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Unaware That They Have Encountered a Microburst, DC-9 Flight Crew Executes Standard Go-around; Aircraft Flies Into Terrain

The approach was continued into severe convective activity and the crew failed to recognize a wind-shear situation in a timely manner. The failure of the air traffic controller to report radar data and other pertinent weather information to the crew was a contributing factor to the accident, the official U.S. report said.

FSF Editorial Staff

The crew of USAir Flight 1016 (a McDonnell Douglas DC-9-31) was being vectored for a visual landing approach to the Charlotte/Douglas International Airport, Charlotte, North Carolina, U.S. There was thunderstorm activity in the vicinity of the airport. As the crew was vectored, they were in visual meteorological conditions (VMC) and had visual contact with the airport, but they were flying the instrument landing system (ILS) approach as a back-up.

As they flew the ILS, a thunderstorm moved across the airport. On final approach, the crew encountered instrument meteorological conditions (IMC), heavy rain and airspeed fluctuations of 20 knots. The captain elected to go around, and the first officer (the pilot flying) initiated a climb and started a right turn. During the climb, the crew lowered the aircraft's pitch attitude; the aircraft descended, transitioning from a headwind of about 35 knots to a tailwind of 26 knots over 14 seconds, and struck the ground 2,180 feet (665 meters) southwest of the runway. The aircraft broke apart and came to rest in a residential neighborhood. Thirty-seven passengers were killed. Two flight attendants and 14 passengers were seriously injured. The captain, first officer, one flight attendant and one passenger received minor injuries. No one on the ground was injured in the July 2, 1994, accident.

[See *Cabin Crew Safety*, March–April/May–June 1995, "Sudden Impact — A Flight Attendant's Story of Courage and Survival," for a first-person account of this accident by flight attendant Richard DeMary, who was also awarded the Flight Safety Foundation's Heroism Award in 1994 for his actions.]

The U.S. National Transportation Safety Board (NTSB) concluded in its final accident report that the probable causes of the accident were: "1) the flight crew's decision to continue an approach into severe convective activity that was conducive to a microburst; 2) the flight crew's failure to recognize a wind-shear situation in a timely manner; 3) the flight crew's failure to establish and maintain the proper airplane attitude and thrust setting necessary to escape the wind shear; and 4) the lack of real-time adverse-weather and wind-shear hazard information dissemination from air traffic control [ATC], all of which led to an encounter with and failure to escape from a microburst-induced wind shear that was produced by a rapidly developing thunderstorm located at the end of Runway 18R."

The report also concluded that contributing to the accident were: "1) the lack of [ATC] procedures that would have required the controller to display and issue ASR-9 [airport surveillance 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 [runway visual range] value information, and the low-level wind-shear 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 wind-shear warning system that did not provide an alert upon entry into the wind shear."

The DC-9-31 was owned and operated by USAir Inc. The accident flight was a scheduled passenger flight, operating under U.S. Federal Aviation Regulations (FARs) Part 121. The crew of the accident flight departed Pittsburgh, Pennsylvania, at 1045 hours local time, and made three en route stops. The accident occurred on the fourth leg, from Columbia, South Carolina, to Charlotte (CLT).

Flight 1016 departed Columbia at 1823, with a planned flying time to CLT of 35 minutes. The first officer was the pilot flying. At 1827, while at an altitude of 12,000 feet (3,660 meters) mean sea level (MSL), the flight crew contacted the Charlotte Terminal Radar Approach Control (TRACON) and said that they had received the current automatic terminal information service (ATIS), the report said.

The ATIS broadcast the following weather for CLT: scattered clouds at 5,000 feet (1,525 meters), visibility six miles (10 kilometers) in haze, temperature 88 degrees F (31 degrees C), dewpoint 67 degrees F (19 degrees C) and the wind 150 degrees at eight knots, the report said. The ATIS also advised that ILS approaches were being conducted to Runways 18L and 18R.

Charlotte approach told the flight to expect Runway 18R, and to descend to 10,000 feet (3,050 meters), which the crew acknowledged. Based on the cockpit voice recorder (CVR) transcript, the first officer then commented to the captain, "There's more rain than I thought there was. It's startin' ... pretty good. A minute ago. Now it's held up," the report said. About one minute later, the captain told the controller, "We're gonna swing just, uh, five degrees to the right here just uh, for about a quarter, half mile," the report said. The controller approved the request.

Crew Saw Heavy Precipitation on Radar

"The flight crew 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 report said. "The weather radar depicted the cell to the south of the airport as having a red center surrounded by yellow edges." [The weather radar color depictions were: green = light precipitation; yellow = moderate precipitation; red = heavy precipitation.]

