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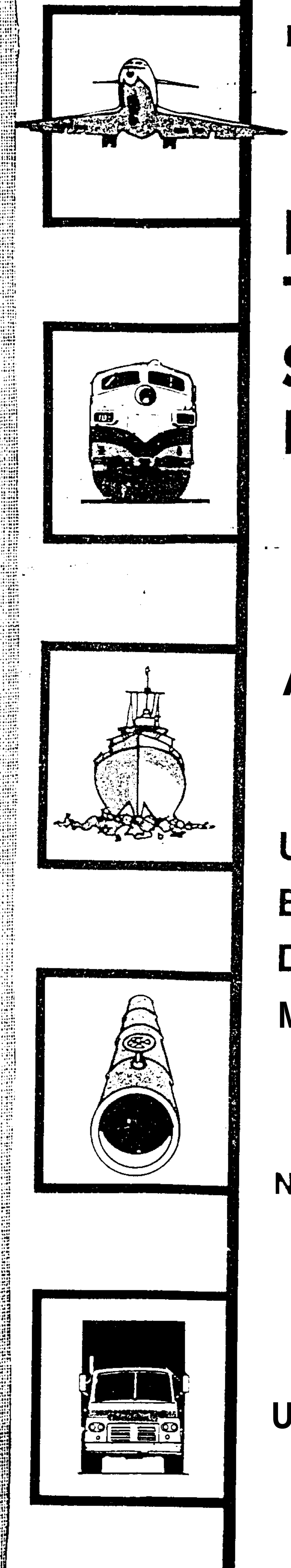

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

UNITED AIRLINES FLIGHT 663
BOEING 727-222, N7647U
DENVER, COLORADO
MAY 31, 1984

NTSB/AAR-85/05

UNITED STATES GOVERNMENT

CONTENTS

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15. Supplementary Notes

16. Abstract On May 31, 1984, at 1334 m.d.t., United Airlines Flight 663, a Boeing 727, struck the localizer antenna 1,074 feet beyond the departure end of runway 35L during takeoff at Stapleton International Airport, Denver, Colorado. The flight was en route to Las Vegas, Nevada, with 98 passengers and 7 crewmembers aboard. The flightcrew said they were not aware that the airplane had struck the antenna. When they were not able to pressurize the airplane after takeoff, the captain decided to return and land at Stapleton. The approach and landing on runway 26L was uneventful. There were no injuries, but the airplane sustained substantial airframe damage when it struck the antenna.

The National Transportation Safety Board determines that the probable cause of the accident was an encounter with severe wind shear from microburst activity following the captain's decision to take off under meteorological conditions conducive to severe wind shear. Factors which influenced his decisionmaking include: (1) the limitations of the low level wind shear 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 wind shear report from a turboprop airplane and the fact that he did not receive a wind shear 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; and (4) the captain's previous experience operating successfully at Denver under wind shear conditions.

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SYNOPSIS

On May 31, 1984, at 1334 m.d.t., United Airlines Flight 663, a Boeing 727, struck the localizer antenna 1,074 feet beyond the departure end of runway 35L during takeoff at Stapleton International Airport, Denver, Colorado. The flight was en route to Las Vegas, Nevada, with 98 passengers and 7 crewmembers aboard. The flightcrew said they were not aware that the airplane had struck the antenna. When they were not able to pressurize the airplane after takeoff, the captain decided to return and land at Stapleton. The approach and landing on runway 26L was uneventful. There were no injuries, but the airplane sustained substantial airframe damage when it struck the antenna.

The National Transportation Safety Board determines that the probable cause of the accident was an encounter with severe wind shear from microburst activity following the captain's decision to take off under meteorological conditions conducive to severe wind shear. Factors which influenced his decisionmaking include: (1) the limitations of the low level wind shear 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 wind shear report from a turboprop airplane and the fact that he did not receive a wind shear 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; and (4) the captain's previous experience operating successfully at Denver under wind shear conditions.

1. FACTUAL INFORMATION

1.1 History of the Flight

On May 31, 1984, United Airlines (UA) Flight 663, a Boeing 727-222, was a passenger flight scheduled to depart Stapleton International Airport in Denver, Colorado, at 1312 1/ for the McCarran International Airport in Las Vegas, Nevada.

UA Flight 663 was dispatched from the United dispatch center in Chicago, Illinois. The dispatcher for UA Flight 663 reported that there were scattered showers in the Denver area and that he did not receive a report of adverse winds for the terminal area. This information was provided to the flightcrew. The predeparture activities

1/ All times herein are mountain daylight time, based on the 24-hour clock, unless otherwise noted.

associated with UA Flight 663 were normal except for an amended dispatch release sent to gate B-9 where the flight was parked. The release was amended because of weather changes at the destination airport which required that an alternate airport be named in the flight plan.

The flightcrew received their dispatch release and flight papers pertinent to the flight via teleprinter. The local weather information contained therein was as follows:

> Terminal Forecast (FT 31) at 1116: Clouds--12,000 feet scattered, 25,000 feet scattered; wind--210 degrees at 15 knots. After 1400--clouds--8,000 feet scattered, 25,000 feet thin broken; wind--240 degrees at 15 knots, gusting to 25 knots; occasional ceiling--8,000 feet broken; cumulonimbus in the vicinity, chance of wind gusts to 40 knots until 2200. After 0400--VFR, becoming marginal VFR due to ceiling.
>
> Local Surface Weather at 1150: Clouds--8,000 feet scattered, estimated 12,000 feet broken, 20,000 feet broken; visibility-50 miles; temperature--79' F; dewpoint--40° F; wind-270 degrees at 10 knots; altimeter-29.95 inHg.

The captain said that as a result of this information and the heavy cumulus cloud buildup, he advised the flight attendants about 20 minutes before departure to stay seated after takeoff until further advised by the flightcrew. He said that the dispatcher indicated there was a forecast for virga 2/ and turbulence in the area.

UA Flight 663 departed gate B-9 about 1310, 2 minutes ahead of schedule with 98 passengers and 7 crewmembers aboard. It was assigned runway 35L for departure, and it made a normal taxi to the runway using only engine Nos. 1 and 3.

The second officer, a rated B-727 captain and a check airman supervisor, said that at the time of computing the takeoff data the weather was reported on ATIS 3/ "x-ray," as clear, temperature 83° F, dewpoint 39° F, wind 290° at 14 knots, and altimeter 29.94. He stated that the takeoff and landing card was computed using a planned takeoff gross weight of 146,887 pounds and a mean aerodynamic chord (MAC) of 19.2 percent. Normal engine pressure ratio (EPR) was 1.90, and maximum EPR was 1.93. Takeoff speeds V1 and VR were 139 knots, and V2 was 150 knots based on a takeoff gross weight of 150,000 pounds and a 5-degree flap setting. However, final changes to the dispatch release provided to the crew showed the takeoff gross weight as 146,377 pounds, zero fuel weight 121,700 pounds, and an MAC of 21.7 percent.

Because of several flights already waiting for takeoff clearance, ground air traffic control (ATC) cleared UA Flight 663 about 1316 to the northeast corner of a holding area, where the captain positioned the airplane and shut down one of the engines. The flightcrew said that while parked they observed and discussed the local weather conditions. They noted high overcast clouds with some virga in the area. The captain said

2/ Wisps or streaks of water or ice particles falling out of a cloud, but evaporating before reaching the earth's surface as precipitation.

3/ Automatic Terminal Information Service--a recording made by air traffic control personnel of current airport weather provided by the National Weather Service.

that, based upon these observations, he elected to use maximum EPR and 5 degrees of flaps for the takeoff. At 1321:26, ground control instructed UA Flight 663 to taxi next to UA Flight 965, a B-727, and to monitor the tower frequency (local control position LC-1) for takeoff sequencing. At 1323:10, UA Flight 663 asked the controller for its takeoff sequence number and was informed that it was No. 9.

From about 1323 until 1332, the controller handled 16 departing airplanes. Eleven were routed for takeoff on runway 35L, and 5 for takeoff on runway 35R. The average time between airplanes departing on runway 35L was about 1 minute, and the average time between airplanes departing on runway 35R was about 2 minutes. Between 1321:47 and 1327, the controller made three wind reports, each stating that the wind was steady from 290 to 300 degrees at 7 to 9 knots. At 1326:19, Rocky Mountain Airline (RMA) Flight 652, a deHavilland Dash 7 (four-engine turboprop short takeoff and landing-type airplane) was cleared for takeoff on runway 35L. No wind shear reports were made by the controller when he gave Flight 652 its takeoff clearance. After takeoff, RMA Flight 652 reported, at 1327:14, a 25-knot loss in airspeed at about 200 feet above the ground.

Immediately afterward, the controller either asked if pilots had received RMA Flight 652's report or provided the wind shear report from the flight to four other departing flights. The controller asked the pilot of a Piper Seneca (N755), which he had cleared for takeoff at 1327:05 on runway 35L, if he had heard the airspeed loss report from RMA Flight 652. The pilot acknowledged hearing the report but did not report encountering a similar condition during his departure. At 1327:14, the controller gave the pilot of a Westwind business jet the airspeed loss report and cleared the airplane for takeoff on runway 35R. This pilot also did not report encountering wind shear. At 1328:12, the controller reported the centerfield wind from 290 degrees at 20 knots and cleared Frontier Airlines (FL) Flight 663, a B-737, for takeoff on runway 35L. The controller asked the flight if it had heard the airspeed loss report, and the flight acknowledged the report.

At 1329:32, the controller gave a centerfield wind report of 290 degrees at 22 knots with gusts to 33 knots, and a northeast boundary wind report of 250 degrees at 15 knots to FL Flight 39, a DC-9-80, which was cleared for departure at that time from runway 35L directly behind FL Flight 663. At 1329:52, the controller asked FL Flight 663 if it had encountered a wind shear, and the flight said "negative." At 1330, the controller cleared UA Flight 757 "heavy," a DC-8, into takeoff position on runway 35R. Five seconds later, the controller cleared UA Flight 965 into takeoff position on runway 35L. At 1330:09, the controller stated, "United four fifteen you're gonna follow company [UA Flight 9651 and United six sixty three you're gonna follow four fifteen." UA Flight 663 acknowledged the sequence information.

The UA Flight 663 flightcrew started the airplane's other two engines, and the captain made a cabin announcement to the passengers that the flight was about to receive its takeoff clearance. He instructed the flight attendants to remain seated because of expected turbulence on departure and advised all passengers and attendants to be sure their seatbelts were fastened tightly.

The captain of UA Flight 663 recalled that the weather at this time was much the same as earlier with high overcast cumulus clouds and some virga. He stated, "Except for the absence of heavy cumulonimbus clouds, it looked like a typical Denver afternoon." Using the black-and-white weather radar on board on a 50-mile scale, he saw a contouring cell 25 miles northeast of the airport which indicated to him thunderstorm activity. "It started at about the 20-mile mark and went out to about the 26-mile mark and looked slightly longer than that, maybe about two or three miles longer than that," he said. He said nothing else was showing on the radar. The captain estimated that virga existed 2 or 3 miles north and possibly 6 to 8 miles northeast. He said that there did not seem to be any unusual weather around the immediate area of the airport at the time, and he believed that the thunderstorm activity to the northeast already had passed through the area.

The captain of UA Flight 663 said that he had heard RMA Flight 652 report a "20 knot" loss of airspeed. He said that he observed RMA Flight 652 at about the midfield position 200 to 300 feet above the runway during its takeoff from runway 35L. He said that he made a mental note to listen for FL Flight 39's report of its takeoff. He observed FL Flight 39's initial departure and recalled that it appeared to have made a normal takeoff roll. The captain said that at this point he was starting to get busy preparing for departure and did not hear anything on the radio from FL Flight 39. He recalled saying to the first and second officers, "Frontier didn't say anything, but I think in light of the other report [that of the RMA Dash 71 , even though it was a smaller aircraft and he was airborne, we'll climb out at V2 plus 20." The captain said that he interpreted the report from the Dash 7 to be comparable to that of a Cessna type of light airplane report, but said that he believed a report from FL Flight 39 would have been more pertinent to his takeoff. He said he did not ask FL Flight 39 for a report because of the amount of congestion on the radio frequency. Even though he did not hear a report from FL Flight 39, he made the adjustment in the takeoff safety speed as a precautionary measure. The second officer recalled that the local control frequency was congested during this time.

At 1330:32, the controller contacted UA Flight 965, reported the wind at 270 degrees at 23 knots with gusts to 33 knots, and cleared the flight for takeoff on runway 35L. Two air carrier flights then asked the controller for their takeoff sequence, and the controller replied, "Ah standby I'll give you all a (unintelligible) a call in sequence everybody have your engines running ready to go no delays." At 1331:14, the controller instructed UA Flight 415, a B-727, to taxi into position on runway 35L and hold; 1 minute later he stated, "Centerfield wind two six zero at two three gusts disregard the gust factor north boundary wind three zero zero at niner three five left cleared for takeoff."

At 1331:48, UA Flight 663 was cleared into takeoff position on runway 35L. The flightcrew said that while on the runway, they observed dust blowing from west to east across the runway in the area near Highway I-70 (midfield). 4/ They said that they associated this phenomenon with a strong wind and a barren knoll located to the left side of runway 35L, the area from which the dust was blowing. In a written statement, the captain later indicated that the control tower had reported the midfield wind as 280 degrees at 14 knots. However, when interviewed he said that the midfield wind was out of the west in excess of 20 knots and that he was concerned and alert to the the possibility of getting a compressor stall from the center (No. 2) engine during the takeoff roll. At 1331:58, UA Flight 757 reported that it was ready for takeoff on runway 35R. However, at 1332:05, 7 seconds later, it reported, "Ah, this is seven fifty seven, our sock 5/ sitting in front of us gives us a pretty good tail wind so we're not ready to go yet." The controller asked the flight to advise him when conditions were better.

4/ Highway I-70 passes underneath both runways 35L and 35R.
5/ A wind sock is a truncated cloth cone open at both ends and mounted in an elevated position near the runway to indicate the direction and speed of the wind.

At 1332:59, UA Flight 663 was cleared for takeoff, and the first officer acknowledged the following takeoff clearance from the controller:

> United six sixty three center field wind two eight zero at two two gust to three four north boundary wind two eight zero at niner numerous wind shears 6/ in three different quadrants three five left cleared for takeoff.

(See figure 1.)

The captain of UA Flight 663 later recalled that when his flight was cleared for takeoff, the controller gave them a north field boundary wind, which was light from the west. He said the controller then reported the midfield wind from 280 degrees at 20 knots. He also recalled that the reported south field wind was relatively light. He said that from the information he received, "it appeared that we were going to have just a normal crosswind takeoff and looking for maybe a gust wind or something like that at that midfield point." The flightcrew said that they did not recall hearing the controller report, "numerous wind shears in three different quadrants," at the time they received their takeoff clearance. Also, they did not recall hearing the wind shift report from UA Flight 757 on runway 35R.

The captain performed the takeoff with the left air conditioning "pack" off and the right "pack" on. 7/ He said he advanced the throttles halfway and checked to see that he had set the thrust evenly. He then pushed the throttles up to the takeoff position and instructed the first officer to set them for maximum thrust. Takeoff thrust was applied by about 150 feet into the takeoff roll. The second officer recalled that after the flight started its takeoff roll, he heard one of the airplanes ahead of them report a hesitation in acceleration on the takeoff roll at midfield, "or something to that effect." (UA Flight 415 made this report at 1333:57, 58 seconds after UA Flight 663 received its takeoff clearance.) About midway down the runway, near I-70, the airspeed of UA Flight 663 seemed to hesitate at 120 knots, according to the first officer. The first officer recalled that just as he called out words to the effect, "we're slow in accelerating," the airspeed began accelerating normally. The captain said that he associated this occurrence with the midfield crosswind earlier observed. He said that he did not have difficulty keeping the airplane on the runway centerline during the takeoff roll. He said that he momentarily considered aborting the takeoff when the airspeed began to hesitate but disregarded the thought when the airspeed began increasing.

The flightcrew recalled that the airplane was rotated for liftoff at or just beyond a VR speed of about 141 knots. During the rotation, the first officer said to the captain, "your airspeed is falling off." The first officer believed that the drop in airspeed occurred about the time he was going to report reaching V2. According to the captain, the first officer's comment was followed immediately by the second officer's, "you've lost 20 knots." The captain said, and the other crewmembers agreed, that the rotation was stopped at approximately 8 to 9 degrees of airplane noseup attitude in order to permit the airplane to regain its VR speed. The captain called for more thrust and pushed the throttles to their forward stops ("firewall") followed quickly by the first officer checking

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6/ A change in wind direction and/or speed in a very short distance in the atmosphere.
7/ The use of air conditioning air cycle machines, commonly referred to as "packs," requires engine bleed air which reduces the thrust output of the engine. Takeoff performance data are based on whether or not air conditioning packs are used. This is standard United procedure.

