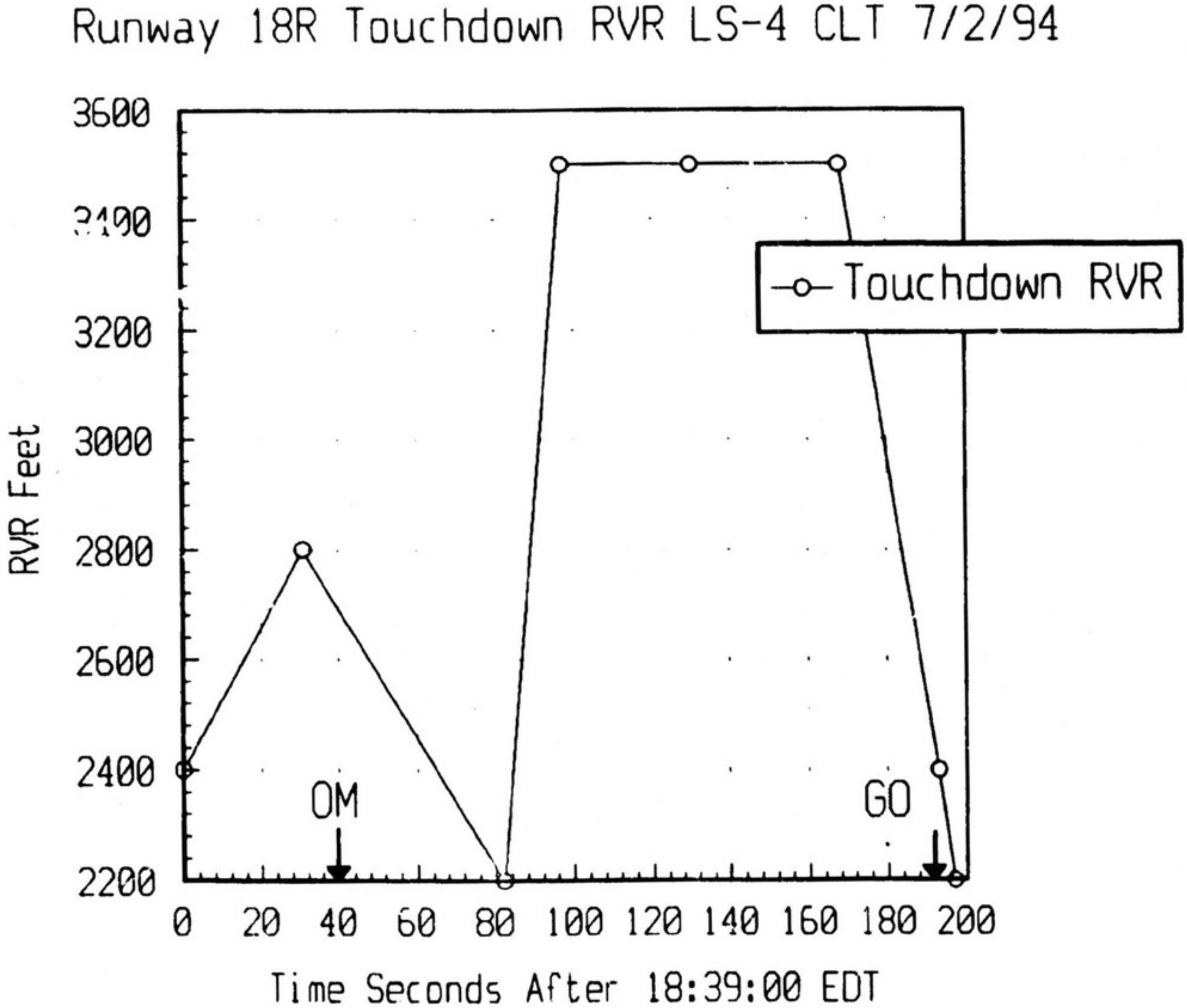
LLWAS SENSOR LOCATIONS





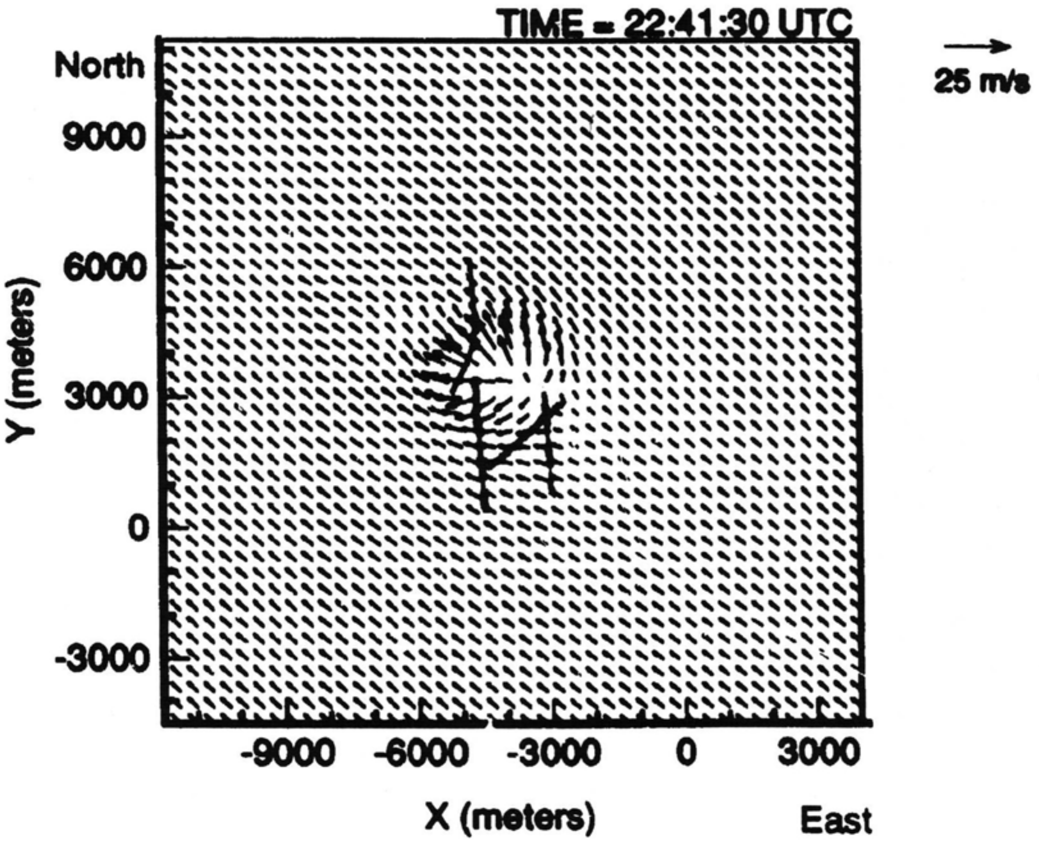
CLT LLWAS ALERTS 18:40:17 TO 18:43:27 EDT
NW
SW
SE
NE
C
C
NE
SE
SW
NW
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
SECONDS AFTER 18:40:17
ACC