At 1832:18, the captain said to the first officer, "Looks like that's [rain] setting just off the edge of the airport," the report said. One minute later, the captain said to the controller, "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." The controller then asked, "How far ahead are you lookin,' [USAir] 1016?"

"'Bout 15 miles," replied the captain. The controller said, "I'm goin' to turn you before you get there, I'm goin' to turn you at about five miles [eight kilometers] northbound," the report said. The flight was then directed to turn to a heading of 360 degrees. One minute later, the flight was cleared to descend to 6,000 feet (1,830 meters).

At 1835:21, the flight was cleared to descend to 4,000 feet (1,220 meters) for Runway 18R. The captain acknowledged the clearance and called for the approach briefing. "The first officer responded, 'Visual back up ILS,'" the report said.

"The weather radar depicted the cell to the south of the airport as having a red center surrounded by yellow edges."

The controller cleared the flight to descend to 2,300 feet (701 meters), and to turn 10 degrees right for vectors to a visual approach to Runway 18R. "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 [approach] controller observed on the airport surveillance radar (ASR-9) scope a VIP [video integrator processor] Level 3 cell 'pop-up' near the airport," the report said. (A VIP Level 3 radar echo is classified by the U.S. National Weather Service as "strong.")

At 1836:55, the approach controller said, "I'll tell you what, USAir 1016, 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 3,000 [feet (915 meters)]," the report said.

At 1837:33, a controller in the Charlotte U.S. Federal Aviation Administration (FAA) Air Traffic Control Tower told the crew of a twin-engine turboprop de Havilland DHC-8 landing on Runway 23 that there was "heavy, heavy rain on the airport now, wind 150 [degrees] at 14 [knots]," the report said.

The approach controller continued vectoring the accident flight and said, "USAir 1016, turn right heading 170 [degrees], four [miles] from SOPHE [the outer marker for the Runway 18R ILS], cross SOPHE at or above 3,000 [feet], cleared ILS 18R approach," the report said.

Source: U.S. National Transportation Safety Board

An aerial view of the crash site shows the wide displacement of the aircraft's tail section and nose section.

The captain told the first officer, "Looks like it's sittin' right on the ... " The remainder of the captain's comment was obliterated by a transmission over the cockpit speaker. The flight was then told to contact Charlotte tower, the report said. The captain acknowledged the frequency change.

After the accident, "The captain testified at the [NTSB'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," the report said.

According to the CVR transcript, the captain said at 1839:02, "If we have to bail out [unintelligible] it looks like we bail out [abort the approach] to the right." Shortly thereafter, the captain added, "Chance of shear."

At 1839:12, the crew of USAir Flight 806, which was on the ground waiting to depart, told the tower, "Looks like, uh, we've gotten a storm right on top of the field here," the report said. The tower controller responded, "Affirmative." The crew of the waiting USAir flight elected to delay their departure. The crew of the accident flight had not yet changed to the tower radio frequency when this exchange took place, the report said.

At 1839:38, the captain of the accident flight contacted the tower. The tower controller said, "USAir 1016, Runway 18R cleared to land following [a Fokker] F-100 short final, previous arrival [USAir 677, a Fokker F-28, which had landed about four minutes earlier] reported smooth ride all the way down the final," the report said. The captain replied, "USAir 1016, I'd appreciate a PIREP [pilot report] from the guy in front of us," the report said.

At 1840:10, according to the cockpit voice recorder (CVR) transcript, 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 report said.

"In his testimony [after the accident], 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 [very high frequency omnidirectional radio range] for distance measuring information, although they had visually identified the runway during the initial portion of the final approach," the report said. "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.'"

As the crew flew the approach, a special weather observation was recorded, and a new ATIS was broadcast, the report said. The new weather report was: measured ceiling 4,500 feet (1,372 meters), visibility six miles, thunderstorm, light rain shower, haze, temperature 88 degrees F (31 degrees C), dewpoint 67 degrees F (19 degrees C), wind 110 degrees at 16 knots.

The crew of the accident flight did not receive the new ATIS, the report said. Because of the rapidly changing conditions, a second special weather observation was taken four minutes later. The new weather was 4,500 feet overcast, visibility one mile (1.6 kilometers) in thunderstorms and heavy rain showers.

At 1840:50, the tower controller told the flight that the wind was 100 degrees at 19 knots, the report said. Moments later, the tower told the flight that the wind was 110 degrees at 21 knots. The captain told the first officer to "stay heads up," the report said. About the same time, the tower transmitted, "Wind-shear alert northeast boundary winds 190 [degrees] at 13 [knots]."

Meanwhile, the tower controller for Runway 18L transmitted, "Attention all aircraft, wind-shear alert, the surface wind 100 [degrees] at 20 [knots], northeast boundary wind 190 [degrees] at 16 [knots]," the report said. The crew of the accident flight did not hear this broadcast because the tower controllers for Runways 18L and 18R were operating on different radio frequencies.