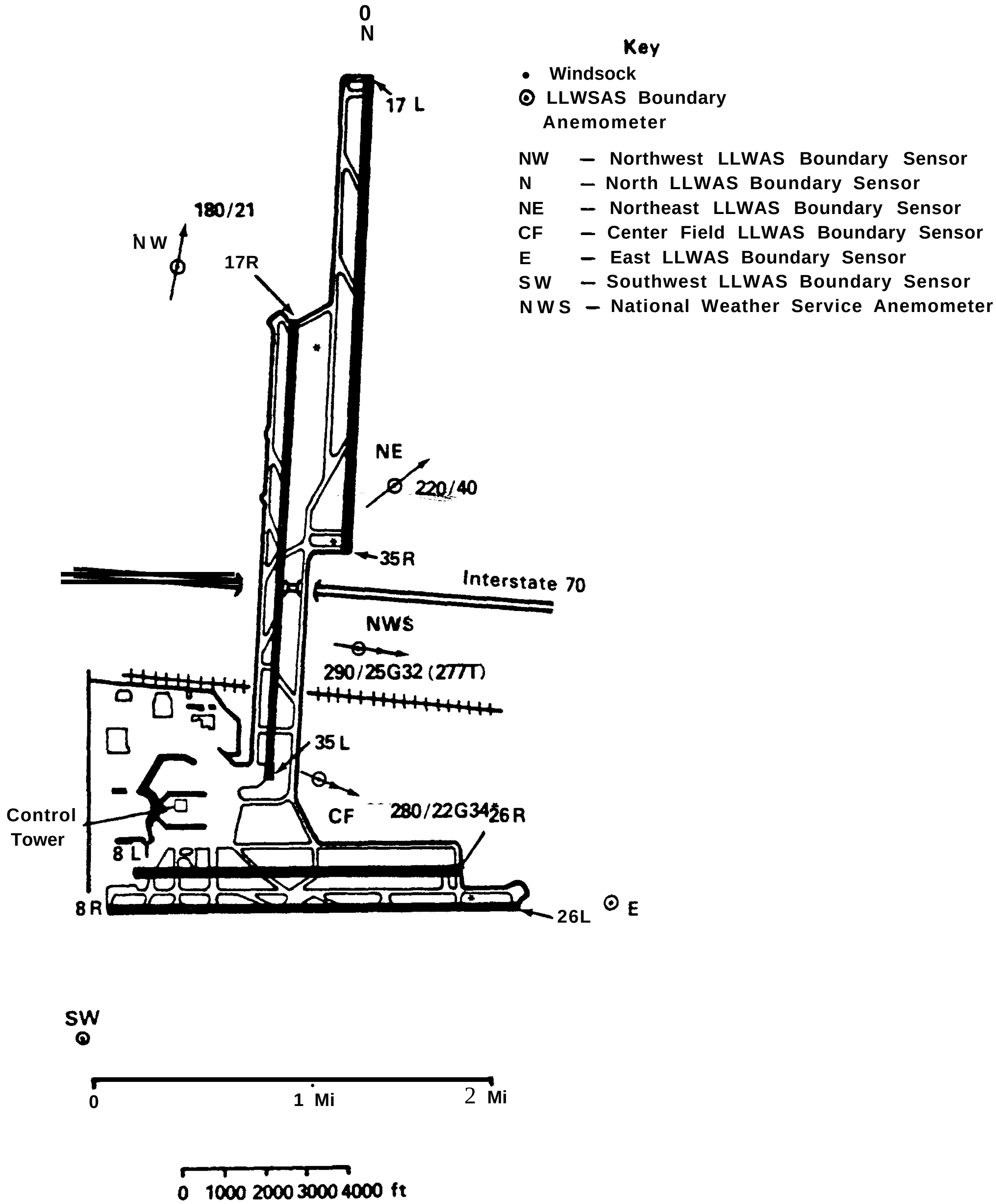


Figure 1.--Partial plan view of Denver Stapleton Airport showing locations of LLWAS boundary sensors and the microburst winds recorded about 1333.

to ensure that the throttles were full forward. The flightcrew said that they believed the airspeed decayed to, or slightly below, about 130 knots before it began to stabilize and subsequently increase. The second officer told the captain that his rate-of-climb (IVSI) was zero and that the climb attitude, or body angle, looked good. He repeatedly called out the rate-of-climb and said words to the effect, "hold the body angle."

The captain said that as the VR speed resumed increasing, the 2,000-foot runway "hash" marks, or overrun markings, flashed by the corner of his eye. At this point, he resumed rotating the airplane to the proper climb attitude. Both he and the first officer said they believed that the climbout finally was made between 12 to 14 degrees of noseup attitude, with the airspeed, according to the captain, fluctuating between V2 -10 and +20 knots. The second officer continued calling out, "You've got a good body angle . . . the airspeed is gradually picking up." The captain recalled that the airspeed suddenly increased to V2 plus 30 knots and stabilized when the airplane was about 700 feet above the ground. The captain estimated that a period of about 2 seconds had elapsed from the initial point of rotation to the point where he checked the airplane's attitude. He further estimated that a period of 7 to 8 seconds had elapsed from the point where he stopped the rotation to the point where the rotation was resumed. He said that he believed they were very close to the end of the runway during the rotation. The first officer said later that he thought they were going to hit the localizer antenna, which was 13 feet high and was located 1,074 feet from the departure end of runway 35L. The flightcrew did not know that the airplane, in fact, had struck the localizer antenna.

While performing the "After Takeoff Checklist,** the second officer of UA Flight 663 reported to the captain, while climbing through 8,500 feet, that he could not pressurize the airplane. The left air conditioning "pack" was then turned on. However, with the outflow valve fully closed, the cabin altitude continued to climb even though the standby and manual modes were used in an attempt to pressurize the airplane. Since the flightcrew was unable to correct the problem, the captain decided that he would return to Stapleton and land.

UA Flight 663 landed uneventfully on Stapleton's runway 26L at 1405. Postflight inspection of the airplane disclosed a 4-inch by 5-foot gash on the right side of the airplane, forward of the aft cargo door, and a crease in the outer skin on the opposite side of the fuselage. There were no injuries to the 98 passengers and 7 crewmembers aboard the airplane.

The flightcrew could not recall with certainty the point at which the airplane lifted off the runway. They indicated that there was no positive "seat of the pants" feeling of the airplane becoming airborne. The captain and first officer said that they did not feel the airplane was flying until it had climbed about 100 feet. The captain called for the landing gear to be retracted after the airplane showed a good positive rate of climb and the airspeed had stabilized. After the landing gear was retracted, the thrust was reduced to the noise abatement profile setting. The flightcrew concluded that a wind shear had affected the airplane's performance, and the captain had asked the first officer to inform the control tower of the wind shear occurrence. The captain said that the primary flight instrument he used throughout the adverse wind encounter was his Collins Flight Director without the command bars (pitch and roll display) in view as well as "keeping an eye on the airspeed.** The flightcrew said that they believed the airplane had cleared the localizer antenna beyond the end of the runway. The captain said that he thought the nose of the airplane had cleared the localizer by about 50 feet.

The captain reported that he did not expect to encounter wind shear during the takeoff roll. He said that he had observed RMA Flight 652 when it was 200 to 300 feet above the runway and heard it later report a loss of airspeed, but he did not recall any other flights being adversely affected by an airspeed loss. However, in his written statement, the captain reported that ". . . a Rocky Mountain Dash 7 reported a 20K loss near liftoff, then a Frontier DC-g-80 reported a hesitation on airspeed increase approximately mid-runway point. . . . when we took position. . . ." When questioned about his statement concerning the Frontier flight, he stated that he was not sure that the report came from the Frontier flight or from someone else. He said it could have been made sometime after his takeoff roll began. He remembered the report distinctly, because when he encountered the airspeed hesitation on his takeoff, he immediately related the encounter with the report from the other flight.

The captain stated that, as a result of his training and experience, he believed that wind shear was only a problem encountered in the air and not while on the ground. He reported also that he could not recall aborting or delaying a takeoff because of an adverse wind advisory. He said that he had never heard an ATC controller use the term "wind shear alert." He said that, had he heard the controller use the term before making the takeoff, ". . . that would ring a fire alarm. Even if I was in position on the runway, then I'd have to say we're going to have to hold here for a minute now." He further stated that, "If I had any idea that somebody was encountering a loss of airspeed on takeoff roll, then now you're in a whole different scenario."

The four flight attendants aboard the airplane, two in the forward (A and D) and two in the aft (B and C) passenger cabin areas, commented that the takeoff roll seemed longer than usual. The "B" flight attendant, seated in the right aft jumpseat, recalled looking out the jet escape window near the I-70 underpass. She said the airplane seemed to be swaying from left to right. The flight attendants recalled hearing and feeling a loud thump and vibration shortly after liftoff. One of them said, "we hit something.** The "C" position attendant called the "A" flight attendant, seated in the forward cabin, and asked if she heard and felt the same thing and if she too was having a problem with her ears. The "A" attendant said yes and was asked if she had called the flightcrew. She told the "C" flight attendant that she did not think they should call since they were over the city and that the flightcrew would be busy with ATC. She stated that she tried to abide by the sterile cockpit rule. 8/ She said that about 30 seconds after the "C" flight attendant called her, the flightcrew made a cabin announcement that there was a pressurization problem and that the flight would be returning to Stapleton. This announcement caused her to assume that her ear problem, and the unusual noise and vibration she felt earlier, were caused by the pressurization problem. The flightcrew stated that the cabin crew should have alerted them about the incident.

Ground witnesses reported observing a dark brown cloud, from ground level to about 100 feet a.g.l., and about 800 feet wide, move at the rate of 40 to 50 knots from the southwest to the northeast across the outer portion of runway 35L at about the time UA Flight 663 took off at 1333.

8/ Reference 14 CFR Part 121.542 prohibits flightcrew members from performing any duties during a critical phase of flight except those duties required for the safe operation of the airplane. See appendix G.

1.2 Injuries to Persons

Injuries	Crew	Passenpers	Others	Total
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	7	98	0	105
Total	7	98	0	105

1.3 Damage to Aircraft

The airplane sustained substantial airframe damage.

1.4 Other Damage

The ILS V-ring localizer antenna array platform located 1,074 feet from the departure end of runway 35L was damaged. The No. 6 antenna array stanchion was bent over, the antenna arrays on top of the Nos. 4, 5, and 7 stanchions were damaged, and some of the platform railing was damaged. The grass was scorched by jet exhaust from a point 300 feet beyond the end of the runway to a point 245 feet in front of the antenna platform.

1.5 Personnel Infor ma tion

The flightcrew, flight attendants, and the local air traffic controllers were qualified in accordance with current Federal regulations. (See appendix B.)

1.6 Aircraft Information

The airplane, a Boeing 727-222, N7647U, owned and operated by United Airlines, was manufactured by the Boeing Company on June 30, 1969. It had accumulated a total of 35,566 flying hours at the time of the accident. It was equipped with three Pratt & Whitney, JT8D-7B turbofan engines, each rated at 14,000 pounds of thrust. (See appendix C.)

The airworthiness of the airplane was maintained in accordance with a continuous maintenance and inspection program approved by the Federal Aviation Administration (FAA). A review of the flight log disclosed no known discrepancies that would have had a bearing on the accident.

The maximum certificated takeoff gross weight limit for the B-727-222 is 172,000 pounds, and the center of gravity (c.g.) range at that weight limit is 11 to 28.8 percent MAC. The maximum allowable takeoff gross weight for runway 35L on the day of the accident was 153,400 pounds. The revised takeoff gross weight for UA Flight 663 was 146,377 pounds. Based on this weight with the left air conditioning "pack" off and the right "pack" on, the V1 and VR speeds were 136 knots, and the V2 speed was 148 knots. Maximum EPR was 1.93. The FAA-approved Airplane Flight Manual (AFM) showed that with 5 degrees of flaps, with no corrections for runway slope, wind, or air conditioning bleeds, the required runway field length for the takeoff was 10,500 feet. The computed stall speed of the airplane under these takeoff conditions was 119 knots.

1.7 Meteorological Information

The surface weather map issued by the National Weather Service (NWS) for 1200 on May 31, 1984, showed the Denver area to be west of a surface trough extending south-southwestward through central South Dakota and across extreme southeast Colorado. A slow-moving cold front, oriented east-northeast, west-southwest over Wyoming, was moving southeast. Conditions over eastern Colorado were characterized by broken clouds and variable, but generally westerly, surface winds.

The 700-millibar (10,000-foot) map issued by the NWS for 0600 on May 31, 1984, showed the area of Colorado east of the escarpment to be under a shallow trough in the westerly winds aloft. The maximum temperature extended through central North Dakota, eastern Colorado and into Mexico, south of the Big Bend area of Texas. The temperature over Denver at 700 millibars was 13° C, dewpoint depression was 21.6’ C, and the wind was from 284 degrees at 21 knots.

An infrared Geostationary Operational Environmental Satellite (GOES) photograph taken at 1301 on May 31, 1984, showed a broken north-south line of convective activity along the edge of the escarpment. Based upon the infrared enhancement curves and a sounding of the winds aloft made in Denver at 0400 on May 31, 1984, the tops of the convective activity were determined to be between 32,000 and 36,000 feet.

Surface Weather Observations.--During the hour between 1251 and 1352 on May 31, 1984, a trace of rain was recorded at the Stapleton International Airport. The following are the surface observations at Stapleton, made by NWS employees, at the times shown:

> 1251--clouds--8,000 feet scattered, ceiling estimated 12,000 feet broken, 20,000 feet broken; visibility-50 miles; temperature--82° F; dewpoint--37° F; wind-350 degrees at 8 knots; altimeter--29.92 inches; remarks-virga south through southwest.
>
> 1334--special--ceiling--estimated 8,000 feet broken, 12,000 feet overcast; visibility-20 miles; light rain showers; wind--290 degrees at 25 knots, gusting to 32 knots; altimeter-29.92 inches; remarks--rain began 1332.
>
> 1352--ceiling--estimated 8,000 feet broken, 12,000 feet overcast; visibility--50 miles; light rain showers; temperature--75° F; dewpoint--40° F; wind-290 degrees 16 knots gusting to 24 knots; remarks--virga south through southwest and north.

At 1251, the weather conditions reported from surrounding airports were similar to those reported at Stapleton. By 1334, the time of the accident, the visibility, wind, and atmospheric pressure at Stapleton had changed considerably from that of Surrounding weather reporting stations. A gust recorder at Stapleton showed an increasing wind speed from a low of 3 knots at 1315 to gusts of 26 knots between 1327 and 1328; 32 knots at approximately 1332; 30 knots between 1336 and 1337; 29 knots at 1338; 26 knots at 1343; and 24 knots at 1347. From 1347 to 1359, the wind speed decreased below 10 knots. It remained less than 10 knots after 1500. In addition, the station Pressure recorded by the barograph at Stapleton showed relatively steady atmospheric Pressure at 24.58 inHg between 1300 and 1345. At 1345, it started a gradual decline to 24.54 inHg at about 1635. There were no apparent pressure jumps between 1300 and 1400.

Radar.--At 1230, the NWS radar at Limon, Colorado, showed several thunderstorms within 65 miles of Stapleton. The closest was an apparent thunderstorm with moderate (level 2) 9/ rain showers approximately 12 miles southwest of the airport. The strongest activity detected was three cells with very heavy (level 4) rain showers about 35 miles south-southeast of the airport.

At 1330, the intensity of the thunderstorm activity in the vicinity of Denver had increased. Stapleton was within an area of rain showers with a heavy (level 3) cell 7 miles to the west. There was an intense (level 5) cell about 20 miles to the southeast of the airport. The maximum top of precipitation was 29,000 feet, 30 miles southeast of the airport. The cells were moving from 220 degrees at 20 knots.

At 1430, Denver was still in the area of rain showers, but the strongest activity, two extreme (level 6) cells, were about 25 miles to the east.

Soundings.--The winds aloft information, obtained from soundings taken at 0600 and 1800 on May 31, 1984, showed that the wind speeds did not exceed 27 knots and 18 knots, respectively, from the surface up to 25,000 feet m.s.l.

The density altitude at the airport at the time of the accident was 7,775 feet m.s.l.

There were no weather advisories in effect at time of the accident.

1.7.1 Doppler Radar Information

At the time of the accident, the National Center for Atmospheric Research (NCAR) was operating a CP-4 doppler radar from a site approximately 15 miles north of Stapleton. NCAR was conducting a field experiment which did not include the observation of the phenomenon known as microburst. 10/ The mechanisms which produce this phenomenon have been examined by researchers using radar-collected data gathered during the Joint Airport Weather Study Project (JAWS) under the auspices of NCAR. The primary objective of the JAWS project was to examine wind shear. Because microburst observations were not part of the field experiment, the doppler radar was not positioned ideally to detect this phenomenon. A hill between the radar site and the airport blocked the radar beam, which prevented observations of wind flow patterns at ground level at the airport. In addition, the experiment required only a 5-minute update rate of the radar data; the previous JAWS program had determined that a 5-minute update rate is too long an interval to observe adequately the microburst phenomenon.

9/ The NWS classifies rain showers from levels 1 through 6, as follows:

Level	Intensity
1	Light
2	Moderate
3	Heavy
4	Very heavy
5	Intense
6	Extreme

10/ Microbursts are produced by small-scale downdrafts. When the air within the downdraft hits the ground, it diverges horizontally. On the average, vertical velocities in the downdraft are about 10 meters (33 feet) per second and the horizontal flow has differential velocities of 24 meters (79 feet) per second. (Wilson et. al., 1984.)

The JAWS project had identified several radar signatures frequently associated with thunderstorms preceding the occurrence of microbursts. These signatures included: "(1) horizontal convergence near cloud base and at mid-cloud levels; (2) descent of a reflectivity core; 11/ and (3) small scale rotation in the downdraft." 12/

NCAR made the data from the field experiment available to the Safety Board during its investigation. A review of the data revealed that all of the features of the radar signatures associated with thunderstorms were present at the time of the accident. The radar showed a northeast-southwest line of echoes with an intensity of light to moderate (level 1 to level 2) southwest of Stapleton. This line of cells was moving from 220 degrees at 16 knots. By 1334:38, an echo on the leading edge of the line was located nearly over Stapleton. This light (level 1) echo was observed descending from approximately 6,600 feet a.g.l. between 1325 and 1330. By 1339, a microburst echo was located northeast of Stapleton and had nearly dissipated.

The outflow from this echo at about 2,300 feet a.g.l. was divergent in relation to the radar, in that the wind shear vectors were directed both toward and away from the radar site beginning at about 1324. At 1324:38, the radar showed a 23-knot approaching flow and a zero-knot receding flow over a distance of about 3/4 mile. Aloft, convergent flow was located from about 3,300 to 11,500 feet and was above the surface divergent flow. Convergence reached a maximum at 1330. Both cyclonic and anticyclonic rotations were observed aloft.

1.7.2 Program for Regional Observing and Forecasting Services (PROFS) Data

The National Oceanic and Atmospheric Administration (NOAA) operates the Program for Regional Observing and Forecasting Services (PROFS) in the northeast Colorado area. The purpose of this system is to gather frequent and detailed weather information in order to provide timely weather advisories and warnings to interested groups in the area. The following are observations from 1100 to 1410 at the PROFS sensors at the Aurora, Colorado, station, located at the NWS Forecast Office at Stapleton:

1. Atmospheric Pressure

   The microbaragraph showed an unsteady fall from 835.14 to 833.74 millibars (station pressure) from 1100 to 1305, a rise to 833.89, and fluctuations between 833.79 and 833.96, thereafter. At 1346, the trace began to fall, reaching 833.72 at 1410.

2. Wind Direction and Speed

   0 The average wind direction was unsteady. It varied from 283 degrees at 1100 to 318 degrees at 1300. It changed to 230 degrees at 1310 and then to 315 degrees at 1321. From 1321 until 1410, it varied between 315 and 275 degrees.

   0 From 1100, the average wind speed fluctuated around 13 knots. This continued until 1315, when it increased rapidly from 4 knots to 17 knots at 1345. Thereafter, it increased to 20 knots at 1410.