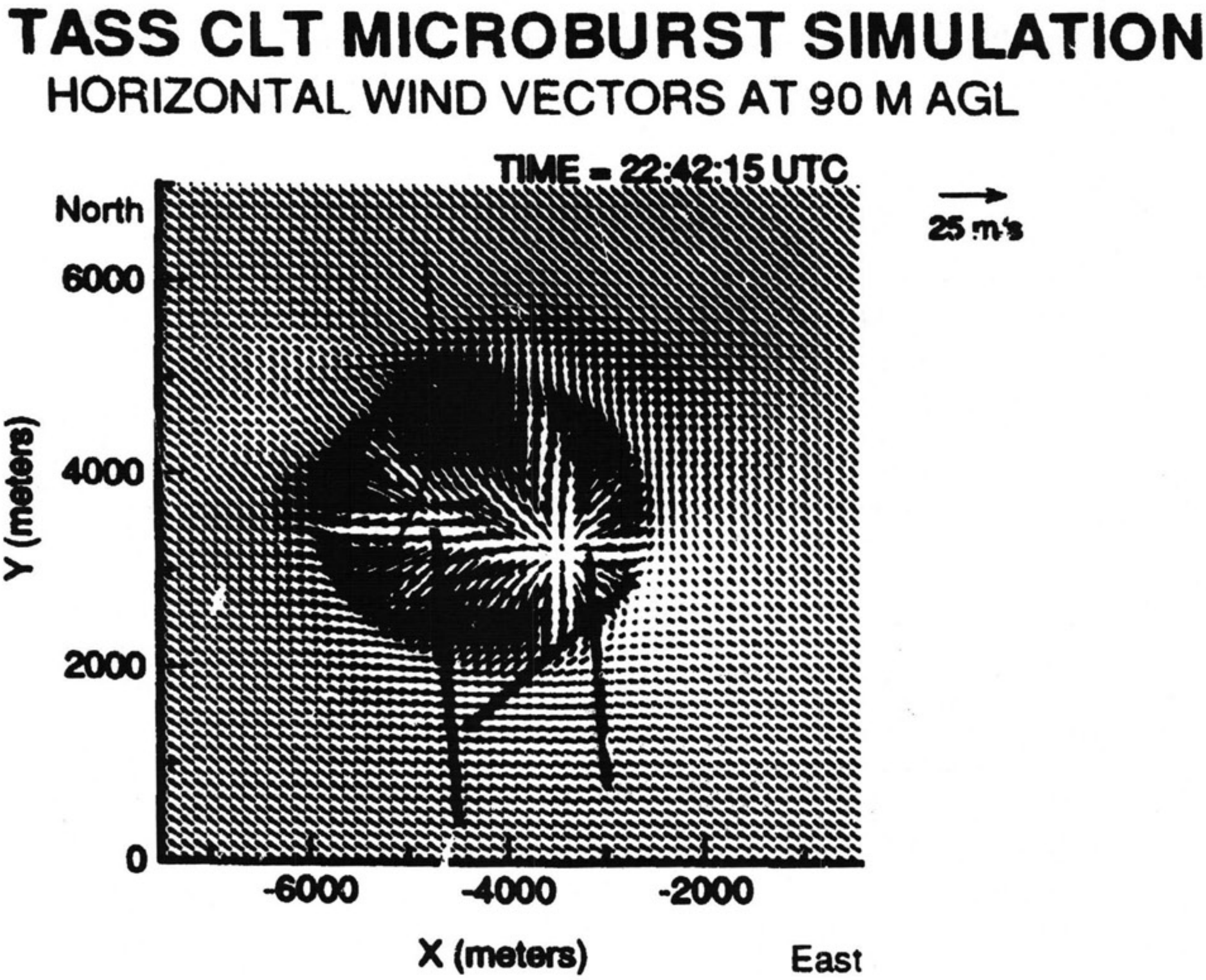

RVR Runway 18R CLT 7/2/94 Light Setting = 4
[RVR 6000+ plotted as 7000 feet]
RVR Feet 7,000 Feet = RVR 6000+
7000
6000
5000
4000
3000
2000
1000
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Time Minutes After 1835 EDT