The captain said, "Okay, you're plus 20 [knots] ... take it around, go to the right."

At 1841:58, the first officer said to the captain, "There's, ooh, 10 knots right there," the report said. This was immediately followed by the captain saying, "Okay, you're plus 20 [knots] ... take it around, go to the right."

Witnesses Report High Winds, Heavy Rain

Witnesses on the ground who were near the approach end of Runway 18R "stated that they observed Flight 1016 emerge from the rain and clouds approximately one-quarter mile from the end of the runway on a heading that was about 45 degrees to the runway," the report said. "The witnesses also stated that the rain was very intense and that the wind was 'blowing very hard.'"

The report described the accident sequence: "The airplane initially touched down in a grassy field located within the airport boundary fence, about 2,180 feet [665 meters] 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 [228 meters] (the elevation of Runway 18R is 743 feet [227 meters]), and a correlation of the ground scars and airplane structure determined it to be consistent with the right main landing gear."

The report continued: "The next ground scar, located 18 feet [5.5 meters] 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."

The aircraft broke apart as it continued over the ground. The aft portion of the fuselage (which was the last major section of the wreckage) came to rest embedded in the carport of a two-bedroom house, located 1,063 feet (324 meters) from the initial impact point, the report said.

A postcrash fire consumed the portions of the aircraft in which fuel was present, the report said. "There was also evidence of flash-over fire in the immediate vicinity of the debris area," the report said. "The crew members, 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."

In reviewing the injuries, the report said: "Of the 37 passengers who received fatal injuries, 32 were the result of blunt-force trauma, four were due to thermal injuries and one 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 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."

The report also said: "A nine-month-old infant, who was unrestrained in her mother's lap in seat 21C, sustained fatal injuries."

The airplane was destroyed by impact and postcrash fire, the report said. The estimated value of the airplane was US$5 million.

When investigators reviewed the wreckage path, they found that "the first large section of the wreckage beyond the right wing [comprised] portions of the first-class and coach cabin flooring and seats from both sides of the aircraft," the report said. "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 report continued: "The second section of wreckage consisted of the cockpit, forward flight-attendant jumpseat,

Source: Pamela Wehner/U.S. National Transportation Safety Board

Investigators sift through the wreckage of Flight 1016's tail section, which lodged in the carport of a house.

forward galley, four first-class seats from the left side of the airplane and approximately 12 feet [3.6 meters] 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 was found severely deformed. "The captain, first officer and observer seats were partially detached from their anchor points," the report said. "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."

Investigators found the third section of wreckage in the front yard of a residence, which included the "left wing and overwing fuselage area, and included the seats from rows 9 through 14," the report said.

The aft section of the airplane, which was embedded in the carport, included the "passenger cabin area and seat rows 17 through 21," the report said. "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 report said.

Investigators found evidence that the landing gear was down and locked at the time of impact, the report said. The wing flaps were found extended; the right flaps were 14 degrees extended, and the left flaps were 16 degrees extended. The flap handle in the cockpit was found set at 15 degrees. The leading edge slats were found to be fully extended at impact, the report said.

Both engines were found and examined. "The left and right engine inlets had large amounts of wood branches and foliage packed against the inlet guide vanes," the report said. 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. Both engines were capable of producing power at impact, the report said.

The airplane was equipped with a CVR and a digital flight data recorder (FDR). Both recorders were found in the wreckage, and all recorded information was usable, the report said.

Investigators reviewed the maintenance records for the airplane, and found "no discrepancies noted in the logbook that would have been cause for the airplane to be unairworthy," the report said.

Source: Pamela Wehner/U.S. National Transportation Safety Board

The tail section of Flight 1016 lodged in the carport of a house. The nose section is in the lower left, to the right of the fire truck. A third section of the fuselage is not visible.

The background and qualifications of the flight crew were reviewed. The captain, 38, held a U.S. airline transport pilot (ATP) certificate, with a multi-engine land airplane rating, and a Douglas DC-9 type rating, the report said. He also held a flight instructor (CFI) certificate with multi-engine land and instrument ratings. At the time of the accident, he held a first-class medical certificate, with no limitations.

The captain had 8,065 total flying hours at the time of the accident, with 1,970 hours in the DC-9. He had been employed with USAir since 1985, the report said. He was also a captain in the U.S. Air Force Reserve, where he had flown the Cessna T-37, the Northrop T-38, AT-38 and the McDonnell Douglas F-4. “His most recent [military] aircraft assignment was in the F-16,” the report said. “He was also a Distinguished Graduate from [U.S.] Air Force pilot training. In addition, he was the squadron safety officer, and was designated as a flight leader and mission commander,” the report said.