11/ A descending volume of precipitation.
12/ NCAR report of June 30, 1984.

0 The gust direction was similar to the average wind direction with a shift from 318 degrees at 1300 to 235 degrees at 1311, and back to 318 degrees at 1326. From 1326 to 1410, the gust direction varied between 273 and 325 degrees.

0 The gust speed profile, like the gust direction, closely followed the average wind speed. From 1100 to 1330, the gust speed varied between extremes of 20 knots and 7 knots, increasing rapidly from 7 knots at 1330 to 30 knots at 1336; dropping off rapidly to 4 knots at 1410.

3. Temperature

The temperature trace showed a variable climb from 79.8° F at 1100 to 82.1° F at 1305. It then dropped steadily to 74.6° F at 1355, climbed to 76.1° F at 1406, and dropped to 75.6’ F at 1410.

4. Dew Point Depression 13/

The dew point depression increased from 38° F at 1100 to 44° F at 1121, and then increased unsteadily to a maximum of 47° F at 1300. After 1300 it decreased rapidly to 34.5° F at 1350, and then increased to 37° F at 1405 and decreased to 33.5° F at 1410.

5. Radar Information

The following is a summary of radar information from the National Weather Service radar at Limon, Colorado, for the times shown as reproduced in graphical form by the PROFS system:

1230: An area of rain showers extended southwest from a point approximately 5 miles southwest of Stapleton Airport. None of the showers in this group exceeded light (level 1) category.

1300: The rain showers immediately southwest of Stapleton Airport had merged into a dense area of rain showers with the eastern edge approximately 4 miles east of Stapleton Airport. Cell activity was moderate (level 2), approximately 10 miles southwest of the airport.

1310: The rain shower area was a single large area approximately 12 miles by 20 miles, with the northeast edge over Stapleton. The center of the area, approximately 10 miles southwest of the airport, was a heavy (level 3) rain shower.

13/ The numerical difference between the temperature and the dewpoint (T - Td). One of the conditions that contribute to a microburst is a large dewpoint depression, nominally 40° F.

1320: The eastern edge of the rain shower area had moved over Stapleton Airport. The strongest echo remained a heavy rain shower (level 3) about 7 miles southwest of the airport.

1330: Stapleton Airport was under the eastern edge of the rain shower activity. The central core, which had diminished to a moderate rain shower (level 2), was approximately 4 miles west of Stapleton Airport.

1335: The major mass of the rain shower system had moved north of Stapleton Airport and continued to diminish in intensity. The central core of the shower was moderate (level 2), approximately 4 miles west of the airport.

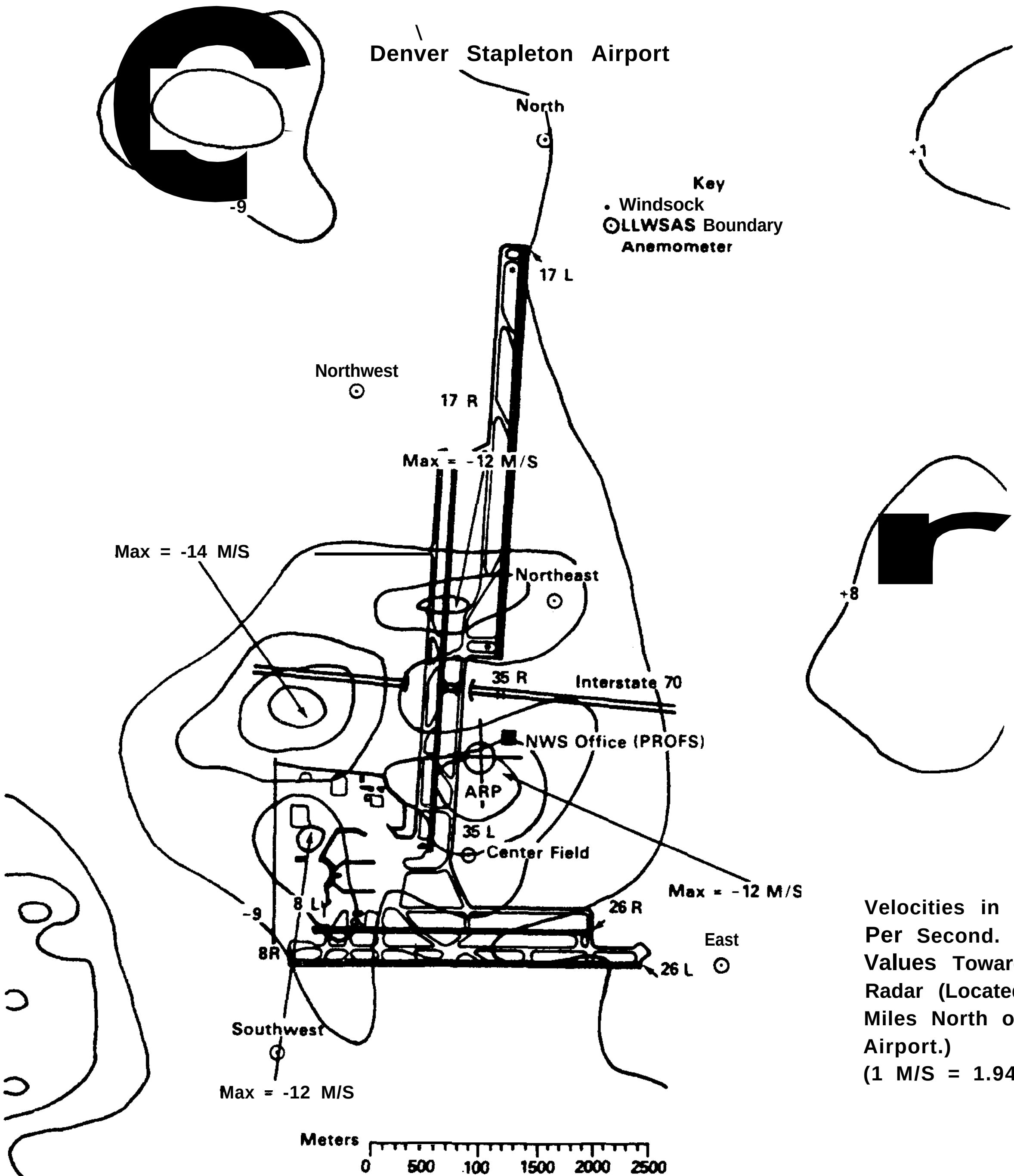
1345: The system had weakened to light rain showers and had moved north of Stapleton Airport. The southern-most edge was about 2 miles west-northwest of the airport.

The area of rain shower movement that affected Stapleton Airport was estimated to have been moving from approximately 225 degrees at 17 knots, and increased to greater than 30 knots as it weakened and moved north of the airport.

1.7.3 Weather Analysis

The available weather data showed that "high base" thunderstorm activity had been approaching Stapleton from the southwest. This type of thunderstorm has a base high above the ground, generally between 8,000 and 12,000 feet, and a dry adiabatic lapse rate 14/ in the atmosphere below the thunderstorms. These high-based thunderstorms are quite common in the summertime over the high plains east of the Rocky Mountains and over the desert to the southwest where the combination of very hot dry surface air and mid-level moisture are present. Descending virga were associated with this activity near Stapleton creating downdrafts which spread outward as they reached the ground, causing strong surface gusts. The evidence disclosed that this event was the result of a microburst. Wind shear from a microburst, as compared to wind shear resulting from a gust front, is particularly hazardous because it is a short-period event which creates very strong wind gusts with a large variation in direction over a very short distance (1/2 to 2 1/2 miles in diameter). All indications were that the microburst which affected the departures on runways 35L and 35R was from a cell which was passing about 1 mile northwest of the control tower. From 1326 to 1334, the microburst apparently affected the surface of the airport only north of runway 8L/26R and south of the departure end of runway 35R. This is based upon the fact that neither the southwest, east, or north LLWAS boundary anemometers showed the effects of a gust during this time. (See figure 2 and appendix E.)

14/ The cooling rate of unsaturated air is 5.5° F or 3° C per 1,000 feet.



Velocities in Meters Per Second. Negative Values Toward the Radar (Located 15 Miles North of the Airport.)
(1 M/S = 1.94 K)

NCAR *Doppler radar scan at 0.7" elevation at* 1334:38 *MDT, 31 Hay 84, representing radial flow with* respect *to CP-4 radar to the north,* at *500-700 meters above runway level. Runway location approximate*

Figure 2.--Radial velocities observed by the NCAR CP-4 doppler radar at 1334.38.

One 'thunderstorm can produce one or several microbursts which show as individual peaks on a windspeed record or as gusts recorded at different anemometers at different times. Also, there can be pulsations in a single microburst event which are recorded as closely spaced, multiple peaks on a wind recorder. The spreading surface gust can travel for several miles over the ground. The direction and speed of the winds emanating from a microburst are generally a vector combination of the diverging air and the motion of the thunderstorm cell from which it was generated.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

There were no known difficulties with communications equipment. However, there was congestion on the local control frequency.

1.10 Aerodrome Information

The Stapleton International Airport is owned and operated by the city and county of Denver, Colorado. The airport, which has an elevation of 5,333 feet and encompasses some 4,600 acres, is certificated under 14 CFR Part 139. The four runways primarily used by air carrier-type aircraft are designated 8L/26R, 8R/26L, 17L/35R, and 17R/35L. All of the runways are grooved. Runway 17R/35L is 11,500 feet long and 150 feet wide, and runway 17L/35R is 12,000 feet long and 200 feet wide. Information extracted from the Airport Master Record (FAA Form 50.10-l) indicates that runway 35L has a 400-foot overrun. The runway has an obstruction clearance slope of 50:1.

The ILS V-ring localizer antenna array platform struck by UA Flight 663 is a nonfrangible structure approximately 13 feet in height. The localizer is located approximately 1,074 feet from the departure end of runway 35L, or about 674 feet from the end of the overrun or pavement area. The localizer is equipped with a warning light that is designed to alert tower personnel if the localizer signal becomes unreliable. Tower personnel did not recall being alerted by the warning light at the time of the accident. FAA airways facility personnel reported that the localizer was off when they arrived at the localizer site shortly after the accident.

The FAA has a national program for replacing certain nonfrangible structures at airports with frangible structures. Such a program was in progress at Stapleton. However, the localizer near runway 35L had not been replaced because it did not meet the planned criteria for conversion, in that it was located outside the obstruction plane criteria. According to airways facility personnel, this particular type of antenna needs a better line of sight from the runway end than some of the newer types. It is an old antenna, and had it been destroyed completely in the accident, it probably would have been replaced by a frangible one. It had the capacity of causing severe structural damage to the airplane. None of the five glide slope antennas at Stapleton are frangible because they are located about 1,000 feet from the runway thresholds and 500 feet to the side. Each of the glide slope antennas is located on a tower about 40 to 55 feet in height.

Stapleton International Airport is one of the most active air carrier airports in the United States. It averaged 1,391 operations per day from January through September 1984, ranking 5th among 22 air carrier airports in the Nation. It also ranks 5th in total passenger enplanements (8,408,409 in the first 9 months of 1983) among the top 30 air carrier airports in the United States. In addition to being a key airport in the ATC system, Stapleton is also a "hub" airport for United Airlines, Continental Airlines, and Frontier Airlines. United has about 41 percent of the total passenger loadings (1983 data) at Denver.

1.10.1 Low Level Wind Shear Alert System

Stapleton is surrounded by mountainous terrain. Pilots and ATC personnel stated that it is not uncommon to have numerous wind shears acting upon the airport daily. For this reason, Stapleton has a Low Level Wind Shear Alert System (LLWAS). The LLWAS consists of five remote and one centerfield wind sensor (anemometer). The five remote sensors are located north, northwest, northeast, east, and southwest of the airport. (See figure 1.) The LLWAS is a computerized system designed to detect the presence of a possible hazardous, horizontal low-level wind shear by continuously comparing the winds measured by the five sensors around the periphery of the airport with the wind at the centerfield location. If the result of the vector difference calculation is equal to 15 knots or greater, the system is designed to produce a wind shear alarm against the boundary sensor that supplied the vector component for the vector difference calculation.

The wind shear data are displayed on a monitor installed in the airport control tower facility. The tower cab at Stapleton was equipped with two display units. These units are positioned at two local control positions; local control 1 (LC-1) and local control 2 (LC-2). The controller working the LC-1 position was responsible for landings and takeoffs on runways 17L/35R and 17R/35L, and the controller working the LC-2 position was responsible for landings and takeoffs on runways 8L/26R and 8R/26L. At the time of the accident, all arrivals were landing on runways 8L/R, and all departures were using runways 35L/R. The wind shear data from all six sensors are displayed simultaneously on both monitors in the tower cab, and the local controllers receive the wind shear data from all six sensors irrespective of the runways for which they are controlling traffic. (See section 1.17.1 for a description of the ATC procedures regarding the use of the LLWAS.)

During the Safety Board's investigation, LLWAS data were obtained for review. Since the LLWAS data are not recorded automatically by recorder equipment designed into the LLWAS, the Safety Board had to rely on the LLWAS data reported by the LC-1 and LC-2 controllers and recorded on the ATC tape. Table 1 shows the LLWAS winds reported by the controllers from 1326:00 to 1356:44.

1.11 Plight Recorders

The airplane was equipped with a Fairchild model 5425 flight data recorder (FDR), serial No. 6175, and a Sundstrand model V-557 cockpit voice recorder (CVR), serial No. 3330. The CVR and FDR were removed from the airplane and taken to the Safety Board's laboratory in Washington, D. C., for examination and readout.

Table 1.--LLWAS winds reported by controllers from 1326:00 to 1356:44.

Controller	Time	CF	SWB	NWB	NB	NEB	EB
LC-2	1326:00	270/15					
LC-2	1327:00	280/16					
LC-2	1327:52	290/18G-28					300/9
LC-1	1328:20	290/20					
LC-2	1328:48	300/21	250/15			240/11	
LC-1	1329:32	290/22G-33				250/15	
LC-2	1330:06	280/21G-33				250/18	
LC-1	1330:32	270/23G-33					
LC-1	1331:35	260/23			300/9		
LC-2	1332:52	280/22G-34	240/9	180/9		220/15	
LC-1	*1332:59	280/22G-34			280/9		
LC-2	1333:28	280/22G-34	240/9			220/40	
LC-1	1334:05	280/19G-34		180/21	280/8		
LC-2	1334:11	280/19G-31		180/21		230/30	
LC-1	1335:21	270/22G-32			270/12		
LC-2	1335:30	260/22G-32				230/23	
LC-2	1336:03	260/24					
LC-2	1336:11			170/26		220/23	
LC-2	1336:30	260/24		180/29		230/31	
LC-2	1337:29		250/14				
LC-1	1339:08	290/25G-37		180/18		240/31	
LC-1	1343:53	300/22			190/15		
LC-1	1345:08	300/22			210/21		
LC-1	1345:48	290/21					
LC-1	1347:15	290/18			220/17		
LC-1	1347:47	290/17			210/16		
LC-1	1348:12	300/17	200/14		220/19		
LC-1	1350:04	300/13	350/2	180/8			
LC-1	1351:14	310/13		180/3			
LC-1	1351:50	300/14					
LC-1	1354:32	280/10					
LC-1	1355:18	280/9					
LC-1	1356:44	310/6					

Legend

CF	Centerfield Wind
SWB	Southwest Boundary Wind
NWB	Northwest Boundary Wind
NB	North Boundary Wind
NEB	Northeast Boundary Wind
EB	East Boundary Wind
LC-1	Local Controller 1 (Takeoffs)
LC-2	Local Controller 2 (Landings)
*	This was the wind given with the takeoff clearance issued to UA Flight 663.
NOTE:	The boundary winds are instantaneous readings, and the centerfield winds are averaged over 2 minutes. The wind directions are given in degrees (magnetic) and the speed in knots.

The tape recording from the CVR was not transcribed because the recorded events began about 16 minutes after the takeoff incident occurred. The audio quality of the recording was very poor, with several areas where there was either a very weak signal or no signal at all. These signal omissions were very intermittent, and there was no pattern to their occurrence.

On July 13, 1982, the Safety Board issued Safety Recommendations A-82-62 and -63 to the FAA concerning Sunstrand Model V-557 CVR's:

> Initiate a program involving all U.S. operators using United Control Corporation (Sunstrand) V-557 cockpit voice recorders to randomly check a representative sample of these recorders in operational use to assure that they are operating within design specifications. If this inspection reveals significant problems with acceptability of recorded data, require the necessary changes in the carriers' maintenance programs to assure continued airworthiness of these recorders.
>
> After a specified period of not more than 2 years, require the removal of all United Control Corporation (Sunstrand) V-557 cockpit voice recorders and installation of suitable replacements.

The FAA responded to the recommendations on January 24, 1983. While the Safety Board was encouraged by the FAA's action to conduct an extensive review program of all CVR/FDR devices, the Board in its reply disagreed over the nature of the problem concerning the V-557 CVR's. The Board stated that this model CVR has exceeded its service life and is of poor quality compared to the available state-of-the-art recorder hardware and technology. FAA-suggested scheduled preventive maintenance requirements and listening checks have not corrected this fundamental problem in view of the Board's examination of this model CVR involved in accidents. The Board classified Safety Recommendations A-82-62 and -63 as "Closed--Unacceptable Action."

A summary of the CVR-recorded events was prepared. The recording began at 1349:50 when the airplane was descending from about 9,000 feet for a landing at Stapleton. During the next 8 minutes, the flightcrew performed their before-landing checklist and made some comments about how the weather conditions had changed since their takeoff. An approach speed of 142 knots was briefed and was flown on final. Approach speeds were called out during the last 30 seconds of the approach and during the first part of the landing rollout until reaching about 60 knots. The airplane landed at Stapleton about 1357 and parked at gate B-9. The auxiliary power unit was started, and the engines were shut down at 1359:42. About 1359:54, the captain instructed the passengers to remain in their seats until he had a chance to determine the cause of the pressurization problem and how long of a delay they could expect. After the passenger briefing, the captain left the cockpit at 1400. During the captain's absence, several flight attendants came into the cockpit and related their experiences during the takeoff roll and their concern about the loud noises they heard just after leaving the runway on takeoff. The flightcrew left the flight deck at 1413:04, but the CVR continued to operate for about 7 minutes, until 1419:27, when the power was turned off.

The model 542 FDR scribes a continuous and permanent record of pressure altitude, indicated airspeed, magnetic heading, vertical acceleration, microphone keying, and time on a metal recording medium. Examination of the recorded traces disclosed that all parameters, including the binary traces, were scribed in a normal manner with no evidence of recording abnormalities or malfunctions. The readout time was chosen to start at a point about 1 minute before the indicated liftoff point and was continued through a portion of the climbout.