Acc
Midpoint RVR
Touchdown RVR
Rollout RVR

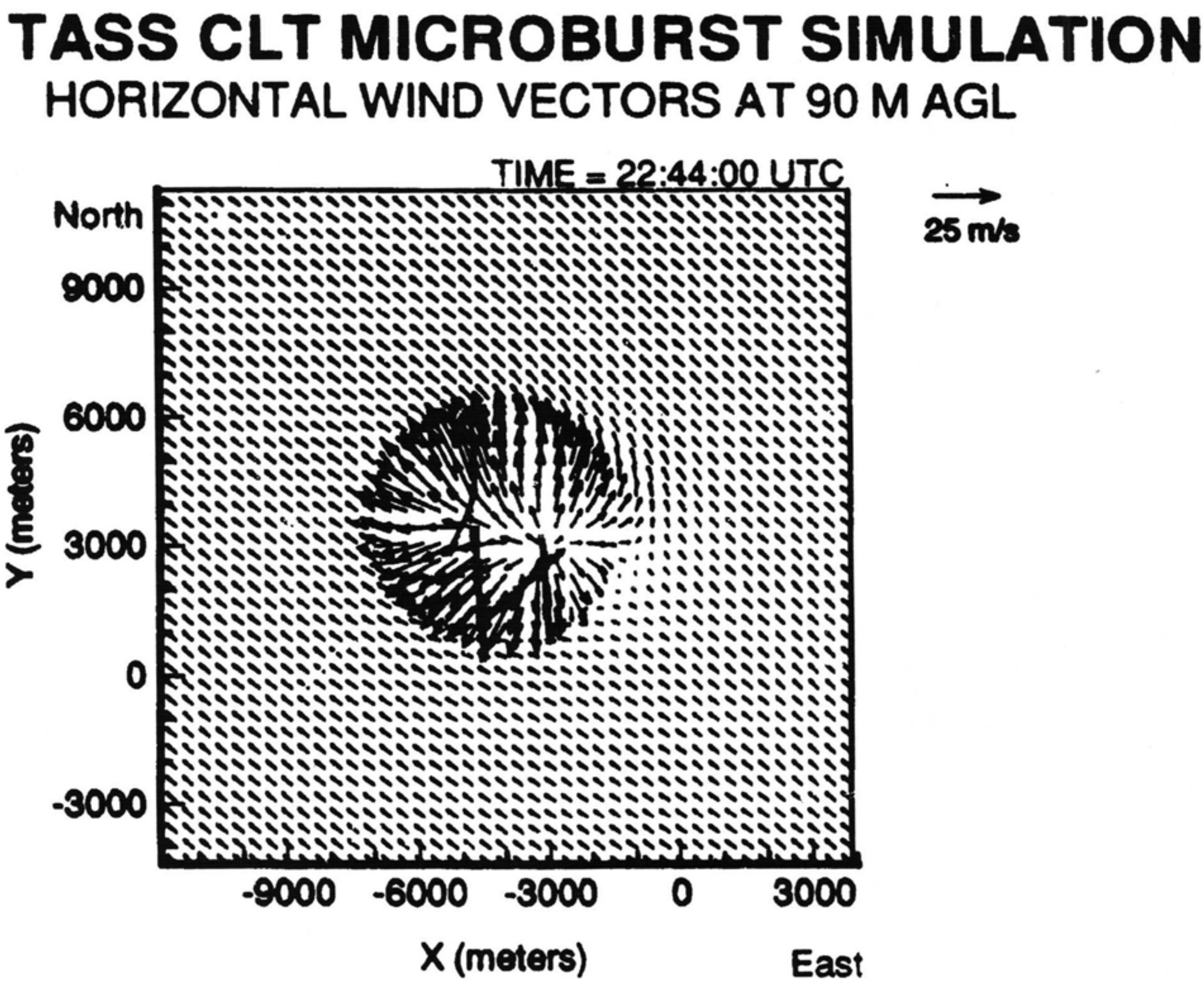

Runway 18R Touchdown RVR LS-4 CLT 7/2/94
3600
3400
3200
3000
2800
2600
2400
2200
RVR Feet
Touchdown RVR
OM
GO
0
20
40
60
80
100
120
140
160
180
200
Time Seconds After 18:39:00 EDT