The first officer, 41, held an ATP certificate, with a multi-engine land airplane rating, and a Mitsubishi MU-300 type rating. He also held a flight instructor certificate, and a first-class medical certificate with no limitations. At the time of the accident, he had 12,980 total flying hours, with 3,180 hours in the DC-9, the report said.

The first officer was originally hired by Piedmont Airlines in 1987, the report said. When Piedmont was acquired by USAir, he continued employment with that company.

The activities of the flight crew before the accident flight were reviewed. The captain was off duty for three days before the accident trip, the report said. On the day of the accident, he awoke at 0455, drove to the airport in Dayton (near his home), Ohio, and departed on a flight to Pittsburgh at 0745, the report said. The reporting time was 0945 for his flight that began in Pittsburgh.

“The first officer flew a four-day trip that ended around 0930 on July 2,” the report said. The report did not specify where the first officer had begun the trip on June 29. “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 2230 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," the report said.

Weather Factors Examined

Investigators reviewed four weather-related elements in this accident: The weather conditions at the airport during the period in which the accident flight flew the approach, the weather information provided by the U.S. National Weather Service (NWS) to ATC, the weather information provided by ATC to the accident flight crew and the flight crew's use of their airborne weather radar to evaluate the conditions.

The report said that the weather at CLT during the accident flight's approach was essentially as forecast. "The forecast and reported weather included convective thunderstorm activity with the associated low clouds, reduced visibility and rain," the report said. "Any time that convective activity is forecast, there is a potential for microburst wind shear in the vicinity of thunderstorms."

The accident flight encountered a microburst wind shear during its missed approach. "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 [9,150 meters]," the report said. "The microburst was determined to be approximately 3.5 kilometers [2.1 miles] in diameter, and was capable of producing a rainfall rate of about 10 inches [25.4 centimeters] per hour. The total wind change near the ground was determined to be about 75 knots (at approximately 300 feet [91.5 meters] the winds were 86 knots), with the strongest downward vertical winds below 300 feet AGL [above ground level] calculated to be 10 [FPS (feet per second)] to 20 FPS [three meters per second to six meters per second]. The outflow winds most likely exhibited asymmetry with stronger winds on the west side of the microburst."

There were witnesses near the approach end of Runway 18R during the accident flight's approach. "Several witnesses reported that the winds were gusty with wind speeds of 20 [knots] to 35 knots, while one witness under the flight path of Flight 1016 reported wind speeds of up to 50 [miles per hour] to 60 miles per hour [80 kilometers per hour to 96 kilometers per hour]," the report said. "The wind directions reported suggest the center of an area of divergence located east of Runway 18R."

Investigators interviewed flight crews of other aircraft, some of which were on the ground and some of which were in the air during the accident flight's approach. These pilots "reported that the thunderstorm appeared as a small echo approximately

Source: Alan M. Pollack/U.S. National Transportation Safety Board

The nose of Flight 1016 sheared off on impact with trees and skidded down a residential street. Another section of the fuselage is behind the nose section.

three miles [4.8 kilometers] in diameter and indicated 'mostly red' on the radar," the report said. "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 ... they saw a wall of water approaching from the south. They said that the 'visibility through the precipitation was nonexistent,'" the report said.

An analysis was conducted of the wind field produced by the thunderstorm that was encountered by the accident flight. At the time of the accident, there was an area of VIP Level 6 echo returns centered near the approach end of Runway 18R, the report said. [A VIP Level 6 echo is the highest radar return, and is classified by the NWS as "extreme."] "These storm areas were capable of producing microburst activity and peak rainfall rates of 10 inches [39 centimeters] per hour," the report said.

The report described the wind shear encountered by the accident flight: "The airplane encountered a wind shear seven [seconds] to eight 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 two [seconds] to three seconds of ground impact), the wind along the flight path 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 report continued: "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 [7.6 meters per second] down, and increased further to 30 FPS [9.1 meters per second] down as the airplane attained its maximum altitude and transitioned into a descent. It was during the latter portions of the descent, approximately two [seconds] to three seconds before ground impact, that the vertical velocity component of the wind field decreased to about five [FPS] to 10 FPS down."

USAir Flight 1016
Final Moments from CVR Transcript

1842: 16 Capt. (radio transmission):	USAir 1016's on the go.
1842:17.7 Capt.:	Max power.
1842:18.5 FO:	Yeah, max power.*
1842:18.5 Tower:	USAir 1016, understand you're on the go sir, fly runway heading, climb and maintain 3,000 [feet].
1842:19.4 FO:	Flaps to 15.
1842:22.0 Capt.:	Down, push it down.
1842:25.5 Capt. (radio transmission):	Up to three [thousand feet], we're takin' a right turn here.
1842:27.9 Tower:	USAir 1016, understand you're turning right.
1842:28.4 (GPWS aural alert):	Whoop whoop, terrain.
1842:28.5 (Unidentified voice on CVR):	[Unintelligible word] 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.)