The FDR's from UA Flight 415, UA Flight 757, and FL Flight 663, whose takeoffs bracketed the takeoff time of UA Flight 663, were read out for their altitude and airspeed traces. The readouts were performed in order to ascertain how these flights may have been affected by the wind conditions existing at the time of their takeoffs. (See Section 1.16.1 for a description of the takeoff performance analysis.)

1.12 Wreckage and Impact Information

The airplane struck the localizer antenna located 1,074 feet beyond the end of runway 35L about 2 to 3 feet from the top of the antenna array. (See figure 3.) The airplane sustained substantial impact damage to the right side of the fuselage, just forward of the aft cargo door between body stations (BS) 1010 and 1090 (see figure 4), and minor impact damage on the opposite side of the fuselage between BS 992 and BS 1246. There also were minor impact damage and paint transfer marks on the number one, outboard main landing gear tire, on the underside of the right inboard trailing edge flap, and on the number four, right main landing tire.

The damage on the right side of the fuselage consisted of a 4-inch by 5-foot gash which was calculated to be at about a 14-degree angle with reference to the longitudinal axis of the airplane. This indicated that the airplane was in a noseup pitch attitude of about 14 degrees and in about level flight at the time it struck the localizer antenna. (See figure 5 and appendix D.)

Figure 3.-Runway 35L ILS localizer antenna.

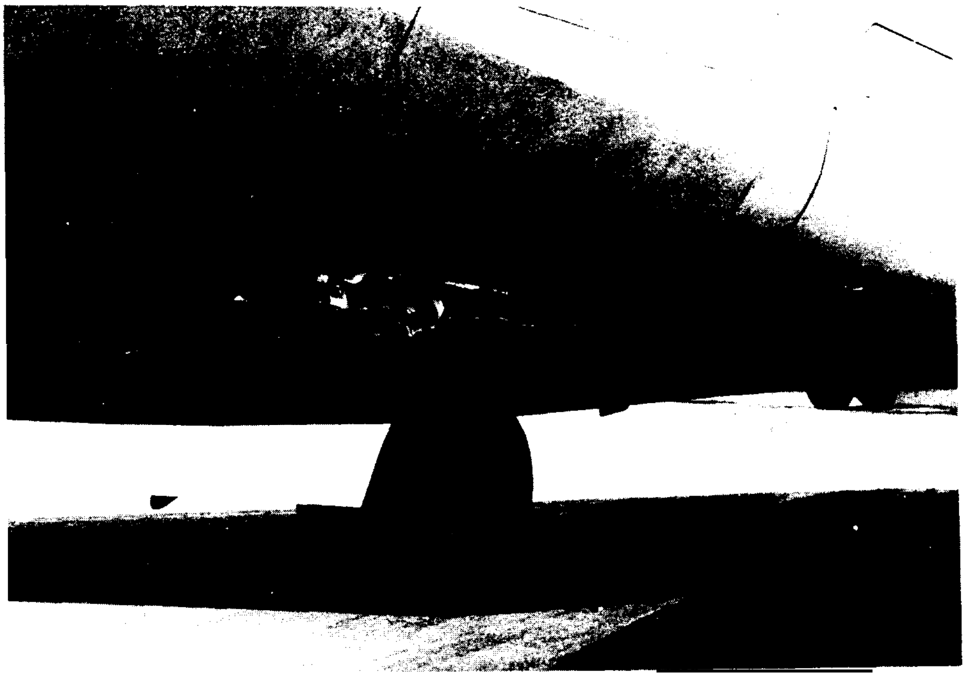


Figure 4.-View of the 4-inch by 5-foot gash on the right side of the fuselage, forward of the aft cargo door.

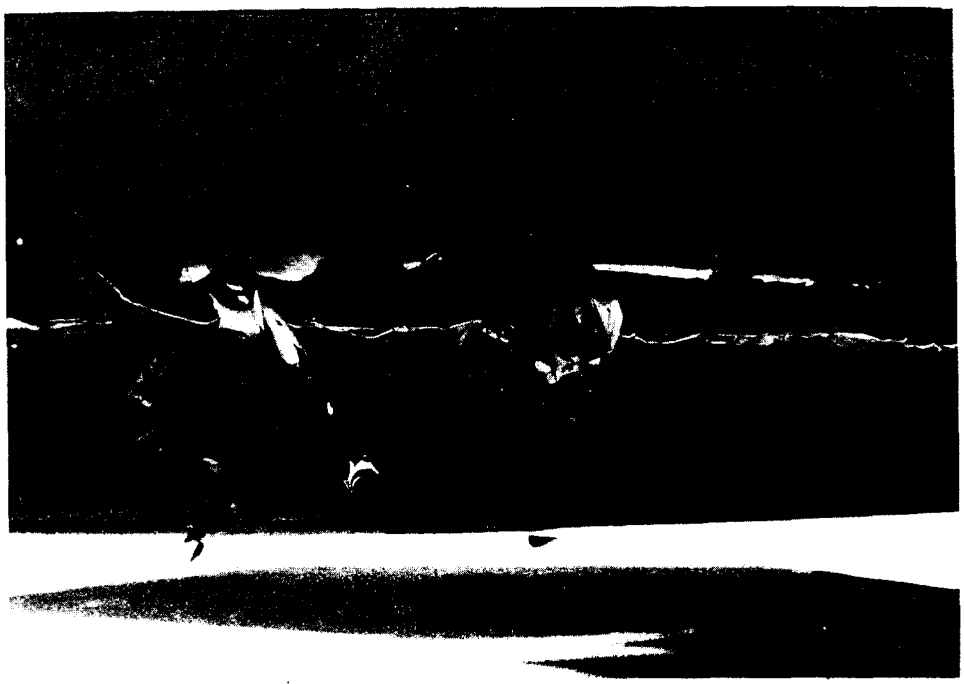


Figure 5.--Close-up of the damage showing a piece of antenna embedded in the fuselage.

The impact severed three body frames (at BS 1030, BS 1050, and BS 1070) and severed two stringers at S22L and S24R. There also was damage to some shear ties. The fuselage structure is a semimonocoque construction, the primary structure of which is the metal skin, reinforced by the circumferential frames and the longitudinal stringers. Almost the entire fuselage shell from BS 178 to BS 1183 is pressurized including the area of the aft fuselage which was damaged. This structure is subjected to various bending, torsional, and shear loads applied by various flight maneuvers and further complicated by loads applied by pressurization. According to the Boeing 727 Supplemental Structural Inspection document No. D6-48040-1, any detail, element, or assembly which contributes significantly to carrying flight, ground pressure, or control loads, and the failure of which could affect the structural integrity necessary for the safety of the airplane, is classified as a structural significant item (SSI). Hence, frames, stringers and skin are SSI's. Items not in this category are classified as secondary or other structure. Based on a careful inspection of the damage, on a review of the appropriate structural repair and maintenance manuals and United Airlines policy, and on the criteria listed in Safety Board Regulation 830.2, the Safety Board concluded that the damage was substantial and, therefore, classified the occurrence as an accident.

1.13 Medical and Pathological Information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival Aspects

Not applicable.

1.16 Tests and Research

1.16.1 Aircraft Takeoff Performance Analysis

The phase of flight in which the accident occurred required a thorough evaluation of the takeoff performance capability of the airplane for the purpose of determining to what extent the takeoff was affected by the microburst. The Safety Board formed an aircraft performance group to make the evaluation, and during the course of its evaluation, the group reviewed the airport information and weather, the takeoff data, and the FDR data.

The 11,500-foot runway 17R/35L has a 0.4-percent-average downslope on runway 35L. The elevation of the departure end of runway 35L is 5,245 feet m.s.l. The top of the localizer V-ring antenna array is 13 feet a.g.l., which is at an elevation of 5,238 feet m.s.l. This puts the top of the antenna array 6 feet above the elevation of the departure end of runway 35L. Runway 35L had a reported obstruction clearance slope of 50:1, which equates to an angle of 1.15 degrees. The angle of elevation between the departure end of the runway and the top of the antenna array computes to less than 1 degree. Therefore, the location and the height of the localizer antenna is below the prescribed 50:1 obstruction clearance slope required by Federal regulation.

According to the second officer, the takeoff data initially were computed based on a planned takeoff gross weight of 146,887 pounds at a MAC of 19.2 percent. Final changes to the dispatch release showed the actual takeoff gross weight to be 146,377 pounds with an MAC of 21.7 percent. However, the takeoff speeds were based on 150,000 pounds with 5 degrees of flaps at a temperature of 83° F. The takeoff speed at 150,000 pounds is 2 to 3 knots greater than at 146,377 pounds. This speed difference would account for only minor differences in the locations on the runway at which the airplane would have lifted off.

The V1 and VR speed calculations indicated to the flightcrew that if an engine were to fail or malfunction before 139 knots indicated airspeed, they would abort the takeoff and be able to stop on the runway. However, if an engine were to fail at or above V1, they would continue the takeoff in accordance with prescribed regulations. Also, at that speed, if no malfunction occurs, the captain would be expected to initiate the rotation by pulling back on the yoke to increase the pitch attitude of the airplane to a prescribed climb attitude, normally about 14 degrees for the B-727-200. However, the takeoff data computations do not tell the flightcrew the distance down the runway at which V1 and VR will be reached, what the total takeoff roll will be before liftoff occurs, or the takeoff distance. 15/ As a result, the crew will not know exactly how much runway they will have remaining at the V1 and VR point. The V2 speed is a takeoff safety speed and is reached as the airplane accelerates and climbs to 35 feet a.g.l. in the climb attitude.

Under the direction of the Safety Board, the Boeing Company analyzed the actual takeoff performance of UA Flight 663 in comparison with the takeoff performance of an identically configured B-727-200. It was determined that such a comparative analysis would reveal the approximate magnitude of the wind shear the flight had experienced.

A successful takeoff requires that the airplane accelerate to a liftoff speed and rotate to a climb attitude within the confines of the runway. Air carrier takeoff calculations take these requirements into account, and the results are a predetermined liftoff speed based on a specific weight, flap setting, runway condition, temperature, and wind condition. In a takeoff performance evaluation, weight can be considered constant since it varies only with fuel consumption. Thrust is primarily a function of throttle position and to a lesser degree of airspeed, the properties of the engine inlet, and of air density. The primary variable in the takeoff situation is wind direction and velocity since it can change constantly. The airplane will accelerate and lift off as planned provided there is no change in the wind.

The effect a wind shear will have on the takeoff depends on the wind direction and speed relative to the airplane's takeoff path. If the airplane is taking off into a headwind and the headwind suddenly increases, the airplane will reach liftoff speed sooner than planned and the takeoff roll will be reduced. Conversely, if the headwind component decreases, or if the airplane suddenly experiences a tailwind because of a wind shear during a takeoff, the airplane will require more time to accelerate to liftoff speed resulting in an increased takeoff roll. A sudden wind shear involving the combination of

15/ 14 CFR 25.113 -- In part, the horizontal distance along the takeoff path from the start of the takeoff to the point at which the airplane is 35 feet above the takeoff surface, determined under 14 CFR 25.111.

the two winds also would have a corresponding effect on the takeoff performance of the airplane; i.e., an increased headwind component will have a positive effect and an increased tailwind component will have a negative effect.

The computations performed during the takeoff performance analysis were based on the following findings and assumptions: the reported weight and flap setting at takeoff; the reported weather and wind conditions (centerfield reading of 280 degrees at 22 knots) at the time of takeoff; engine and airplane performance parameters derived from Boeing documentation; an assumed engine thrust setting at brake release based on company procedure; the elapsed time of 64.8 seconds and the distance of 12,494 feet from the point of brake release to impact with the localizer antenna; the point where rotation began and stopped based on FDR data; the time at which maximum takeoff thrust was applied based on flightcrew statements; and the point at which liftoff occurred based on FDR data.

Reconstruction of the takeoff path from the FDR data showed that the altitude trace duplicated closely the runway surface profile. However, for reasons of accuracy, the altitude trace from brake release to liftoff was substituted with the known runway surface profile. From liftoff to the antenna, a smooth curve was drawn to pass through the antenna at an elevation of 5,248 feet m.s.l.--the altitude of the airplane when it struck the localizer. From this point, Boeing flight test data were used to correct the FDR altitude trace for attitude and ground effect up to about 100 feet a.g.l. The resulting curve was extended smoothly to fair back into the FDR altitude at about 90 seconds of FDR elapsed time. In the airborne portion of flight, the corrected altitude was used to compute a normal acceleration from which the lift coefficient could be derived. Using this lift coefficient and the FDR airspeed, the angle of attack was calculated.

Next, ground acceleration was computed using the excess thrust capability for the airplane under the assumed conditions, decreased by the rate of climb component derived from the corrected FDR altitude. This acceleration was then integrated--once to obtain groundspeed and again to obtain ground distance. The FDR airspeed was corrected for altitude and temperature to yield true airspeed. By comparing true airspeed and ground speed, a horizontal wind component was derived.

In addition, in order to determine the anticipated takeoff distance for UA Flight 663 under a no-wind condition, the Boeing Performance Engineer's Manual for the B-727-200 was used. Since the wind was from 280 degrees, the wind was considered essentially a direct crosswind with no anticipated effect on the takeoff distance. Based on the takeoff data used by the flightcrew, the manual showed that the distance to liftoff (takeoff roll) was calculated to be 7,300 feet. The time required to reach this point in the takeoff path from a standing start position was determined to be about 49 seconds. However, except from experience, the flightcrew would not actually know the number of seconds it would take to become airborne.

Examination of the FDR aboard FL Flight 663 showed that the airplane did not encounter wind shear during its takeoff at 1328:12--4 minutes and 47 seconds before UA Flight 663 took off. The FDR's from UA Flight 415 and UA Flight 757 confirmed the presence of wind shear as evidenced by a loss of airspeed during their takeoff rolls. UA Flight 415 experienced a 14-knot loss in airspeed about 18 seconds before rotation was commenced. The airspeed trace also showed that the airspeed fluctuated for a lo-second period following the loss before it increased prior to the point of rotation. UA Flight 757 experienced a 12-knot loss in airspeed for a 7-second period. This loss in airspeed was regained only 4 seconds before rotation was commenced.

1.17 Additional Information

1.17.1 Air Traffic Control Procedures

Stapleton International Airport has an approved informal preferential runway use program 16/ designed to take into consideration the runway locations, prevailing winds, and noise abatement requirements. Paragraph 7d(c) of FAA Order 8400.9, "National Safety and Operational Criteria For Runway Use Programs," dated November 9, 1981, upon which Stapleton Airport's program is based, specifies a 7-knot maximum tailwind component as one criterion which must be met in preparing a runway use program. Because of the nature of the prevailing wind conditions with respect to the airport site, a waiver to the 'I-knot maximum tailwind component requirement was granted to Stapleton. This requirement was increased to a maximum tailwind component of 10 knots.

The preferential runway use program at Stapleton applies to airplanes weighing 12,500 pounds or more and to all turbojet airplanes. The runway program is used provided there is no significant wind shear detected by the LLWAS, a pilot does not give an adverse wind report, or a thunderstorm is not within 5 nautical miles of the initial departure of final approach path of the selected runway(s) in use. Furthermore, the following conditions also must be met:

- Runways are clear and dry, i.e., there is no ice, slush, etc;
- Reported visibility is not less than 1 statute mile (runway visual range (RVR) 5,000);
- The tailwind component does not exceed 10 knots;
- The crosswind component does not exceed 20 knots; and
- The airplane gross weight and runway length availability does not exceed individual operator's manuals.

The program recognizes that it may be necessary to deviate from these procedures because of aircraft emergencies, adverse weather, runway closures, or extraordinary air traffic volume.

The program was in effect at the time of the accident using runways 35L/R for takeoffs and runways 8L/R for landings. The order of runway preference is as follows:

Departures	Arrivals
8 L/R	17 L/R
35 L/R	26 L/R
17 L/R	35 L/R
26 L/R	8 L/R

16/ Denver Control Tower Order 7110.2D, dated February 25, 1982.

In addition, FAA Order 8400.9, states, in part, as follows:

3.b. Under ideal conditions aircraft takeoffs and landings should be conducted into the wind. However, other considerations such as delay and capacity problems, runway length, available approach aids, noise abatement, and other factors may require aircraft operations to be conducted on runways not directly aligned into the wind.

* * *

3.d. This order is not intended to restrict a pilot's use of the full certificated capability of an aircraft. This order also does not limit a pilot in the use of instrument approach procedures or any other such factors. Applicable FAR's, flight and operations manuals and advisory material address the necessary safety aspects of aircraft operations for pilots and aircraft operators.

* * *

5.a. Runway Use Programs. A noise abatement runway selection plan designed to enhance noise abatement efforts with regard to airport communities for arriving and departing aircraft. These plans are developed into runway use programs and apply to all turbojet aircraft 12,500 pounds or heavier; turbojet aircraft less than 12,500 pounds are included only if the airport proprietor determines that the aircraft creates a noise problem. Runway use programs are coordinated with FAA offices as outlined in Order 1050.11. Safety criteria used in these programs are developed by the Office of Flight Operations. Runway use programs are administered by the Air Traffic Services as "Formal" or "Informal" programs.

b. Formal Runway Use Program. An approved noise abatement program which is defined and acknowledged in a Letter of Understanding between Flight Standards, Air Traffic Service, the airport proprietor and the users. Once established, participation in the program is mandatory for aircraft operators and pilots as provided for in FAR Section 91.87.

c. Informal Runway Use Program. An approved noise abatement program which does not require a Letter of Understanding and participation in the program is voluntary for aircraft operators/pilots.

* * *

7. OPERATIONAL SAFETY CRITERIA FOR RUNWAY USE PROGRAMS. Except as provided for in paragraph 8 (waivers), the following criteria shall be applied to all runway use programs:

a. Wind Shear or Thunderstorms. There should be no significant wind shear or thunderstorms which affect the use of the selected runway(s) such as:

(1) That reported by an operating Low Level Wind Shear Alert System (LLWAS), or

(2) Pilot report (PIREP) of wind shear, or

(3) No thunderstorms on the initial takeoff departure path or final approach path (within 4 nm) of the selected runway(s).