TASS CLT MICROBURST SIMULATION

HORIZONTAL WIND VECTORS AT 90 M AGL




TASS CLT MICROBURST SIMULATION
HORIZONTAL WIND VECTORS AT 90 M AGL
TIME = 22:42:15 UTC
25 m/s
North
6000
4000
2000
0
Y (meters)
-6000
-4000
-2000
X (meters)
East



TASS CLT MICROBURST SIMULATION
HORIZONTAL WIND VECTORS AT 90 M AGL
TIME = 22:44:00 UTC
25 m/s
North
9000
6000
3000
0
-3000
Y (meters)
-9000
-6000
-3000
0
3000
X (meters)
East

APPENDIX D

AIRCRAFT PERFORMANCE INFORMATION

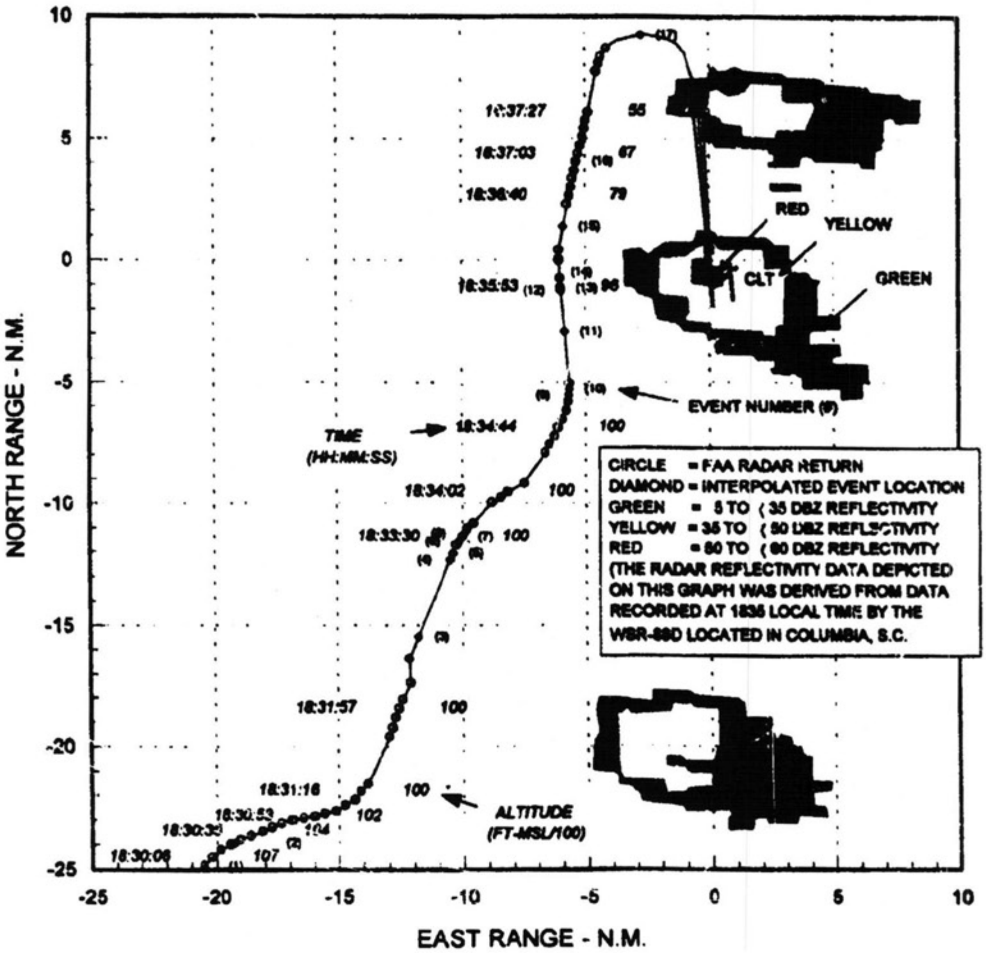
Selected Events, USAir Flight #1016

(1) 18:30:15, RDO-1 we're gonna swing just uh, five degrees to the right here just uh, for about a quarter half mile.
(2) 18:30:44, CAM-1 bumpy in there
(3) 18:32:18, CAM-1 looks like that's settin' just off the edge of the airport.
(4) 18:33:14, CAM-2 let's go right through that hole.
(5) 18:33:19, RDO-1 we're showin' a, little build-up here at uh looks like it's sittin' on the radial. like to go about five degrees to the left, to the west.
(6) 18:33:27, APR1 how far ahead are you lookin' ten sixteen?
(7) 18:33:30, RDO-1 'bout fifteen miles.
(8) 18:33:32, APR1 I'm goin' to turn you before you get there. I'm goin' to turn you in about five miles northbound.
(9) 18:35:01, APR1 USAir ten sixteen, descend and maintain six thousand.
(10) 18:35:04, RDO-1 out of ten for six. US ten sixteen.
(11) 18:35:32, CAM-1 OK, your cabin's down, four pumps on, seat belt sign's on, hydraulics', on high on check, altimeters flight instruments thirty oh one, set.
(12) 18:35:52, CAM-1 approach brief?
(13) 18:35:53, CAM-2 visual back up ILS.