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

** The FDR recorded an increase in engine power to above 1.82 EPR and an airspeed increase at about 1842:29.

Capt. = Captain
FO = First officer
GPWS = ground-proximity warning system
CVR = cockpit voice recorder
FDR = flight data recorder

Source: U.S. National Transportation Safety Board

ATC Role Questioned

The investigation also reviewed the failure of the air traffic controllers to provide pertinent weather information to the accident flight. "The radar and tower controllers had indications that the weather was deteriorating when Flight 1016 was 16 miles [26 kilometers] from the runway, on the downwind leg of the visual approach," the report said. "The [NTSB] also believes that the combination of [ATC] procedures and a breakdown in communications within the Charlotte ATC tower prevented the flight crew 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 NTSB believed that the flight crew might not have initiated the approach, or might have abandoned the approach sooner, had the crew known about the severe weather in the terminal area, the report said.

The NTSB also criticized the approach controller who vectored the accident flight for not informing the crew about the VIP Level 3 precipitation echoes depicted on radar. "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,'" the report said. "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*."

The report said that the controller's "use of the words 'some rain' might have been interpreted by the flight crew 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 report concluded that the controller's "choice of words to describe the weather event [was] improper, [but] all other aspects of the handling of Flight 1016 were satisfactory."

The investigation considered why CLT tower controllers did not issue a wind-shear alert to the accident flight in a timely manner. The Charlotte/Douglas International Airport was equipped with a Phase II low-level wind-shear alerting system (LLWAS), consisting of six wind-sensor remote stations located strategically throughout the airport property. Investigators were particularly concerned with sensor 1, known as the centerfield sensor, to the east of Runway 18R/36L; sensor 2, northeast of the airport, whose transmitted data had led the tower controller to issue a wind-shear alert; and sensor 6, about one-half mile northwest of the airport.

"The LLWAS centerfield sensor indicated an alert at 1840:27, when Flight 1016 was about 4.5 miles [7.2 kilometers] from the runway. Each of the controllers [in the tower] stated that they issued the wind as indicated by the centerfield sensor. Considering the fact that the LLWAS was alerting, the wind was [described] by the controllers as a wind gust, from 100 degrees at 19 knots gusting to 21 knots, rather than as a wind shear. However, the [NTSB] determined that the data measured by the centerfield sensor [were], in fact, the result of a wind shear and not a wind gust as reported," the report said.

The Charlotte LLWAS system had been the subject of several internal communications within the FAA between April and June 1993.

The report concluded that "the LLWAS system indicated a wind-shear condition in various quadrants of the airport, [and] the controllers chose to ignore the alarm and not to issue an alert [before the northeast boundary wind-shear alerts were issued 23 seconds later]."

The NTSB commented that the tower controller handling the accident flight "should have recognized the rapidly deteriorating weather conditions, including lightning in the vicinity of the airport and the decrease in tower visibility from six miles [9.6 kilometers] to one mile [1.6 kilometers], especially since he stated that he could not see the approach end of Runway 18R," the report said. "Additionally, he [the controller] was not aware of the centerfield wind-shear alert or the multiple sensor alerts."

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

The Charlotte LLWAS system had been the subject of several internal communications within the FAA between April and June 1993. "The system was identified as having problems, specifically, 'inaccurate reporting of wind conditions,'" the report said. Investigators determined that no upgrades had been made to the system before the accident. The FAA conducted a Site Performance Evaluation Study at Charlotte/Douglas after the accident, the report said, which found that sensor 2 (northeast boundary) and sensor 6 (northwest boundary) were sheltered by obstacles "significant enough to degrade the system."

A research engineer from the Massachusetts Institute of Technology Lincoln Laboratory testified at the NTSB's public hearing concerning the accident that, approximately one minute before the accident, sensor 6 had failed to achieve the alarm threshold by 0.7 knot, the report said. Citing the tolerances built into the LLWAS to avoid false alerts, the engineer said that "the system didn't give alerts as early as we would have liked ... ." But he added that although the northwest sensor was sheltered against winds from the north, east and west, its performance was not degraded during the time leading up to the accident, when winds were from the south.

About 20 seconds after the accident flight made initial contact with CLT tower, the RVR had dropped to 2,400 feet [732 meters], "which was the USAir minimum value permissible to execute the ILS approach," the report said. "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," the report said.

The NTSB concluded 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 a result of these findings, the [NTSB] believes that the FAA should amend the *ATC Handbook* and take other actions to correct deficiencies identified in this accident," the report said.