The following is an excerpt from Appendix 1.--Table of Maximum Wind Values in FAA Order 8400.9:

CROSSWIND COMPONENT TABLE 1
(DRY RUNWAY)

Wind angle from runway heading (degrees)	Wind velocity (knots)
10	114
20	58
30	40
40	31
45	28
50	26
60	23
70	21
80	20
90	20

TAILWIND COMPONENT TABLE 3
(WITH ANEMOMETERS)
(DRY RUNWAY)

Wind angle from runway heading (degrees)	Wind velocity (knots)
100	20
110	20
120	14
130	10
135	9
140	9
150	8
160	7
170	7
180	7

FAA Handbook 7110.65C, "Air Traffic Control," Section 6, dated January 1982, specifies the procedures air traffic controllers are to follow when providing LLWAS information to pilots when they are about to take off. Paragraph 981, "Low Level Wind Shear Advisories," states that, when an alert is received, controllers shall issue the centerfield wind and the displayed field boundary wind. The paragraph provides this corresponding example: "Centerfield wind, two seven zero at one zero. East boundary wind, one eight zero at two five." The handbook further states:

> b. If unstable conditions produce multiple alerts, issue an advisory that there are wind shear alerts in several/all quadrants. Then, issue the centerfield wind . . . followed by the field boundary wind most appropriate to the aircraft operation.
>
> Example:
>
> "Wind shear alerts all quadrants, Centerfield wind, two one zero at one four. West boundary wind, one four zero at two two."
>
> c. If requested by the pilot, issue specific field boundary wind information even though the LLWAS may not be in an alert status.

When the controller provided UA Flight 663 with the takeoff clearance, he advised the flightcrew of numerous wind shears in three different quadrants. Since the LLWAS data are not recorded, the Safety Board asked the controller if he recalled which three LLWAS boundary sensors were alarming when he issued the clearance. The controller stated that he advised the flight of the north boundary wind because of the difference between the centerfield wind velocity of 22 knots gusting to 34 knots and the north boundary wind velocity of 9 knots and because the north boundary sensor was alarming. He stated further that he normally gives the northwest boundary wind data to traffic departing from runway 35L, but when UA Flight 663 was cleared for takeoff, the northwest sensor was not alarming. He could not recall which other two boundary sensors were alarming when he gave the advisory.

On August 13, 1984, the FAA issued the following General Notice (GENOT) 7110.907: Subject: Low Level Wind Shear Alert System/Revision to Handbook 7110.65C, Paragraph 981.a and b.:

> Effectively immediately, the following procedure is in effect:
>
> Paragraph 981.a
>
> If an alert is received, issue the centerfield wind and the displayed field boundary wind.
>
> Phraseology:
>
> Wind shear alert, centerfield wind (direction) at (velocity). (Location of sensor) boundary wind (direction) at (velocity).
>
> 981.a Example-
>
> "Wind shear alert, centerfield wind, two seven zero at one zero. East boundary wind, one eight zero at two five."

Paragraph 98 1.b

If unstable conditions produce multiple alerts, issue an advisory that there are wind shear alerts in two/several/all quadrants. Then issue the centerfield wind in accordance with 980.b followed by the field boundary wind most appropriate to the aircraft operation.

Phraseology:

Wind shear alerts two/several/all quadrants. Centerfield wind (direction) at (velocity). (Location of sensor) boundary wind (direction) at (velocity).

981.b Example-

"Wind shear alert two quadrants. Centerfield wind, two one zero at one four. West boundary wind, one four zero at two two."

1.17.2 ATC Handling of Aircraft

The local controller later described the prevailing visibility as unlimited when he cleared UA Flight 663 for departure at about 1333. He stated that he observed high broken clouds over the mountain area. He was not aware of any precipitation at the airport. He described his workload at the time as heavy but routine. He stated that traffic was landing to the west and departing to the north. The tower cab supervisor was standing behind him and assisting him in coordinating functions. The controller said that he did not see UA Flight 663's initial rotation for liftoff, but he saw the liftoff, which generated a dust cloud at the departure end of runway 35L after which the climbout appeared to be normal. He noticed that no Mode C altitude data block for UA Flight 663 was acquired on the BRITE radar display, 17/ so he had no altitude inform'ation available initially.

At 1333:12, seconds after UA Flight 663 took off, the controller cleared UA Flight 161 into position on runway 35L. Forty-five seconds later, UA Flight 415 reported, "Okay, we got no acceleration midfield for about two thousand feet." The controller acknowledged the report, and 6 seconds later UA Flight 757 reported ready for takeoff on 35R. The following is the exchange of communication between the controller and airplanes under his control, from that point until 1336:09:

Time	Source	Message
1334:05	LC-1	United seven fifty seven three five right cleared for takeoff centerfield wind two eight zero at one nine gusts to three four north boundary wind two eight zero at eight northwest boundary wind one eight zero two one three five right cleared for takeoff.
1334:17	UA 757	United seven fifty seven heavy's cleared for takeoff and this sock here really gave us a strong southwest ah wind with debris going across the runway.

17/ A Mode C altitude data block should appear when a flight has reached an altitude of 300 feet a.g.l.

Time	Source	Message
1334:24	LC-1	Roger we have a front moving through at this time we're not sure what the winds are going to be.
1334:44	UA 663	And ah tower United six sixty three we lost about twenty knots there at rotation it was kind of touch and go
1334:50	(Unknown)	Try United four fifteen again
1334:50	LC-1	Roger
1334:52	LC-1	United seven fifty seven you copy
1334:56	LC-1	United four fifteen contact departure
1334:58	UA 757	Seven five seven roger
1335:03	(Unknown)	(Unintelligible)
1335:04	(Unknown)	That twenty knot loss on the left runway or the right one
1335:05	LC-1	Ah it was on three five left
1335:03	LC-1	United six sixty three contact departure
1335:11	(Unknown)	. . . Let somebody else go
1335:14	LC-1	Do it
1335:15	UA 861	What's the wind now for United eight six one heavy
1335:16	LC-1	United eight sixty one heavy you request the winds
1335:20	UA 861	Yeah
1335:21	LC-1	United eight sixty one heavy centerfield wind two seven zero two two gusts to three two the northwest north boundary wind two seven zero at one two we're not departing at this time
1335:30	(Unknown)	(Unintelligible)
1335:38	UA 161	United one sixty one is not going to take off with this wind ah we'll either sit here or we'll get off the runway for ya
1335:43	LC-1	United one sixty one continue holding in position we're not gonna issue any takeoff clearances for a while until the wind settles down

Time	Source	Message
1335:49	UA 161	Okay thank you
1335:51	LC-1	United seven fifty seven heavy did you encounter any wind shear sir
1335:44	UA 757	Ah roger seven five seven heavy on the runway we had no acceleration at V one for a good thousand feet and then we got a forty knot increase right away when we got airborne
1336:05	LC-1	United seven fifty seven heavy thank you for your report contact departure.
1336:08	UA 757	Roger going over thank you
1336:09	LC-1	Good day

After the controller cleared UA Flight 757 for takeoff on runway 35R at 1334:05, and after UA Flight 663 reported at 1334:44 the 20-knot loss of speed at rotation, he stopped departures after being told to do so by the tower cab supervisor. At 1334:50, the controller advised UA Flight 861 that he had stopped departures. He recalled that when he stopped departures, he had from five to seven airplanes awaiting takeoff clearance. He resumed departures after about 7 minutes, at which time he recalled that there were westerly winds at a moderate velocity. Another RMA Dash 7 pilot awaiting takeoff clearance had requested the winds and said he was capable of departing. The tower cab supervisor told the controller to resume departures at that time. The controller had gone home at the end of his scheduled duty shift when UA Flight 663 landed.

The tower cab supervisor stated that he and the controller were both wearing headsets, and he had override capability. He recalled that UA Flight 663 was at about midfield when UA Flight 415 reported no acceleration at midfield on takeoff. He stated that UA Flight 663 lifted off at the far north end of runway 35L, and he recalled that there was no runway left when it lifted off. He said that he did not watch UA Flight 663 after it lifted off, but that he noticed dust at the end of the runway at the time of liftoff. He recalled seeing high clouds moving through the area at the time, with the weather building up to the northeast. He did not remember observing virga and did not remember any significant weather reports. He further stated that in the exercise of his supervisory discretion, he made the decision to stop departures based on a northwest boundary wind indication change from west to south (180 degrees at 20 knots). After about 7 minutes, the wind had settled down and a RMA Dash 7 training flight requested takeoff clearance. He lifted the takeoff restrictions. He described the traffic volume as moderate to heavy with about 15 arrivals and 65 departures during the hour. He commented that the LLWAS alarms about 70 percent of the time when a thunderstorm is passing through the airport area, and that these alarms were very common at Stapleton. There were about six or seven other controller personnel in the tower cab at the time. He stated that the facility was fully staffed in accordance with current staffing levels and that no training was being conducted in the tower cab at the time.

The tower cab supervisor stated that he was still in the tower cab when UA Flight 663 landed. He said the pilot did not request any special handling and that the landing was normal. He recalled that UA Flight 663 had Mode C when it was inbound. At about 1415, United called the control tower and reported that UA Flight 663 might have struck a runway light on departure and requested that the airport operator check the runway. There is no alarm in the tower cab if a runway light is damaged. He did not recall if the instrument landing system (ILS) warning light came on at the time of the accident. At about 1420, he received another report from United stating that UA Flight 663 had incurred damage to the tail section of the airplane. The tower cab supervisor forwarded this information to his area manager.

1.17.3 Pilot Reports

The first officer of RMA Flight 652 (Dash 7) said that he remembered the wind was from 10 degrees at 12 knots and that his flight was not given any wind shear reports before taking off. He said the takeoff was normal until the airplane reached about 400 feet a.g.l., at which time the airspeed dropped from 100 knots to 75 knots. He said this drop occurred just north of the I-70 overpass. He recalled that it took only about 2 seconds to regain the lost airspeed. He said that his initial attempts to report the wind shear occurrence were blocked because of the congestion on the tower frequency, but he finally was able to make the report on his third attempt.

FL Flight 663 (B-737) was the next air carrier to depart after RMA Flight 652 on runway 35L. The first officer reported that he and the captain saw RMA Flight 652 sink during its initial climbout. After hearing of the wind shear report from RMA Flight 652, they used maximum takeoff thrust when cleared for takeoff. The first officer believed that after they retracted the landing gear, they lost about 50 feet of altitude during initial climbout. He reported experiencing no problem when the controller queried his flight about wind shear. He stated that airspeed losses are common at Denver.

The third flight in the takeoff sequence on runway 35L was FL Flight 39 (DC-9). The captain remembered reporting to the departure controller that when the airspeed had reached about 110 knots during the takeoff roll, it stagnated at that speed for about 1,000 to 1,500 feet of roll. Thereafter, the airplane continued to accelerate normally, and he rotated it just before passing the I-70 underpass. He said he did not experience any wind shear after the airplane became airborne.

UA Flight 965 (B-727) was the fourth airplane to take off on runway 35L after the wind shear report from RMA Flight 652. The captain stated that he heard the airspeed loss report from RMA Flight 652 but that the airplane following it did not report any difficulty. He said that his airplane was 45,000 pounds below maximum allowable takeoff gross weight, and he felt confident in using the normal EPR takeoff thrust setting. He stated that he saw some “dust devils” during his takeoff roll. He said he lost some airspeed for 2 to 3 seconds about two-thirds of the way down the runway at about 110 knots. He then pushed the throttles to the maximum EPR setting, and the airplane quickly responded. He rotated the airplane for liftoff well above VR. The liftoff and climbout was normal. He said he had the first officer report the loss of acceleration to the tower. The captain said that had the airplane been at maximum allowable gross takeoff weight, he would have aborted the takeoff.

UA Flight 415 (B-727) followed UA Flight 965. The captain of UA Flight 415 said that he also heard the airspeed loss report and that one airplane ahead did not comment. He said the controller gave no significant wind reports when he made his takeoff. The takeoff was made at a 5-degree flap setting at a gross takeoff weight of 137,000 pounds. He reported that, when he taxied the airplane onto the runway, he noticed that the windsock showed a slight tailwind, so he used maximum takeoff thrust instead of normal rated thrust. He said that at 120 knots the airspeed "hung" there for 2,000 to 2,500 feet of takeoff roll. However, since the airplane was at a light weight, he believed it was safe to continue the takeoff. He reported that there was a sudden increase in lift, and the airspeed rapidly increased about 15 knots as soon as the airplane became airborne. The climbout was normal. He stated that the first officer reported the hesitation in acceleration during the takeoff roll to the controller. However, his report was delayed because of so much "chatter" on the tower frequency.

UA Flight 757 (DC-8) was positioned on runway 35R before UA Flight 663 was given takeoff clearance. When UA Flight 757 taxied onto the runway, the flightcrew noticed the windsock was fully extended, indicating a direct tailwind. Based on the position of the windsock, the captain decided to delay the takeoff. The second officer said that the takeoff rolls that afternoon were longer than normal. He said that he recalled UA Flight 663 raised a lot of dust when it passed over the end of the runway. He stated that its takeoff roll was quite long, that it appeared to have rotated to a normal climb attitude, but that he did not remember seeing the airplane strike anything. At about this time, the winds shifted from south to west and decreased in velocity. Because it now was a direct crosswind, the captain decided to make the takeoff. When the airplane reached 140 knots in the takeoff roll, the airspeed "just hung there" for 5 to 8 seconds and then jumped to 180 knots in about 2 seconds, according to the captain. The rotation and climbout were normal.

UA Flight 161, a B-727, was cleared to taxi onto and hold on runway 35L at 1333:31, 32 seconds after UA Flight 663 was given its takeoff clearance. The captain stated that he was held for 30 minutes before being told that he was number one for takeoff. He described the weather conditions as consisting of a "spooky sky" with virga as widespread as he had ever seen. He said facing north it filled the entire cockpit windscreen. He stated that it was eerie with virga shafts extending as low as 100 feet a.g.l. near the north end of runway 35L. He had observed RMA Flight 652 settle after liftoff, and as he taxied onto the runway, he observed UA Flight 663 on its takeoff roll. He did not observe anything unusual about the takeoff initially. He said UA Flight 663 appeared to be tracking along the runway centerline. When it lifted off, he saw a dust cloud at the end of the runway; he said that the initial climbout was fairly flat. He stated that debris was blowing across the runway at about 3,000 feet from the takeoff end. The windsock showed a stiff wind from about 330 degrees. He heard UA Flight 663 make the "touch and go" comment and heard the strong tailwind report transmitted by UA Flight 757. Based on his observations and the reports from the other flights, he decided not to take off.

The captain of UA Flight 861, a DC-10, was in takeoff sequence behind UA Flight 161. He stated that there was a high base thunderstorm just to the southwest of the airport. He said that the thunderstorm had moved across the airport from southwest to northeast with strong gusty winds from about 290 degrees. He reported that airplanes taking off were experiencing wind shear or loss of airspeed on the north end of 35L. When the captain of UA Flight 161 decided not to take off, he realized there would be a further delay so he requested clearance to taxi to runway 26L. His takeoff from runway 26L was uneventful.

1.17.4 Company Wind Shear Training Program

United Airlines' wind shear education program is based upon the premise that the best way to avoid the hazards of wind shear is to be knowledgeable about the causes, characteristics, and visible signs of the phenomenon and that avoidance is the preferable course of action. The other aspect of this education is the proper procedure to follow if wind shear is inadvertently encountered at low altitude. According to United's Bulletin No. 106, of June 17, 1983:

> United's policy is to avoid encounters with wind shear on takeoff and landing by delaying takeoff or aborting the approach when strong wind shear is known or suspected. We define strong wind shear as that involving and indicated airspeed change of 20 knots or more.

The program consists of classroom and simulator training about the causes and effects of wind shear, how it can be detected and avoided, and how the airplane should be flown in the event of an encounter. The program also includes the company's policy and procedures concerning this phenomenon. The wind shear training is a required segment of United's flight training program and is administered during the flightcrew's initial, recurrent, and transition training. United disseminates its policy and procedures about wind shear through the use of training manuals, flight operations manuals, operations bulletins, and other safety-related materials. In addition, the company widely uses videotapes to present graphic illustrations and examples of safety problems. As an example, within a few days of the UA Flight 663 accident, the company developed a videotape concerning the accident for distribution to all its flightcrew bases.

United's program is administered by its flight operations training instructors and their training check airmen. These pilots receive the same initial wind shear training and are supervised by the FAA Principal Operations Inspectors as a normal part of their additional training duties.

United's flight operations manual (FOM) specifies some conditions that can cause wind shear. The following conditions are to be considered by the flightcrew:

1. Thunderstorm or frontal system activity
2. Temperature inversions
3. Virga from high-level cumuliform clouds

The manual also states that they may be alerted to the presence of wind shear by pilot and LLWAS reports, and blowing dust, rings of dust, dust devils, trees blowing in several directions, etc. (See appendix G for excerpts from the United FOM and operational bulletins concerning wind shear.)

The following wind shear models, three of which are based on actual accident profiles, are used by United in its B-727 Phase II 18/ simulators as of May 31, 1984:

18/ There are five levels of aircraft simulators: nonvisual, visual, and Phase I, II, and III, with Phase III simulators being the most sophisticated. The more sophisticated the simulator, the more simulator training and checking may be approved by the FAA. The maximum amount of training and checking that may be approved for a simulator is described in Appendix H to 14 CFR Part 121.

- Three generic models provided by the simulator manufacturer;
- Eastern Airlines, B-727 accident at JFK (severe intensity shear);
- Iberia Airlines, DC-10 accident at Boston-Logan (moderate intensity shear); and
- Allegheny Airlines, DC-9 accident at Philadelphia (severe intensity shear).

All of the wind shear models involve landing approaches. There were no profiles at the time of the accident specifically designed for use in a takeoff encounter. However, all the wind shear profiles may be used for training in the takeoff phase of flight. This change is accomplished by reversing the simulated airplane and then positioning it at the opposite end of the runway for takeoff.

Programming a wind shear model or profile into a simulator does not provide automatically any level of turbulence. To make the training as effective as possible, United believes that some level of turbulence should be introduced, and its training program calls for a turbulence level of between 10 and 25 percent.

At the time of the accident, United had plans to incorporate five wind shear profiles designed for use to meet specific training requirements in each simulator by August 1, 1984. The basic scenarios for each of these shears are as follows:

1. Shear on the runway
2. Shear on rotation
3. Shear at 500 feet
4. Shear at V2 + 5
5. Shear on approach

United intends that within a year of implementation of this new wind shear training program, all of its B-727 flightcrews will have participated and/or witnessed each of the new shears in a simulator. This will be accomplished during the annual proficiency check and/or during transition training. As is the case with the current wind shear training program (pre-August 1984), the new program will be a required training objective. The McDonnell Douglas DC-10 and Boeing 737 fleets are expected to follow, but firm completion dates have not been established yet.