(14) 18:35:54, APR2 USAir ten sixteen turn ten degrees right, descend and maintain two thousand three hundred vectors to visual approach to one eight right.
(15) 18:36:24, CAM-1 slats out.
(16) 18:36:59, APR2 I'll tell you what, USAir ten sixteen. may get some rain just south of the field. might be a little bit comin' off north, just expect the ILS now. amend your altitude maintain three thousand.
(17) 18:38:27, APR2 USAir ten sixteen, turn right heading one seven zero, four from SOPHE, correction four from yeah SOPHE, cross SOPHE at or above three thousand cleared ILS one eight right approach.
(18) 18:38:38, CAM-1 looks like it's sittin' right on the [unreadable due to unrelated ATC transmission through cockpit speaker]
(19) 18:38:47, CAM-2 flaps to five.
(20) 18:39:02, CAM-1 if we have to bail out *-
(21) 18:39:06, CAM-1 it looks like we bail out to the right.
(22) 18:39:09, CAM-2 amen.
(23) 18:39:09, CAM-1 ten miles to the VOR which is off the end of the runway 'bout a mile off the end of the runway.
(24) 18:39:14, CAM-2 yeah.
(25) 18:39:16, CAM-1 so I think we'll be alright.
(26) 18:39:20, CAM-1 chance of shear.
(27) 18:39:24, APR2 Air ten sixteen, contact tower one two six point four.

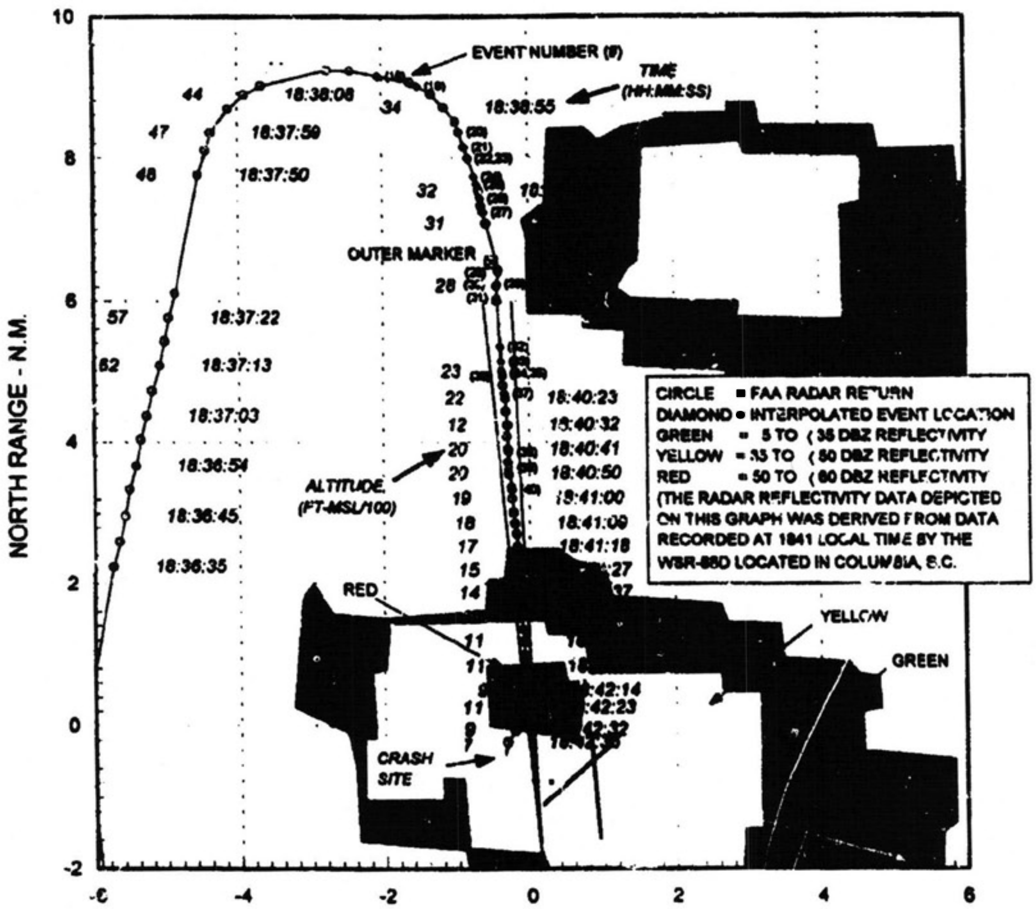
The dialogue shown in italics occurred on the tower frequency before US1016 switched on at 18:39:30.
18:39:12, US806 and eight oh six looks like uh we've gotten a storm right on top of the field here
18:39:16, TWR USAir eight zero six affirmative
18:39:20, US806 We'll just delay for a while