Flight Profile During Missed Approach Examined

Investigators reviewed the flight profile of the accident aircraft during the missed approach and encounter with the microburst wind shear. When the captain commanded the first officer to initiate a missed approach, "the FDR recorded a significant increase in the engine pressure ratio (EPR) indication of both

Source: Alan M. Pollack/U.S. National Transportation Safety Board

Firefighters examine the tail section of Flight 1016. This section was engulfed by fire.

engines," the report said. "At the time the missed approach was initiated, the airplane was at a speed of 147 KIAS [knots indicated airspeed], on a magnetic heading of 170 degrees, and at an altitude of about 200 feet [61 meters] AGL. Airplane pitch attitude began increasing, and roll attitude moved gradually right wing–down."

As the first officer retracted the flaps to 15 degrees, "the airplane encountered a 35-knot headwind and 30 [FPS] down vertical wind," the report said. At this point, the captain said, "Down, push it down," and the control column moved forward, the report said.

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 report said. At this time, the airplane reached its maximum roll attitude of 17 degrees right wing–down, and maximum pitch of 15 degrees nose-up, the report said.

Over a four-second period, the airspeed decreased from 138 KIAS to 120 KIAS, and the vertical climb rate reached its maximum of 1,500 feet (525 meters) per minute, the report said. After this occurred, "the airplane transitioned from a nose-high attitude and a positive rate-of-climb to a nose-down attitude and descending flight," the report said.

When the captain radioed CLT tower and said, "Up to three [thousand feet], we're takin' a right turn here," the airplane's pitch decreased through seven degrees nose-up, the report said. "At this point, the airplane leveled momentarily, approximately 350 feet [107 meters] above the ground, and the airspeed decreased to less than 120 KIAS," the report said. "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 maximum value of 0.4 G."

When the airplane's ground-proximity warning system (GPWS) "terrain" warning sounded, the airspeed was 116 KIAS. "The pitch attitude was decreasing through two degrees nose-up, while the altitude above the ground decreased to below 330 feet [100 meters]," the report said.

"About 1842:29, the CVR recorded a flight crew member state, '[unintelligible] power,'" the report said. The captain told investigators after the accident that he commanded "firewall power" when the GPWS activated. The engine EPR values increased above 1.82, where they had remained since 1842:23, and the airspeed increased following the captain's command. "At 1842:30, [the] control column position moved abruptly aft, and the airplane pitch attitude began increasing about one second later," the report said. "However, at 1842:31, the FDR recorded the airplane's pitch attitude to be five degrees nose-down, and the rate of descent to be in excess of 2,000 feet [610 meters] per minute down."

The engine values reached a maximum of 2.09 and 1.99 for the left and right engines respectively, which was an 8 percent increase in the net thrust over the target EPR of 1.93, the report said.

"At 1842:33, the FDR recorded the airspeed at 132 KIAS and the normal acceleration value of 1.4 G," the report said. "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 five degrees nose-up and four degrees right wing–down, the airspeed was 142 KIAS, the magnetic heading was 214 degrees, and the normal acceleration value was 3.1 G."

Aircraft Performance During Wind-shear Encounter Analyzed

Investigators analyzed the airplane's performance during the wind-shear encounter to determine if the crew could have flown through it successfully. The report said: "Simulations revealed that ... the airplane could have escaped the wind-shear 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 degrees nose-up."

The NTSB concluded that "Flight 1016 could have successfully flown through the wind shear encountered if the flight crew had executed an optimum missed-approach procedure, and if 'firewall' thrust had been applied as the airspeed decreased below 120 knots," the report said. "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 wind-shear encounter if the flight crew had executed the wind-shear escape maneuver (maximum effective pitch attitude and maximum 'firewall' power) immediately after the initial airspeed decay," the report said.

The accident aircraft was equipped with a Honeywell Standard Windshear Detection System that was capable of providing the crew with wind-shear detection alerts during the takeoff, approach and go-around phases of flight, the report said. The accident flight crew said that they never received any warnings from the wind-shear alert system during the flight. This was confirmed by a review of the CVR, the report said.

A study, using data from the accident airplane's DFDR, conducted during the investigation "determined that a longitudinal shear that exceeded the computed threshold [of the wind-shear alert system] was encountered when the airplane was on the missed approach; thus, the flight crew should have received both the red warning lights and the aural wind-shear warning," the report said. "However, the warning would not have occurred until the airplane was at an altitude of between 100 [feet (30.5 meters)] and 150 feet [45.6 meters] above the ground, or approximately three [seconds] to four seconds before ground impact."

At the time of the wind-shear encounter, the airplane's wing flaps were retracting from 40 degrees to 15 degrees, the report said. The wind-shear detection algorithms in the wind-shear computer were designed to prevent nuisance alerts by desensitizing 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 five seconds earlier, or about eight seconds to nine seconds prior to ground impact, if the detection threshold had not been desensitized [because of] the flaps being in transition," the report said.