1.17.5 Government and Industry Wind Shear Hazard Abatement Activities

The ongoing and planned future activities for reducing the wind shear hazard in the terminal environment involve enhancing and developing the following: (1) operational procedures; (2) ground-based detection systems; (3) airborne detection systems; and (4) forecasting techniques. Governmental organizations actively involved are the FAA, NOAA, and the National Aeronautics and Space Administration, Industry participants are the Air Transport Association and their member airlines, the Boeing Commercial Airplane Company, Lockheed-California Company, McDonnell Douglas Corporation, and several independent organizations.

In the operational category, emphasis is being directed toward improving flightcrew and air traffic controller wind shear awareness by training them to recognize the visual signs of its development as well as to practice methods of avoidance. The industry also is seeking to improve flightcrew flying techniques in the event a wind shear penetration is unavoidable. The approach being taken in this area by the manufacturers and the airlines consists of modeling the takeoff and landing wind shear accidents and incidents, and of conducting engineering analysis and pilot training with the use of state-of-the-art airplane simulators. The simulators have been an excellent training tool because they have shown flightcrews how the airplane behaves in a wind shear penetration and how previous accidents might have been avoided by improving certain piloting techniques. It has been learned that flightcrews did not achieve the maximum climb performance available from their airplanes in some previous wind shear accidents. This discovery focused attention on improving pilot recognition of a wind shear encounter by visual cues, flight instrument indications, and management of pitch attitude and power control. To reinforce these disciplines, procedures have been developed to require a nonflying crewmember to call out certain flight instrument indications during the encounter. These procedures also improved the overall coordination between the flightcrew members.

Enhancement of the ground-based detection sytems by increasing the number and improving the distribution of the LLWAS sensors at selected airports is in progress. Nationwide recording of the LLWAS data is contemplated for statistical and accident investigation purposes. The use of terminal-area doppler radar will result in a significant improvement in wind shear detection systems. However, use of doppler radar is still some time away, and there is a present need to develop procedures for discerning and disseminating wind shear information using current technology and new operational procedures.

In addition, efforts are underway to identify areas where improvements can be made in weather forecasting techniques. The FAA has funded a program to test and verify forecasting techniques to forewarn operators of microbursts and other adverse weather conditions in the Denver terminal area. This program, entitled "Operational Application of Microburst Forecast and Detection Techniques," and informally referred to as the CLAWS Project (Classify, Locate, and Avoid Wind Shear), was conducted from July 2 to August 15, 1984, between 1100 and 2000 daily. With the use of the PROFS data, doppler radar, LLWAS, and the NOAA Wave Propagation Laboratory (WPL) Profiler, 19/ two radar meteorologists at the doppler radar site and two aviation meteorologists in the tower cab provided timely weather advisory information to the tower cab supervisor. This advisory information consisted of microburst location identification, detailed information regarding wind shear shifts and their estimated time of arrival and duration, and forecasts of thunderstorms that were likely to affect air traffic operations.

1.17.6 Wind Shear Accident History

Since 1970, the Safety Board has identified low-level wind shear as a cause or contributory factor in 15 accidents involving transport category airplanes. (See appendix F.) Nine of these accidents were nonfatal, but six accidents resulted in 440 fatalities. Five of the fatal accidents and at least seven of the nonfatal accidents occurred after the airplanes encountered the convective downburst or microburst winds associated with thunderstorm activity. Three accidents were attributed to convective

19/ A ground-based remote sensing system which measures continuously the temperature, wind, and humidity in the atmosphere aloft.

wind shear; 20/ one occurred during a landing approach, one during an attempted go-around, and the third during the takeoff phase of flight. One of the fatal accidents occurred during a landing when the airplane encountered a wind shear caused by surrounding terrain features; the wind shear was cited as a contributory factor. Two of the nonfatal accidents occurred after the airplanes passed through frontal system boundaries during the landing approach.

One of the frontal system wind shear encounters involved an Iberian Airlines DC-10 which struck the approach light piers and seawall embankment during an ILS approach at Boston Logan Airport in December 1973. The airplane was substantially damaged when the landing gear sheared off, and there were serious injuries during crew and passenger evacuation. This accident prompted the Safety Board to recommend that the FAA require that wind shear be included in pilot training programs and that the development of wind shear detection systems be expedited.

The crash of an Eastern Air Lines B-727 inbound to John F. Kennedy International Airport, New York, New York, on June 24, 1975, cost 113 lives. That accident occurred when the airplane encountered the outflowing winds and downdraft associated with thunderstorms near the final approach. The airplane experienced a rapid loss of airspeed and developed a high descent rate from which it did not recover. Following the investigation of the accident, the Safety Board issued 14 safety recommendations which addressed the development of both ground-based and airborne equipment for detecting wind shear, the determination of operational limitations for various types of airplanes, the enhancement of airborne vertical guidance equipment, and reiterated the need for enhanced pilot training programs.

Acknowledging the serious hazard of wind shear, the FAA and other government and industry organizations began extensive research and development programs which were in general consonance with actions recommended by the Safety Board. The occurrence of three more air carrier accidents between 1975 and 1977, attributed to encounters with convective wind shear, placed more emphasis on the need for research and development efforts. Several positive actions have followed: pilot training programs have been enhanced to increase flightcrew awareness of the hazard; operational techniques were evaluated in simulation; and various technologies for both ground-based and airborne wind shear detection and monitoring equipment were evaluated.

Unfortunately, the tangible benefits of the research and development, which have been underway for the past 18 years, have not yet been achieved completely. The only operational wind shear detection system installed thus far is the LLWAS. The limitations of the system were acknowledged from the beginning and it consistently has been recognized as an interim measure until more sophisticated equipment is developed. The limitations of the LLWAS as an operational decisionmaking aid to flightcrews were demonstrated by the crash of a Pan American B-727 during takeoff from New Orleans, Louisiana, on July 9, 1982. 21/ Although the LLWAS indicated wind shear in the vicinity

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20/ Wind shear caused by thunderstorm activity.
21/ 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).

of the airport, there were no established means to relate the information to the hazard of a particular takeoff. Consequently, the flightcrew of the accident airplane failed to perceive the danger; 153 persons died when the flight encountered a characteristic microburst at or immediately after the point of takeoff.

The Safety Board again recommended actions to be taken by the FAA, several of which addressed the need to improve the current technology for systems so they could be used effectively for flightcrew operational decisions. Other recommendations addressed the application of information gained from the JAWS program at the Denver Stapleton Airport. The Board suggested that the information be used to improve the LLWAS system and its procedural use, to evaluate the potential of other technologies such as the microwave doppler radar for detecting wind shear, to develop better methods to communicate information to controllers and pilots, and to provide better information for pilot training.

In response to urging by the Congress, the FAA contracted with the National Academy of Sciences for a study of the wind shear hazard to formulate accident prevention measures. 22/ The Safety Board furnished the National Academy study committee with detailed accident data and all related safety recommendations. The committee's findings and recommendations, which were issued in September 1983, were consistent with the Safety Board's views.

1.18 New Investigative Techniques.

None.

ANALYSIS

2.1 General

The airplane was certificated, equipped, and maintained in accordance with Federal regulations and approved procedures. There was no evidence of a malfunction or failure of the airplane, its components, or its engines that would have affected its performance. The flightcrew was certificated, qualified, and experienced for the flight. Each crewmember had received the training and off-duty time prescribed by FAA regulations. There was no evidence of any preexisting psychological or physiological conditions that might have affected adversely the flightcrew's performance. The local air traffic controller and the tower cab supervisor on duty in the Stapleton Airport control tower at the time of the accident were certificated and qualified, and each controller had received the training and off-duty time prescribed by FAA regulations. Also, there was no evidence of any psychological or physiological conditions that might have affected adversely their performance of air traffic control duties. Accordingly, the Safety Board found no deviations from prescribed Federal regulations or company requirements concerning the airworthiness of the airplane and qualifications of the flightcrew and air traffic controllers that would have had a bearing on the accident.

Evidence gathered during the early phases of the Safety Board's inquiry indicated that the accident was the result of a wind shear encounter. Therefore, the Safety Board directed its attention to the environmental factors, the airplane's takeoff performance, and operational and human performance factors involved in this accident to determine how it occurred and how it could have been avoided.

22/ "Low-Altitude Wind Shear and Its Hazards to Aviation," published by the National Academy Press, 1983.

2.2 Environmental Factors

On the day of the accident, air traffic was typically heavy at Stapleton. For example, United alone had 10 flights ready for departure within about **a** 13-minute period. The tower cab supervisor, who had been assigned at Stapleton for 15 years, described the traffic volume as moderate to heavy; the LC-1 controller stated that it was heavy but routine; at one point, the LC-1 controller had handled 16 airplanes within a g-minute period prior to issuing UA Flight 663's takeoff clearance.

In addition to the delays endemic throughout the ATC system, Stapleton experiences severe traffic congestion on parking ramps and taxiways. Stapleton experienced an increase from 8 to 126 delays per 1,000 operations in September 1984 versus September 1983. In order to handle the increased traffic, airport authorities have begun improving the airport facilities. In particular, the holding area has been expanded to accommodate flights operating to and from runways 17R/35L and 17L/35R. But, in spite of these improvements, airlines still faced delays over which they had limited control. Although UA Flight 663 departed the terminal gate 2 minutes ahead of schedule, the flight experienced a 23-minute delay on the ground before takeoff clearance was issued.

Because of the manner in which the north/south runways are constructed at Stapleton, runway separation criteria require that ATC implement wake turbulence avoidance procedures that require airplanes of certain types to be separated by establishing an appropriate interval between them in order to insure an acceptable level of safety for departing flights. Therefore, a controller cannot allow simultaneous takeoffs. Thus, the controller must provide for this separation while clearing airplanes for takeoff in addition to other duties, such as monitoring the LLWAS and providing wind shear reports to other flights. The separation of flights on the day of the accident was more than adequate. There were l-minute intervals between flights taking off on runway 35L and 2-minute intervals between those on runway 35R.

It is common knowledge among pilots who have flown in the Denver terminal area during summer months that one can expect to encounter thunderstorms and associated variable, gusty winds. The interaction of the prevailing weather with the Rocky Mountain Range in proximity to the Stapleton Airport frequently produces unstable weather conditions and has prompted a great deal of ongoing aviation environmental research in the Denver area. The tower cab supervisor and various pilots stated that the LLWAS system frequently alarms because of the thunderstorm activity present, and that airspeed losses are common as a result of convective wind shear.

The day of the accident was typical of the summertime weather at Stapleton. "High base" thunderstorm activity had been approaching the airport for about 1 to 2 hours. Wind records and LLWAS reports disclosed the probability of two and possibly three microbursts associated with these thunderstorms. Analysis of all the available weather data disclosed that the microburst that eventually affected departures from runways 35L/R originated from a level 1 cell about 1 mile northwest of the ATC tower. Recorded wind data revealed that the duration of the microburst activity was only about 8 minutes--a short period compared to the duration of other adverse weather conditions which result in instrument flight rules and extensive delays in air traffic operations at Stapleton. The evidence indicated that the most severe of the three microbursts affected the takeoff of UA Flight 663. Because of the 2-minute averaging feature of the centerfield wind anemometer, neither this instrument nor the PROFS data show the true variability of the wind during the period of thunderstorm passage from 1326 to 1357.

However, the centerfield wind report confirmed that the airplane had about a lo-knot headwind component at the start of its takeoff roll. Extrapolating the outflow from the calculated center of the microburst, the wind over the departure end of runway 35L would have been from 210 degrees. Based upon the wind speeds, which were up to 40 knots, and the variability of the gusts reported by the several anemometers, the gust speed at the departure end of runway 35L was probably between 25 and 40 knots. This would have given a tailwind component of between 22 and 36 knots. The maximum wind may have exceeded 40 knots; since the LLWAS sensors are not spaced closely enough to record accurately the parameters of a microburst, there is insufficient evidence to confirm this possibility. However, based upon the extended takeoff roll and climb performance of the airplane, it was estimated that the wind speed was 210 degrees at about 40 knots at the departure end of runway 35L.

The wind shear reached its maximum intensity only 5 minutes 45 seconds after it was first reported; a period in which UA Flight 663 received its takeoff clearance. Analysis revealed that what had been a steady wind from the west at 8 to 9 knots shifted to a southerly wind at a speed of about 40 knots within this relatively short period. This shift resulted in a tailwind component of between 22 and 36 knots, speeds 12 to 26 knots in excess of the general maximum tailwind component limitation for air carrier airplanes.

Although the microburst developed rapidly, there were signs predicting the likelihood that one might occur. NCAR data in the form of radar signatures from the doppler radar used in the field experiment in progress confirmed that the thunderstorm activity had the characteristics which contribute to the development of microbursts. The radar recorded a segment of the atmosphere from 3,300 to 11,500 feet a.g.l. The doppler return from the precipitation particles in the cell showed the beginnings of convergence with cyclonic and anticyclonic rotations indicating microburst development. At 1324, a divergent flow was detected in this development. From 1325 to 1330, the precipitation within the level 1 cell producing this phenomenon descended from about 6,600 feet a.g.l. By 1334:38, it was nearly over the airport. By about 1339, it dissipated when it was northeast of the airport. Since NCAR was conducting a field experiment not directly involving the microburst phenomenon, the Stapleton ATC tower was not provided with this early information.

As a result of previous wind shear accidents and Safety Board recommendations, the FAA developed the LLWAS to be used by ATC as an interim measure to reduce the wind shear hazard until a more sophisticated system could be employed. Not only have its limitations previously been recognized and underscored as a result of the Pan American B-727 accident in New Orleans, they were reinforced by this accident as well.

Based on the ATC transcript of communications, the first wind shear alert reported to departing flights was not made until about 1329:32--5 minutes 32 seconds after the doppler radar detected the microburst development. One minute 40 seconds later, the LC-1 controller noted the northeast boundary sensor alert on the LLWAS monitor and provided the report to departing FL Flight 39 in accordance with prescribed procedures. The LC-2 controller, working traffic on the east/west runways, began giving boundary wind reports at this time. Also, the east and southwest boundary anemometers were producing alarms at that time, and these alarms evidently were not considered by the LC-1 controller to be pertinent to the operations on runways 35L/R.

However, the Safety Board noted that the LC-1 controller failed to provide UA Flight 663 with the northwest boundary wind report when he cleared the flight for takeoff; according to the LC-2 controller's radio transmission, the northwest boundary anemometer alarmed 7 seconds before the LC-1 controller issued the clearance. Instead, the LC-1 controller said he gave the north boundary wind because of the differences in wind speed and because it was alarming. The calculated vector difference between the centerfield and the north boundary winds at this time was only 13 knots. Therefore, the north sensor should not have been alarming. The Board believes that the LC-1 controller probably misread the monitor because he was busy providing air traffic separation. The northwest boundary wind would have been more appropriate to UA Flight 663's takeoff.

2.3 Airplane Takeoff Performance

The analysis disclosed that the airplane was exposed to a headwind component of about 8 knots at the initiation of its takeoff roll. The first effect of a wind shear was detected at 34 to 42 seconds into the takeoff, at a speed of about 115 KIAS with the airplane about 3,800 feet down the runway. An average shear rate of about 2.5 knots per second resulted in an interruption in acceleration at this point with the airspeed remaining at 115 to 120 KIAS for 7 to 10 seconds. Between 55 and 62 seconds into the takeoff, the shear rate averaged 5 knots per second and then dropped to about 0.75 knot per second for an additional 4 seconds. The airplane did not rotate until it was about 8,000 feet down the runway, and it became airborne 62 seconds after brake release. The total along-the-runway wind component sheared from an 8-knot headwind to about a 56-knot tailwind over a 44-second period.

The airplane gained a height of only 4 feet before it struck the localizer antenna 2.4 seconds after liftoff. This indicates that the airplane was barely able to fly within ground effect and explains why there were scorch marks from the jet exhaust in the grass about 300 feet from the localizer antenna. The heading trace from the FDR showed that, except for a 1.5 degree-per-second change in the airplane's heading at 80 seconds after brake release, its heading remained constant up to and through liftoff.

The analysis also showed that the pitch attitude of the airplane reached 8 to 9 degrees 4 seconds after rotation was initiated and that it was increased to about 13 degrees before the airplane struck the localizer. The physical evidence of the damage to the fuselage corroborated the accuracy of the pitch attitude calculation derived from the FDR data. The airplane became airborne with an airspeed of about 136 knots. Flight test data indicated that the airplane's angle of attack was about 1 degree below the angle of attack at which the stall warning/stickshaker would have activated.

The airplane's maximum allowable takeoff gross weight was computed to be 153,400 pounds. At this weight, the takeoff roll was calculated to be about 8,300 feet--1,000 feet more than the required distance at the actual takeoff gross weight. Consequently, at the actual takeoff gross weight, there would have been 4,200 feet of runway remaining had the wind not been a factor in the takeoff. The captain told his crew that he planned to increase VR by about 5 knots. The FDR data confirmed that the airplane was rotated at about 141 KIAS. Although an increased VR speed alone would result in an extended takeoff roll, the performance analysis showed that the wind shear was the most significant factor in the takeoff distance used. The airplane's computed groundspeed at VR was about 175 knots. The airplane did not become airborne until it had used an additional 3,600 feet of runway, 11 seconds after rotation. This placed the airplane about 100 feet past the runway end, or about 100 feet into the overrun before it became airborne.

2.4 Operatianal Factors

Although the doppler radar information concerning the microburst was not available to the controllers and flightcrews, there were other visible signs indicating the probability of wind shear. Research has determined that convective activity, virga, large temperature/dewpoint spread, variable and gusty winds, and blowing dust are some indications of a high probability of a microburst. As a part of its wind shear training program, United publishes in its FOM a policy of wind shear avoidance and recommended procedures for flying the airplane in the event of a wind shear encounter. Included are the visible signs flightcrews should be aware of to assist them in practicing the company's policy of wind shear avoidance. The program emphasizes the microburst phenomenon. United recommends that flightcrews give serious consideration to delaying a takeoff or selecting another runway if strong wind shear "is known or suspected to exist along the takeoff path . . . ." United defines strong wind shear as any reported airspeed loss or gain of 20 knots or more.

The investigation determined that all of the signs listed in United's FOM and operational bulletins were present on the day of the accident. These signs were:

- High-based thunderstorm activity
- Widespread virga
- Temperature/dewpoint spread of 40° or more
- Blowing dust
- Pilot and LLWAS reports of wind shear.