(28) 18:39:30, CAM-2 fifteen [sounds similar to flap handle movement]
(29) 18:39:43, CAM-2 gear down
(30) 18:39:44, TWR Charlotte tower, runway. .one eight right cleared to land. following F one hundred short final. previous arrival reported smooth ride all the way down the final.
(31) 18:39:49, RDO-1 USAir ten sixteen, I'd appreciate a pirep from the guy in front of us.
(32) 18:40:06, CAM-1 twenty five. [clicks similar to flap handle being moved]
(33) 18:40:10, CAM-2 yep, laying right there this side of the airport, isn't it?
(34) 18:40:14, CAM-1 well.
(35) 18:40:15, CAM-2 the edge of the rain is, I'd say.
(36) 18:40:15, CAM-1 yeah
(37) 18:40:21, CAM-2 flaps forty please.
(38) 18:40:42, TWR USAir ten sixteen, company "FK" one hundred just exited the runway, sir he said smooth ride.
(39) 18:40:48, TWR USAir nine sixteen wind is showing one zero zero at one nine.
(40) 18:40:56, CAM-2 one zero zero at one nine. eh?
(41) 18:40:59, TWR USAir ten sixteen, wind now one one zero at two one.
(42) 18:41:05, CAM-1 stay heads up.
(43) 18:41:06, TWR wind shear alert northeast boundary winds one nine zero at one three.
(44) 18:41:18, TWR Carolina fifty two eleven Charlotte tower, runway one eight right, cleared to land, wind one zero zero at two zero. wind shear alert, northeast boundary wind one nine zero at one seven.
(45) 18:41:32, TWR USAir eight zero six, you want to just sit tight for a minute sir?
(46) 18:41:35, US806 yes sir, we'd like to just sit tight.
(47) 18:41:37, TWR USAir seven ninety seven company aircraft in front of you is going to sit and wait a while sir. do you want to go in front of him?
(48) 18:41:43, US797 no no, it wouldn't sound like a good plan. we'll uh, it didn't look like a whole lot to us on the radar taxiing out so it shouldn't be uh, shouldn't be too many minutes.
(49) 18:41:54, CAM-1 here comes the wipers.
(50) 18:41:56, CAM-2 alright
(51) 18:41:57.6, CAM [sound similar to rain concurrent with sound similar to windshield wipers starts and continues to impact]
(52) 18:41:58.9, CAM-2 there's, ooh, ten knots right there.
(53) 18:42:06.4, CAM-1 OK, you're plus twenty.
(54) 18:42:14.0, CAM-1 take it around, go to the right.
(55) 18:42:16.1, RDO-1 USAir ten sixteen's on the go. (US1016's altitude equal to approximately 200 feet-agl)
(56) 18:42:17.7, CAM-1 max power.
(57) 18:42:18.5, CAM-2 yeah max power ...
(58) 18:42:18.5, TWR USAir ten sixteen understand you're on the go sir, fly runway heading. climb and maintain three thousand.
(59) 18:42:19.4, CAM-2 flaps to fifteen.
(60) 18:42:20.8, CAM [clicks similar to flap handle being moved]
(61) 18:42:22.0, CAM-1 down, push it down.
(62) 18:42:25.5, RDO-1 up to three we're takin' a right turn here.
(63) 18:42:27.9, TWR USAir ten sixteen, understand you're turning right? (US1016's altitude begins decreasing below 350 feet-agl)
(64) 18:42:28.4, CAM-5 ["whoop whoop terrain" sound begins and continues to first sound of impact]
(65) 18:42:28.5, CAM-? ** power.
(66) 18:42:32.7, CAM [vibrating sound similar to aircraft stick shaker begins]
(67) 18:42:33.5, CAM [vibrating sound similar to aircraft stick shaker ends]
(68) 18:42:35.3, CAM [one beep similar to trim in motion]
(69) 18:42:35.6, CAM [sound of impact]
18:42:36.6, END of CVR RECORDING