When they reviewed the CVR for the accident flight, investigators found that the crew "did not adhere to standard operating procedures (SOPs) set forth in the USAir pilot operating handbook during the flight from Columbia to Charlotte," the report said. Examples included "an incomplete predeparture briefing by the first officer; the nonessential conversation between the crew members below 10,000 feet [3,050 meters] ([a violation of the] sterile cockpit [rule]); and the captain's failure to make the required '1,000 [feet] above the airport' and the '100 feet above minimums' altitude call-outs."

The report concluded that "the nonstandard operating practices during the final phase of flight might have caused the pilots to lose situational awareness during the approach."

The crew failed to conduct the standard ILS approach briefing required by company SOPs, the report said. This would have included a review of items such as the localizer frequency, inbound course heading, minimum altitudes and the missed-approach procedure. The NTSB believed the crew's incomplete briefing resulted from an expectation that they would complete the approach in visual conditions, the report said.

Investigators analyzed why the captain commanded the first officer to lower the nose during the missed approach, after a climb attitude had been established. "Examination of the circumstances during the last minute of the 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 report said. "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."

The report added: "Because the flight crew 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 flight crew's vestibular and proprioceptive sensory systems and produced a form of spatial disorientation known as somatogravic illusion." [The somatogravic illusion is a false perception of attitude, caused by unusual forces on the ear's balancing mechanism.]

The report concluded that lowering the pitch attitude eliminated the altitude margin necessary to escape the wind shear.

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Crew Acted As "Individuals"

The investigation reviewed the accident crew's use of crew resource management during the flight. "The [NTSB] believes that the crew of Flight 1016 appeared to be comfortable with each other in the cockpit," the report said. "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 report noted: "The [NTSB] 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."

During the investigation, various check airmen with USAir were interviewed. The interviews indicated that "individual pilots have different methods of accomplishing checklists," the report said. "The [NTSB] 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 crew members to brief visual approaches, while another check airman believed that crew members were required to brief the visual approach," the report said.

The NTSB reviewed the wind-shear training program at USAir, and concluded that the program "met industry standards, and the pilots [of the accident flight] had received the requisite training," the report said. "However, the pilots did not apply the principles of this training adequately during the accident flight. Therefore, the [NTSB] believes that the FAA should re-examine the circumstances and findings of this accident as a basis for a review and revision, as necessary, of airline industry wind-shear training programs," the report said.

The report noted that "typically, the wind-shear cues always provided to the flight crews in the simulator occurred in the form of either turbulence immediately before the wind shear and/or a fluctuation in airspeed. ... [T]here 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 FAA principal operations inspector (POI) responsible for the oversight of USAir's operations was questioned at the NTSB public hearing. "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 wind-shear training to only one of two captains [who] were paired together during a simulator period," the report said. "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 [for the other captain], rather than [bringing] the other captain back for the required wind-shear training."

Some USAir Pilots Lacked Wind-shear Training

The report added: "The 1993 NASIP inspection also revealed that 51 USAir pilot training records were lacking entries that would indicate exposure to wind-shear 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 NTSB concluded that the FAA's responsibility for oversight of the carrier had been compromised by the fact that the POI failed to follow up on the training records of these pilots, the report said.

As part of its investigation, the NTSB reviewed the passenger manifest for the accident flight, and found that there were two in-lap infants that were not listed, the report said. "Neither of the flight coupons for the adults associated with the two in-lap infants included an 'infant boarding pass' sticker," the report said. "Although one coupon included a handwritten notation '+ infant,' the second coupon did not; thus, the infant was not included on the passenger manifest."

The report noted: "The [NTSB] believes that the [FAA] regulation that permits children two 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."

One of the in-lap infants on the accident flight was killed. "The child's mother was unable to maintain a secure hold on the child during the impact sequence," the report said. "The [NTSB] believes that if the child had been properly restrained in a child-restraint system, she probably would not have sustained fatal injuries."