Furthermore, FAA Advisory Circular (AC) 00-50A, "Low Level Wind Shear," dated January 23, 1979, lists five conditions that, when existing in combination, should cause flightcrews to assume that severe (strong) wind shear is present. United's wind shear information is basically consistent with AC OO-50A. United's FOM does not state specifically that if such a combination of these visible signs exists, flightcrews are to assume that a strong wind shear condition is present and that they should delay their takeoff until more favorable conditions are present. However, the Safety Board believes that United's material provided sufficient guidance to the flightcrew. Since they had attended United's wind shear education program, the Board concludes that they were knowledgeable about the causes, characteristics, and visible signs that indicate the presence of wind shear. Furthermore, they observed some of the telltale signs before their takeoff on the day of the accident. Based on these signs, the flightcrew, as well as other flightcrews operating at that time, should have delayed their takeoffs. A lo-minute delay would have permitted them to avoid the microburst wind shear. The Board also believes that the flightcrew should have anticipated encountering a wind shear during their takeoff roll.

In addition to the physical manifestations of possible wind shear, United also recommends that flightcrews use the LLWAS as a tool to alert them to the presence of wind shear. However, the description of LLWAS in United's FOM does not state clearly that when a controller reports a boundary wind in conjunction with the centerfield wind, the report constitutes a wind shear alert. The flightcrew did not recall the two boundary wind reports made by the LC-1 controller at 1329:32 and 1331:14. Also, other flights departed in spite of the wind shear alerts. Based on the ATC transcript, there were a total of six wind shear alerts after RMA Flight 652 reported the airspeed loss. Two were reported by the LC-1 controller and four by the LC-2 controller. This indicates that flightcrews may not understand clearly the significance of a boundary wind report when it is not accompanied by the words "wind shear alert." Furthermore, the captain stated that he had not heard the phrase "wind shear alert" used before and that it would have influenced his decision to take off.

The Safety Board is pleased that the FAA issued the GENOT after this accident, to require the phrase "wind shear alert" in all reports. Nevertheless, a flightcrew still could become distracted and not hear a wind shear report while performing their cockpit tasks in preparation for departure, particularly if there is a lot of congestion on the radio frequency, as was the case in this accident. The flightcrew of UA Flight 663 did not recall hearing the tailwind report from UA Flight 757 at 1332:05 while it was positioned on runway 35R. This report was made while UA Flight 663 was positioned on the runway, 54 seconds before it received its takeoff clearance. It is difficult to believe that when they were given their takeoff clearance, the flightcrew did not hear the LC-1 controller report, "numerous wind shears in three different quadrants . . . ." The Board noted in review of the ATC tape of communications that as the LC-1 controller completed issuing the clearance, the inflection in his voice did not tend to emphasize the importance of his remark. He sounded as if the occurrence was routine and it was business as usual, which probably reflects correctly that it was a routine matter in air traffic operations at Stapleton at that time of year. The matter-of-fact manner in which the radio transmission was made could have led the flightcrew not to recognize it as an alert.

United further recommends that flightcrews be cognizant of pilot reports of wind shear and states in its FOM, "Reports which give airspeed gain/loss are the greatest value." The ATC transcript of communications disclosed five pilot reports of wind shear on the local control frequency before UA Flight 663 was given its takeoff clearance. The flightcrew recalled the airspeed loss report from RMA Flight 652 but said they did not hear any report from FL Flight 39.

Although the flightcrew of UA Flight 663 did not hear a report from FL Flight 39, the Safety Board believes that the captain should have been concerned upon hearing RMA Flight 652's airspeed loss report rather than reassured. (In an interview, the second officer said he had agreed with the captain's assessment.) The wind shear encounter would not have been as detrimental to the Dash 7 as it would have been to a B-727. The four propellers on the Dash 7 generate lift over 70 percent of the wing span independent of the airplane's indicated airspeed. Thus, the Dash 7 has a greater lift reserve than the B-727. Additionally, a propeller-driven airplane can generate this reserve lift almost instantaneously with an increase in power, and as a result, such an airplane has a lower stall speed with power on than it does with power off. Conversely, a B-727 must depend entirely on its forward speed in order for the wing to generate lift. It stalls at the same airspeed, regardless of whether or not the engines are developing thrust. Furthermore, the flightcrew recalled hearing a 20-knot airspeed loss when, in fact, a 25-knot loss was reported. The report of RMA Flight 652, in fact, was more significant than the captain realized.

At 1333:57, 58 seconds after UA Flight 663's takeoff clearance, UA Flight 415 reported a wind shear condition after departure from runway 35L. Allowing for the time it took to give the clearance, 3 seconds for UA Flight 415's report, and 3 to 5 seconds for the captain of UA Flight 663 to make an assessment and 3 seconds to react, the airplane would have been about 40 seconds into the takeoff at an airspeed of about 116 KIAS and nearly to the point where even a rejected takeoff was not an option when the pilot report was made. This probably accounts for the fact that the captain and the first officer did not recall when in the departure sequence of events the UA Flight 415 report was made.

Probably more significant is the fact that microbursts occur suddenly and are of short duration and varying intensities. Thus, the fact that some flights encounter one and other flights do not or that a flight does not encounter difficulty should not mislead pilots into thinking that a hazard does not exist. If the conditions for a microburst are present, all cues are important. In this case, the difference between the centerfield and north boundary winds, and the observation of blowing dust and virga alone should have been enough to influence the flightcrew's decision to delay the takeoff.

The Safety Board noted also that the preferential runway use program at Stapleton stipulated that the program would be followed provided a thunderstorm is not within 5 nautical miles of the final approach or departure flight paths. However, the weather data disclosed that a level 3 thunderstorm had approached within 7 miles southwest of the airport about 13 minutes before the accident. About 2 minutes before UA Flight 663 received its takeoff clearance, the airport was under the eastern edge of rain shower activity from a level 2 thunderstorm located about 4 miles west of the airport. Perhaps the runway use program should have been suspended because of the approaching thunderstorm. Furthermore, for about a 5-minute period before UA Flight 663's takeoff, the winds had exceeded the crosswind limitation established in the program. A runway change under these circumstances would be contemplated.

However, the controllers were cognizant of the possible need to change runways in the event of adverse weather. At 1334:24, the LC-1 controller stated that there was a front coming through and that they were not sure what the winds were going to be like. Changing runways involves delays depending on the weather conditions and how many airplanes are under ATC control. Controllers generally wait for some period of time before taking action to make a runway change in order to determine whether the wind shift is of a temporary or permanent nature. Because wind shifts associated with thunderstorms can be unpredictable, a decision to change runway operations can be difficult to reach. In this accident, it was not until after UA Flight 663 reported a 20-knot airspeed loss at takeoff rotation and concern about the wind shear had been expressed by other flights waiting to take off--a period of about 2 minutes 30 seconds--that the tower cab supervisor decided to halt the departures. Although he dir' not have the authority to prevent a flight from departing had a captain chosen to do sc, the Safety Board believes that he exercised prudent judgment. The Safety Board believes that under these circumstances, any additional information transmitted by ATC, such as the potential need to change runways, would assist flightcrews in making their "go-no go" decision.

When the captain decided to make the takeoff, he anticipated encountering wind shear after becoming airborne and took action to counteract its effects. His decision to use maximum EPR, 5 degrees of flaps, VR plus 5 knots, and a climb speed of V2 plus 20 knots was in conformance with United's procedures. United's FOM states, "If the performance and runway limits permit, a lesser flap setting should be selected and speed for rotation and initial climb-out should be increased by an amount equal to the known gust factor or reported shear velocity." However, except for the V2 plus 20, the performance adjustments were made prior to any of the reports of wind shear, many of which reportedly were not heard by the flightcrew. Therefore, the Safety Board believes that the flightcrew cannot be said to have acted in specific response to "known gust factor or reported shear velocity."

2.5 Human Performance Factors

In view of the fact that the captain had received wind shear training, that he was aware of the existing meteorological conditions and the hazards associated with them, and that he had anticipated an encounter with wind shear after becoming airborne, the Safety Board considered various factors in an attempt to determine why he elected to take off and why the first and second officers supported that decision.

The wind shear hazard.--The first of these concerns considered by the Safety Board involves the flightcrew's perceptions of the potential hazards associated with wind shear. According to the second officer, if flightcrews responded to every wind shear alert, there would be 40 to 50 takeoff delays or cancellations each day at Denver. The captain stated, "I'd be surprised if a good majority of the flights did not encounter some form of wind shear coming into Denver." In addition, it appears that flightcrews may not know or appreciate the significance or validity of the impending microburst telltale signs in combination. Neither this flightcrew, nor nine other air carrier pilots interviewed, ever recalled in their careers delaying or cancelling flights due to unverified reports of wind shear. The Safety Board believes that these factors have a bearing on the flightcrew's perception of the wind shear hazard.

In recent years, there have been significant advances in the technology available to pilots to detect hazardous weather conditions. At the same time, this technology has its limitations. As a result, pilots may reject information supplied by technology that is not always accurate. The Safety Board believes that LLWAS limitations and nuisance alarms bring about such a situation. (Nuisance alarms are those which involve proper operation of the LLWAS but do not involve conditions affecting aircraft operations.) Furthermore, continued operations into a hazardous area, when the outcome is repeatedly successful, reinforces a pilot's confidence in his ability to successfully operate in similar hazardous conditions. The captain's repeated successful operations at Denver, in the presence of LLWAS wind shear information and other wind shear manifestations illustrates this pattern of reinforcement. This tendency closely follows established behavioral principles of response and reinforcement.

Wind shear is a dynamic condition, and its effects are transitory. Often, by the time the LLWAS anemometers have measured the shear, the computer has assessed its intensity and alerted the controller, who in turn alerts the pilot, the shear may no longer be a factor. At the same time, the LLWAS may not register a shear because of the system's limitations. Thus, both nuisance alarms and severe wind shears which are not reported occur despite the LLWAS. The captain of UA Flight 663 reported that he believed that the LLWAS nuisance--alarm rate was too high; that is, too often it alerts pilots to dangers that do not exist. The captain also believed that, because wind shear today is reported so often by flightcrews without serious adverse effects, the reports begin to lose their significance. The Safety Board concludes that pilots cannot be expected to depend only on LLWAS data to make "go" or "no-go" decisions.

The level of certainty about wind shear hazards increases when additional information is added to the LLWAS alerts. The flightcrew stated that they scanned their weather radar and were listening closely for pilot reports of shear. However, relying on these sources sometimes presents difficulties. Airborne radar "sees" or detects precipitation, not turbulence specifically. Given the position of the airplane when the captain was using the radar, he was only able to detect a thunderstorm cell 25 miles to the northeast. As a result, he did not receive radar information indicating that his takeoff would be affected. The thunderstorm cell that produced the microburst was about 1 mile away to the northwest.

Pilot reports can provide conclusive evidence of wind shear, since pilots can interpret for other pilots the effects of weather on aircraft performance. Other pilots can, as a result, readily interpret the potential hazards under the prevailing weather conditions. However, these types of reports, as in this accident, present many of the same difficulties of timeliness as do LLWAS data. Although the captain used, to some degree, the report of RMA Flight 652 to assess the safety of continuing the flight, he did not place much significance on the report. He was prepared to accept a report from FL Flight 39 to be more valid. Therefore, when he failed to hear such a report, he appears to have assumed that the wind shear hazard would not be substantial and that he would not encounter it during his takeoff roll. The Safety Board believes that such an assumption is fallacious, proceeding from a misunderstanding of the facts about wind shear. The absence of a report from FL Flight 39 by no means necessarily implied the absence of danger. The captain should have been aware that the hazardous conditions that led to the report still were present since the other indications of the hazard had not disappeared. The captain of UA Flight 161, which was immediately behind UA Flight 663, described the weather conditions as a “spooky sky,” with virga more widespread than he had ever seen, and he elected not to take off.

It is difficult for a pilot to justify delaying or canceling a flight in the presence of less-than-certain indications of hazards, particularly when other similar airplanes are operating successfully. The Safety Board believes that the captain’s decision to take off was based on his previous experience of operating successfully at Denver under various wind shear conditions, nuisance LLWAS alarms, a succession of successful takeoffs by other flights, and pilot reports of wind shear that he interpreted as supportive of his decision. Many of these flights were United airplanes. Furthermore, since the flightcrew had modified the takeoff profile in anticipation of encountering wind shear at some point after liftoff, they believed that such action was prudent and sufficient to counteract the expected shear conditions. United’s FOM and those of most other air carriers provide their flightcrews with guidance on wind shear operations but do not prohibit such operations because it is difficult to delineate hard and fast rules. The decision must rest with the captain, since he is in the best position to make a decision involving specific circumstances, and by Federal regulation he is ultimately responsible for the safety of the flight.

The role of the second officer.--The second officer aboard UA Flight 663 was a management pilot for United, whose title was "Lead Training Check Airman.” In this capacity, he reported directly to United’s B-727 fleet captain. His duties with the company included being a supervisor of training and operations for the B-727. He was a rated captain in the airplane as well as a turbojet-rated flight engineer. He was assigned to UA Flight 663 to perform the duties of flight engineer and not of a check airman.

His position and stature in the company contributed to his commanding presence in the cockpit. Although the Safety Board believes that the captain’s authority as pilot-in-command was not compromised in any way by the presence of the second officer, the Board is of the opinion that his views on wind shear may have played a part in the captain’s decision to take off. This opinion is enhanced by the second officer’s involvement in United’s activities to upgrade its B-727 wind shear training program prior to the accident. This involvement contributed to his authoritative knowledge of the company’s wind shear takeoff procedures.

UA Flight 663 had to wait 23 minutes after leaving the gate before it took off because of the volume of flights preceding it in sequence for takeoff. The crew had ample time to observe and comment on the meteorological conditions and the actions of other flights in response to those conditions. United is committed to crew coordination in its flight operations and conducts both initial and recurrent training for all members of its flightcrew in applying crew coordination concepts to decisionmaking. Given the time available to the crew before takeoff and the company's policies, it is likely that all members of the flightcrew of UA Flight 663 participated in the captain's decision to take off.

Following the accident, the second officer, as well as the captain, reiterated a belief that the decision to take off was the correct one given the conditions at the time. As the second officer told the Safety Board, "Given the transient nature of these severe wind shears, the limited duration, the fact that they move across the airport and are gone, I'm not sure that -- probably 99 times out of 100 it would be wise to go ahead and take off." His view, given his status within the company, would reinforce the captain's decision to take off. Even if he were silent and did not express a view that the takeoff should be delayed, the captain could interpret his silence as support for the decision to make the takeoff. With the second officer's extensive experience and his awareness of the B-727's wind shear performance characteristics, such a view might be somewhat difficult for the captain to ignore. This is especially true since other United flights, including B-727's, were operating successfully. The Safety Board believes, therefore, that the second officer's presence and his views on wind shear probably influenced the captain's decision to take off.

LLWAS information.--The wind shear report given in the takeoff clearance to UA Flight 663 was not entirely in accordance with prescribed procedures. The controller was required to use the phrase "wind shear alert" when he issued the takeoff clearance. In view of the captain never having heard the term before, it is possible, but not probable, that he would have delayed the takeoff had the controller used the correct terminology; none of the members of the flightcrew even recalled hearing the report of numerous wind shears. While troublesome to the Safety Board, the failure to hear the report is somewhat understandable given the tempo of the takeoff operations and the rapidity with which the controller issued the clearance and the inflection in his voice. In addition, the wind data given are complex and difficult to interpret in a very short period of time. Studies as far back as 1956 23/ have shown consistently that the human short-term memory limitation averages about seven pieces of data, ranging from five to nine. Generally, there are five LLWAS sensors at selected airports. Adding the centerfield wind direction and velocity to the direction and velocity from each of the boundary sensors, controllers potentially can provide pilots with 12 pieces of numerical data, and more when gusts are reported. It is almost impossible for a pilot given 12 pieces of numerical data or even half that many to remember, to understand the implications, and to act on it immediately in a meaningful way. This situation can be alleviated if flightcrews are given the winds in sufficient time for them to write it down and study it. However, several factors effectively preclude this practice. Controllers rarely have sufficient time while performing their primary duties of controlling aircraft to state the winds at a slow enough rate for the pilots to write them down. Also, wind shear situations are rarely stable and almost invariably will change shortly after the controller makes a report. This episode indicates that it might not be feasible to expect a controller to repeat quickly LLWAS data along with other instructions when air traffic becomes congested.

23/ Miller, G. A. The Magical Number Seven, Plus or Minus Two: Some Limits on our Capacity for Processing Information. Psychological Review, 1956, 63, 81-97.

As a result, pilots often fail to perceive or analyze the significance of LLWAS reports. When aural information is transmitted from multiple sources at the same time, individuals "selectively perceive" 24/ the relevant information. Selective perception enables pilots, for example, to hear ATC instructions relevant to their flight only, thereby allowing them to cope readily with the multiplicity of information received in a brief interval. However, these same individuals will have little or no memory of the information that was screened out through selective perception. This may explain, to some extent, why the flightcrew did not recall hearing the LLWAS winds but were able to remember other information such as, "cleared for takeoff."

The Safety Board believes that to increase the utility of the LLWAS the information should be modified and presented in a manner that recognizes the limitations of human short-term memory and information processing. The Safety Board believes that rather than presenting 12 to 13 numbers at a rapid rate with flightcrews attempting to determine the relative severity of shears in their approach paths in a short period of time, current computer technology should be used to perform these calculations for flightcrews. Controllers could provide not only the presence of shears, but also their relative severity for the assigned runway. This is currently done with thunderstorm reports where severity is categorized into one of six levels. Until that occurs, LLWAS wind reports will provide pilots with substantially less information than would be possible by only reporting the severity levels with which they are associated.

In its report of the accident involving the Pan American B-727 that encountered wind shear during takeoff from New Orleans on July 9, 1982, 25/ the Safety Board issued Safety Recommendation A-83-20 to the FAA:

> Make the necessary changes to display Low Level Wind Shear Alert System wind output data as longitudinal and lateral components to the runway centerline.

The FAA has informed the Board that it is conducting evaluations of various displays of wind shear information to improve the capabilities of the LLWAS system. Safety Recommendation A-83-20 is classified as "Open--Acceptable Action."