USAIR FLIGHT #1016 RADAR-DERIVED GROUNDTRACK



USAIR FLIGHT #1016 RADAR-DERIVED GROUNDTRACK



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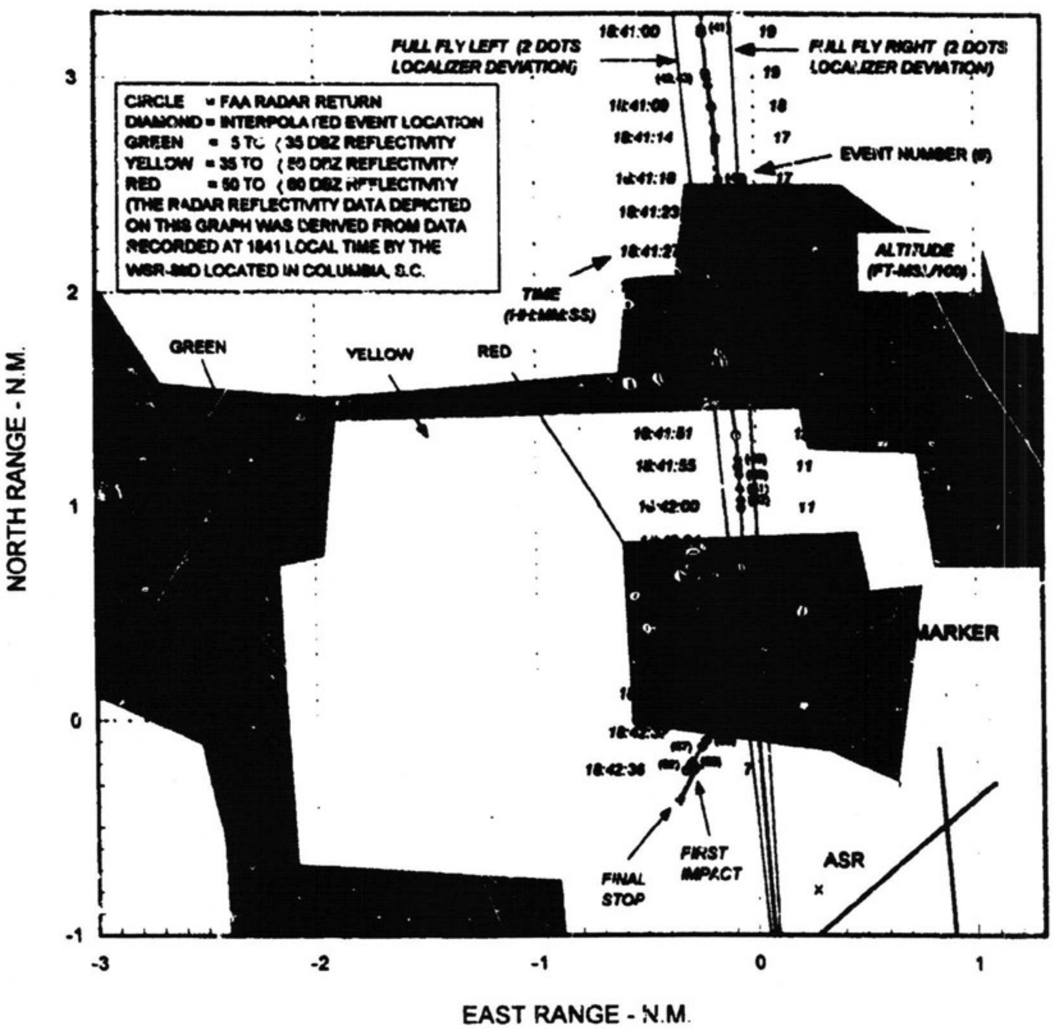
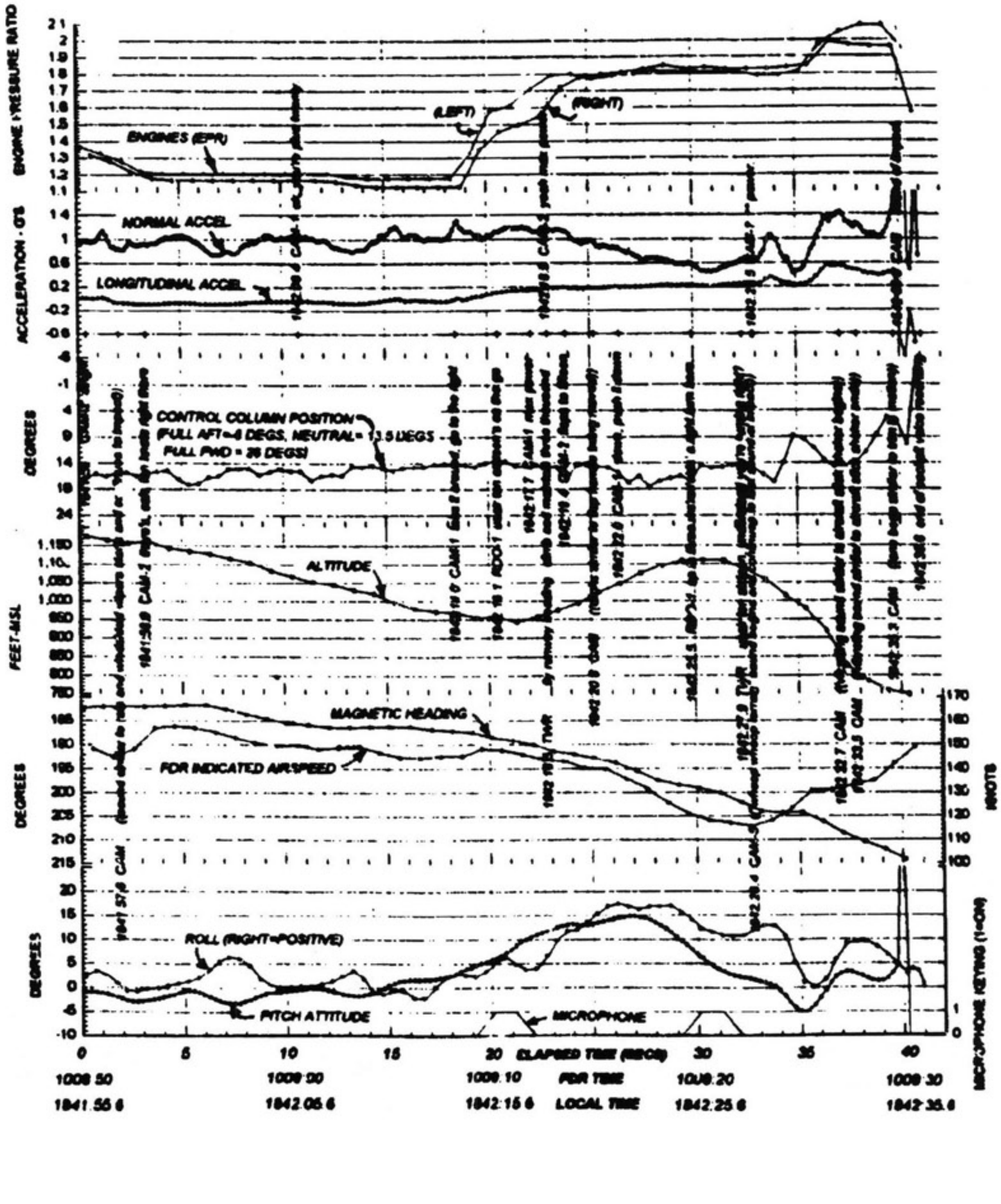