As a result of its investigation, the NTSB developed the following major findings:

- "The flight crew was properly certificated and had received the requisite training and off-duty time prescribed by Federal Aviation Regulations;

- "There was no evidence of pre-existing medical or physiological conditions that would have adversely affected the flight crew's performance;

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

- "The airplane was certificated, equipped and maintained in accordance with Federal regulations and approved procedures;

- "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;

- "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 rain shower activity;

- "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;

- "The Phase II low-level wind-shear 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;

- "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;

- "The flight crew's decision to continue the approach into an area of adverse weather may have been influenced by weather information by the crews of preceding flights that had flown the flight path to Runway 18R previously;

- "The thunderstorm over the airport produced a microburst that Flight 1016 penetrated while on its approach to Runway 18R;

- "The horizontal wind shear calculated for the microburst was as much as 86 knots; however, Flight 1016 encountered a wind shear computed to be 61 knots over a period of 15 seconds;

- "An inadequate computer software design in the airplane's on-board wind-shear detection system prevented the flight crew from receiving a more timely wind-shear alert;

- "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 wind-shear escape procedure;

- "The first officer initially rotated the airplane to the proper 15 degree nose-up attitude during the missed approach. … ;

- "According to performance simulations, the airplane could have overcome the wind-shear encounter if the pitch attitude of 15 degrees nose-up had been maintained, the thrust had been set to 1.93 and the landing gear had been retracted on schedule;

- "The FAA's principal operations inspector and USAir's management were aware of inconsistencies in flight crew adherence to operating procedures within the airline; however, corrective actions had not resolved this problem; [and,]

- "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."

As a result of its findings, the NTSB made the following recommendations to the FAA:

- "Amend [the FAA *ATC Handbook*] to ensure that [ATIS] broadcasts are promptly updated whenever any conditions conducive to thunderstorms are observed. These conditions would include, but not be limited to, wind shear, 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 this information;

- "Amend [the *ATC Handbook*] 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 three miles [4.8 kilometers]. 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;

- "Amend [the *ATC Handbook*] to require radar and tower controllers to display (including BRITE [which reproduces the ASR-9 display]) 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 flight crews;

- "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;

- "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;

- "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;

- "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;

- "Review all low-level wind-shear 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;

- "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 wind shear, to FAA TRACONS and tower facilities immediately upon detection;

- "Re-evaluate 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 wind shear, and to include procedures for using the wind-shear escape maneuver, in lieu of a missed-approach procedure, when the airplane is in the final approach phase (below 1,000 feet [305 meters]) and conditions conducive to wind shear are present, regardless of whether the pilot encounters airspeed fluctuations or precipitation;

- "Develop standards for forward-facing, integrated child safety seats for transport category aircraft; [and,]

- "Revise [FARs] 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."

The NTSB made the following recommendation to the U.S. National Weather Service: "Re-evaluate, 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-level wind shear, to FAA TRACONS and tower facilities immediately upon detection."

The NTSB made the following recommendations 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;

- "Re-emphasize the necessity for flight crews to achieve and maintain diligence in the use of all applicable checklists and operating procedures;

- "Re-emphasize in pilot training and flight checking the cues available for identifying convective activity and recognizing associated microburst wind shears; and provide additional guidance to pilots on operational (initiation and continuation of flight) decisions involving flight into terminal areas where convective activity is present; [and,]

- "Review company procedures regarding passenger counts on manifests to ensure their accuracy and accountability of all occupants on the airplane."

In November 1994, as a result of the design feature in the on-board wind-shear warning system that prevented nuisance alerts while the airplane's flaps were in transit, the NTSB made the following safety recommendations to the FAA:

- "Issue a Flight Standards Information Bulletin to operators of aircraft equipped with a Honeywell Standard Windshear [Detection] System to [ensure] that flight crew members of those airplanes are advised of the current limitations of the system that delays wind-shear warnings to flight crew members when the flaps are in transition;

- "Conduct a review of the certification of the Honeywell Standard Windshear [Detection] 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; [and,]

- "Modify Technical Standard Order [TSO] C-117 to ensure that wind-shear warning systems undergo testing with the flaps in transition before granting certification."

In February 1995, the FAA responded to these recommendations, and indicated that it would take the following actions:

- "FAA will issue a flight standards bulletin by March 1995;

- "FAA is reviewing the Honeywell Standard Windshear Detection System and other systems to determine if these systems delay detection of wind shear during flap configuration changes; [and,]

- "FAA is revising the Technical Standard Order (TSO) C-117 ... to require the applicant [to] show by analysis or other suitable means that the system threshold is above the point at which nuisance warnings would be objectionable under conditions of severe turbulence or aircraft changes of configuration, i.e., flaps and/or gear retraction. … "

The report noted: "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 flight crew that during flap configuration changes the system is desensitized, and that alerts resulting from wind-shear encounters will be delayed. Additionally, the FAA will require Honeywell to design a modification to the system that ensures that wind-shear warning system activation will occur during flap transition."♦

Editorial note: This article was adapted from *Flight Into Terrain During Missed Approach, USAir Flight 1016, DC-9-31, N954VJ, Charlotte/Douglas International Airport, Charlotte, North Carolina, July 2, 1994*. Report no. NTSB/AAR-95/03, prepared by the U.S. National Transportation Safety Board (NTSB). The 187-page report includes charts, diagrams and illustrations.

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