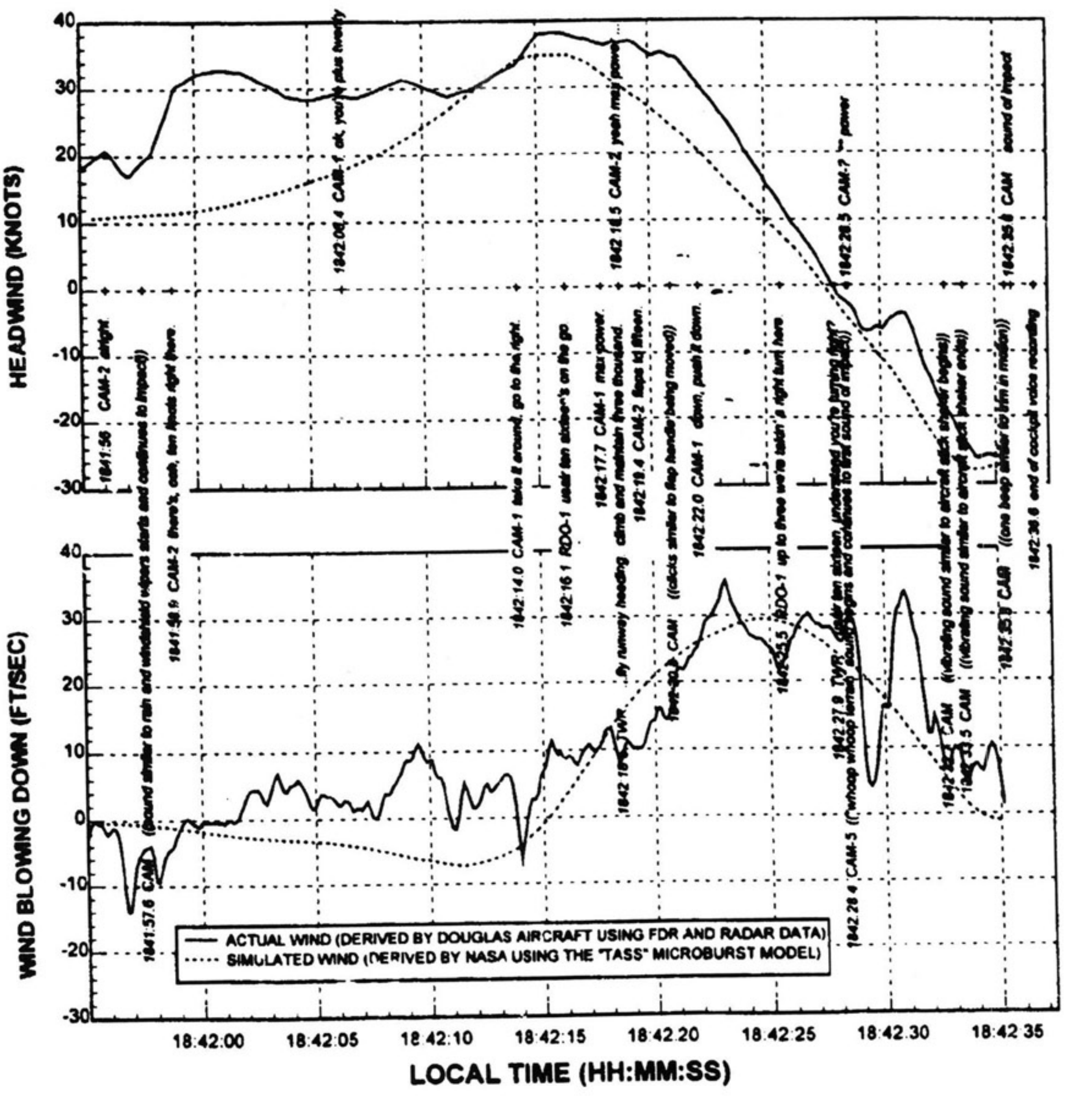


USAIR FLIGHT #1016 FLIGHT DATA RECORDER (FDR) GRAPHS



WIND CALCULATIONS FOR THE FLIGHTPATH OF USAIR FLIGHT 1016



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