Flying Technique and Crew Coordination.--After the decision to take off was made, the flying technique used by the flightcrew after rotation was a critical factor in the prevention of a potential disaster. Had the airplane struck the antenna support structure rather than the antenna, a severe postcrash fire probably would have resulted. The considerable attention which has been given to the flying techniques required to be used in a wind shear encounter have resulted in the aviation industry reevaluating and emphasizing the basic flying techniques of pitch attitude and power control. The captain's handling of these control inputs accounted for the airplane retaining the height it had gained after liftoff.

The other factor involved was the flightcrew's coordination during the encounter. The Safety Board believes that the actions by the crew in recognizing and responding to the hazard illustrates an effective application of crew coordination

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24/ Gibson, E. J. Principles of Perceptual Learning and Development. New York: Appleton-Century-Crofts, 1969.
25/ Aircraft Accident Report--(NTSB/AAR-83/02).

techniques in response to a potentially dangerous situation. The first and second officer's callouts drew the captain's attention to the presence of the wind shear and forced him to concentrate and exercise precise pitch control in order to minimize the airplane's tendency to descend. The Safety Board believes that the successful performance of the flightcrew in flying the airplane during the encounter can be attributed to United's program of providing thorough flight training in this area. Furthermore, United recommends that the airplane be flown toward "stickshaker" as necessary under such circumstances. Flight test data showed that the captain increased the pitch attitude to within about 1 degree of "stickshaker" activation at the point at which the airplane lifted off.

The degree to which flightcrews effectively coordinate their activities in managing the airplane while responding to an unexpected event can determine the extent to which a flight will be operated successfully. In general, many factors can account for an effective, coordinated crew response. Individual personalities or behavioral styles, for example, often influence the particular assertiveness levels of individual flightcrews that, in turn, influence their willingness to offer suggestions or give information. Conversely, the responsiveness of the other crewmembers, the degree to which they can receive information in a nonthreatened, objective manner, also can be attributed, in part, to individual personality.

In addition, the perceived roles of the individual flightcrew members influence their communications. This principle, which has been recorded extensively in the social psychological literature, states that, in general, there is a direct relationship between the perceived stature of an individual and the degree to which other people are willing to listen and respond to that individual. Conversely, the lower the perceived stature, the less likely people are to listen and respond. Applying this to the flightdeck, where crewmember roles are delineated sharply among the captain and first and second officers, the input of the captain can be predicted to be more influential than that of the first officer whose input will be more than the second officer's. In addition, the captain can be expected to be most willing to offer input, with the second officer least willing.

Experience levels work similarly to perceived role stature. More experienced individuals can be expected to give suggestions more easily than less experienced individuals. In addition, these suggestions, one would predict, would be received more readily by others than those of less experienced individuals. These factors do not work in isolation. As in all areas of human behavior, many events can work together to influence a particular outcome or set of outcomes. Thus, one would expect a relatively inexperienced second officer to be more reluctant to give suggestions to a captain than an experienced first officer. However, in this accident, because of the qualifications and experience of the second officer, the flightcrew composition was unique.

Regardless of the variables of the crew composition in this accident, in general, human behavior can be influenced in a positive way. Training can affect outcomes beyond what one would predict based on factors such as experience level, role stature, and personality. Training in specific aspects of communication can influence flightcrews to communicate in a manner that would optimize their overall cockpit performance, regardless of their experience level or role.

It is difficult to attribute the effective cockpit communication and interaction of UA Flight 663's flightcrew to a single cause, since multiple factors were involved. All three crewmembers are close in age. The captain and second officer each accumulated over 12,000 hours of flight time while the first officer had over 8,000 hours. The second officer, in addition to being a management pilot, recently had been a key participant in the enhancement of United's wind shear scenarios and training programs. He was quite knowledgeable about the wind shear hazards at the time of the departure of UA Flight 663 from Denver. He discussed these hazards with the other crewmembers before takeoff and probably influenced the captain's modification of the takeoff procedure. He also was quite forceful in alerting the captain to the airspeed loss at rotation.

United has implemented a comprehensive training program in crew coordination and communication techniques which is given to all flightcrew members. This training program parallels instruction in aircraft operations in that crews receive initial and recurrent training in both the classroom and simulator. After initial instruction in crew coordination techniques, flightcrews receive and practice these techniques as part of their yearly proficiency training. The training sessions are designed to encourage flightcrews to communicate and interact within the cockpit as a unit. First and second officers are trained to provide input into the captain's decisions, while captains are trained to be receptive to such input.

The perception of the sterile cockpit rule by the A flight attendant is pertinent to this discussion of communication among the flightcrew. The cabin crew is also a vital part of the total crew complement and contributes to the overall level of safety of any air carrier flight. The fact that the A flight attendant did not report the noise because of the sterile cockpit rule is significant. The rule was developed, in part, to limit communication with the flightcrew during critical phases of flight to matters related only to the safety of flight. There was a loud thump and vibration, and one flight attendant thought they had hit something during the takeoff. Also, they felt the effects of a pressurization problem. These indications obviously raised the question of safety in the minds of the attendants. Yet, they did not alert the flightcrew because of the A attendant's interpretation of the rule. The flightcrew believed that the flight attendants should have informed them of the incident, which could have assisted them in troubleshooting the problem. The Safety Board believes that there may be a common misconception of the sterile cockpit rule among many airline flight attendants. This concern was expressed by the FAA at a recent Civil Aeromedical Institute (CAMI) Cabin Safety Workshop in Oklahoma City, Oklahoma, on September 18-19, 1984.

Although not identical, another flightcrew and cabin crew coordination problem came to light as a result of the Eastern Airlines accident near Miami, Florida, on May 5, 1983. 26/ This prompted the Safety Board to issue Safety Recommendation A-84-43 to Eastern Airlines on May 7, 1984:

> Review and modify as needed, its flight manuals, flight attendant manuals, and training programs to assure compatibility of emergency procedures and checklists and to require joint cockpit and cabin crew training with respect to emergency procedures; specific attention should be given to conducting periodic emergency drills in which cockpit/cabin crew coordination and communication are practiced and passenger briefings are simulated regarding events that may be expected during such emergencies.

The Board continues to urge industry efforts to make improvements in the area of cockpit and cabin crew coordination.

26/ Aircraft Accident Report-"Eastern Airlines Flight 855, Lockheed L-1011, N334EA, Near Miami, Florida, May 5, 1983" (NTSB/AAR-84/04).

The Safety Board recognizes the multiplicity of variables which influenced the flightcrew coordination on UA Flight 663. The absence of CVR information about predeparture conversation precluded an absolute assessment of the role each flightcrew member played in the decisionmaking process before takeoff. Therefore, the degree to which any one variable affected the outcome cannot be determined. Nevertheless, because United's training in flightcrew coordination techniques was designed specifically to result in the kind of effective communication and interaction that took place at the time of the takeoff rotation, the training can be credited with playing a significant part in that crew's coordination. The Safety Board believes that as flightcrews can be trained to perform aircraft maneuvers in a variety of conditions, their ability to perform fully their roles as providers of information and decisionmakers also can be addressed in training. In the light of previous accidents in which the breakdown in cockpit resource management was a contributing factor, the Safety Board believes that United's program in training in cockpit resource management is a positive method to prevent this from being a factor in future accidents. All carriers will benefit by training all crewmembers in their respective roles--first and second officers as providers of information and captains as decisionmakers acting on that information. This training would result in more effective cockpit resource management industrywide.

Previous accident history and the circumstances of this accident illustrate the need for close and timely coordination between the NWS and FAA air traffic control. The insidious nature of wind shear and of the phenomena which produce it requires scrutiny and advanced warning of its presence in order for flightcrews to assess more adequately its potential adverse effects on their operation. Since ATC specialists probably will have more information in the future about the weather at their disposal, they will be in a unique position from which to provide an accurate overall assessment of how the weather might affect air traffic operations.

For this reason, the Safety Board is encouraged by the FAA's action to fund projects such as CLAWS. An example of how this program could have been useful is further demonstrated by an incident that occurred the day after the CLAWS Project began. On July 3, 1984, at 2317, American Airlines Flight 639, a B-727-100, was making an instrument approach to runway 26L at Stapleton. The surface wind during the landing approach was from about 010 degrees at 16 knots. But, during the landing the wind had suddenly intensified to 18 knots with gusts to 28 knots from 20 degrees. As a result, the flightcrew could not maintain directional control of the airplane during rollout, and it was blown off the left side of the runway. Fortunately, there were no injuries, and the airplane sustained only minor damage in the incident.

Of particular interest in this incident was the sudden increase in the wind speed which probably exceeded the crosswind capability (29 knots) of the B-727. Throughout the day and early evening, the weather was good with only some scattered clouds and unrestricted visibility and variable winds of 10 knots or less. Not until 2308 did the wind suddenly make a significant change in direction and speed. At that time, it was reported from 340 degrees at 11 knots with gusts to 22 knots. Between 2316 and 2325, the wind was from the north-northeast with peak gusts to 34 knots. A gust front developed by thunderstorms traveling southeast over the extreme eastern portion of Colorado was responsible for this sudden change in the wind shear. The CLAWS Project team had concluded its daily activities at 2000, but had it been in operation at the time of the American flight's landing approach, the Safety Board believes that they probably would have detected the phenomenon and appropriately advised the tower cab supervisor. The American flight could have been alerted and given another runway on which to land. As it happened, ATC specialists were caught unaware and were not able to recognize the phenomenon even though the LLWAS had detected the wind shift because of the distance of the north boundary sensors with respect to runway 26L.

The Safety Board and the aviation industry have known for several years that such a system for detecting wind shear phenomena could play an instrumental role in reducing the hazards associated with adverse weather in the terminal environment. The Board issued several safety recommendations directed to achieving this goal as a result of the Pan American B-727 accident on July 9, 1982. The CLAWS Project has merit, and preliminary findings indicate that the response of operators and ATC specialists is positive. The Board believes that the FAA should continue this program and take action to institute a similar program on a permanent basis at appropriate locations as soon as possible.

In addition, research efforts to develop an effective airborne detection and warning system also must continue. Such a system must be capable of detecting all known wind shear conditions several miles ahead of the airplane. It is believed that such a system could be based on the concept of a pulsed, microwave doppler radar, although other techniques such as measurement of infrared spectrum ahead of the airplane also are being studied.

It is evident that, for the moment, no single solution or action exists to eliminate the wind shear hazard. The variety of approaches underway are the most logical and are likely to correct overall weaknesses in the system. The Safety Board believes that through the united efforts of government and the aviation industry, solutions can be found to diminish the wind shear hazard.

The Safety Board recognizes that technological and system advances that are necessary to provide accurate, timely, and useful information about wind shear and other types of adverse weather in the terminal environment will not be forthcoming in the immediate future. Therefore, flightcrews must develop a healthy respect for adverse wind phenomena, be alert to the visible signs of wind shear, take advantage of all the available information at their disposal, and be conditioned to make the appropriate "go-no go" decision. Wind shear from microburst activity is of relatively short duration, and its severity is difficult to ascertain. Since safety is paramount to other factors of the flight, a decision to delay a takeoff when confronted with a hazard is the prudent course of action. The circumstances of this accident will continue to illustrate a slim margin that exists between a successful takeoff and a catastrophe in air carrier operations in a wind shear environment if prudent judgment is not exercised.

3. CONCLUSIONS

3.1 Findings

1. The airplane was certificated, equipped, and maintained in accordance with Federal regulations and approved procedures. There was no evidence of a malfunction or failure of the airplane.

2. The flightcrew was certificated and qualified and had received the training and off-duty time prescribed by Federal regulations. There was no evidence of preexisting psychological or physiological problems that might have affected their performance.

3. The air traffic controllers were certified and qualified and had received the training and off-duty time prescribed by Federal regulations.

4. United Airlines' dispatching procedures were in accordance with Federal regulations, and the airplane was dispatched within authorized weight and balance limitations.

5. Stapleton International Airport regularly experiences wind shear conditions of sufficient intensity to adversely affect air carrier operations.

6. Weather conditions conducive to the development of microburst activity were approaching the airport from the southwest for 1 to 2 hours before the accident.

7. Microburst activity from a level 1 cell located 1 mile northwest of the airport traffic control tower affected the air traffic operations on runways 35L/R.

8. The wind shear resulting from the microburst activity reached its greatest intensity during the takeoff of UA Flight 663.

9. The wind component sheared from an 8-knot headwind to 40 to 56 knots over a 44-second period.

10. The microburst activity was detected by a doppler radar, which presented a classic radar picture of its occurrence even though the radar was not in use for air traffic control and weather forecasting purposes.

11. The LLWAS detected the resulting wind shear about 5 minutes after the doppler radar detected the microburst development.

12. The flightcrew of UA Flight 663, as well as other air carrier flightcrews, observed the visible signs that indicated the potential for severe wind shear and were aware of a possible wind shear encounter.

13. The flightcrew considered the weather conditions but decided to make the takeoff after modifying their takeoff profile. They should have expected to encounter severe wind shear during the takeoff roll based on visual cues and a pilot report.

14. The captain erred in his takeoff performance assessment of the significance of a reported wind shear encounter from RMA Flight 652.

15. The captain may have been mislead when he did not receive a wind shear report from FL Flight 39.

16. Because of technical limitations, the LLWAS often inaccurately reflects the extent, location, and the severity of wind shear.

17.' LLWAS wind shear reports given by controllers to flightcrews often exceed human short-term memory capacity.

18. LLWAS data transmitted by controllers should be modified to make them more useful to flightcrews.

19. The flightcrew probably failed to recognize the LLWAS reports in their takeoff clearance because of the rapidity with which they were issued, human short-term memory limitations, the tempo of takeoff operations, and the congestion on the radio frequency.

20. The flightcrew correctly followed the flying techniques recommended to be used in a takeoff wind shear encounter as delineated in the company's flight operations manual.

21. The flightcrew effectively communicated and coordinated their actions in response to the wind shear encounter at takeoff rotation.

22. United Airlines trains its flightcrews in effective communications and coordination, and this training contributed to their success in flying the airplane through the encounter.

23. The control tower cab supervisor did not have the authority to prevent flights from taking off, but he acted prudently when he suspended issuing takeoff clearances.

24. The controller did not use the correct terminology in reporting the wind shear information when he issued the flight's takeoff clearance.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was an encounter with severe wind shear from microburst activity following the captain's decision to take off under meteorological conditions conducive to severe wind shear. Factors which influenced his decisionmaking include: (1) the limitations of the low level wind shear 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 wind shear report from a turboprop airplane and the fact that he did not receive a wind shear 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; and (4) the captain's previous experience operating successfully at Denver under wind shear conditions.

4. RECOMMENDATIONS

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

> In cooperation with air carriers and manufacturers, develop a common wind shear training program, and require air carriers to modify airline training syllabi to effect such training. (Class II, Priority Action) (A-85-26)

Conduct research to determine the most effective means to train all flightcrew members in cockpit resource management, and require air carriers to apply the findings of the research to pilot training programs. (Class II, Priority Action) (A-85-27)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

March 21, 1985

5. APPENDIXES

APPENDIX A

INVESTIGATION AND PUBLIC HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident about 1500 m.d.t., on May 31, 1984, and dispatched an investigation team the following day to the scene from its Washington, D.C., headquarters. Investigative groups were subsequently formed for Operations, Air Traffic Control, Weather, Structures, Flight Recorders and Airplane Performance. Also, a human performance investigator was subsequently assigned to the investigation.

Parties to the investigation were the Federal Aviation Administration, United Airlines, the Boeing Commercial Airplane Company, and the Air Line Pilots Association.

2. Public Hearing

No public hearing or depositions were held as a result of this accident.

APPENDIX B

PERSONNEL INFORMATION

Captain Arthur G. Gore

Captain Gore, born on August 7, 1937, was employed as a pilot by United Airlines on December 30, 1963. He holds Airline Transport Pilot Certificate No. 1575198, issued February 25, 1970, with an airplane multiengine land rating and a type rating in the B-727. He holds a current first-class medical certificate, issued on March 6, 1984, with no limitations.

Captain Gore has over 19 years' experience on the B-727, 4 years of which have been spent as captain. His total flight time is approximately 12,400 hours.

Captain Gore successfully completed his last annual proficiency check on the B-727 in January 1984; his most recent en route check on the same equipment was in July 1983.

At the time of the accident, Captain Gore had been on duty for 1 hour. He had 7 hours 20 minutes of duty time in the preceding 24-hour period.

Prior to the accident, Captain Gore's flight time on this flight was 24 minutes. During the 24 hours prior to this flight, he had logged 6 hours 24 minutes of flight time. His preceding 'I-day and 30-day flight time totals were 18 hours 39 minutes and 69 hours 5 minutes, respectively.

First Officer Newton R. Rutter, Jr.

First Officer Rutter, born February 17, 1938, was employed as a pilot by United on April 8, i968. He holds Commercial Pilot Certificate No. 1580911, issued on April 3, 1968, with an airplane multiengine land instrument rating. He was issued a first-class medical certificate on December 6, 1983, with the limitation that the holder must possess corrective lenses for near vision while exercising the privileges of his certificate.

First Officer Rutter has 5 years' experience as a first officer, approximately 11 months of which have been spent as first officer on the B-727. His total flight time is approximately 8,182 hours.

First Officer Rutter successfully completed his last annual proficiency check on the B-727 in April 1984; his most recent en route check on the same equipment was in May 3.984.

At the time of the accident, First Officer Rutter had been on duty for 1 hour. Prior to the flight, he had been off duty for 24 hours.

Prior to the accident, First Officer Rutter's flight time on this flight was 24 minutes. During the 24 hours prior to this flight, he had logged no flight time. His preceding 7-day and 30-day flight time totals were 14 hours 25 minutes and 38 hours 24 minutes, respectively.

Second Officer John B. Perkins

Second Officer Perkins, born on August 15, 1930, was employed as a pilot by United on June 20, 1966. He holds Airline Transport Pilot Certificate No. 1264493, latest issue July 17, 1980, with an airplane multiengine rating and type ratings in the DC-6, DC-7, Learjet, B-727, B-737, and B-747. Additionally, he holds Flight Engineer Certificate No. 2009581, issued May 7, 1970, for turbojet-powered' aircraft. His current first-class medical certificate, issued on April 24, 1984, contains the limitation that the holder shall possess correcting glasses for near vision while exercising the privileges of his airman certificate.

Second Officer Perkins has approximately 132 months' experience on the B-727, approximately 50 months of which have been spent as Second Officer. His total flight time is approximately 12,000 hours.

Second Officer Perkins successfully completed his last annual proficiency check on the B-727 in May 1984; his most recent en route check on the same equipment was in April 1984.

At the time of the accident, Second Officer Perkins had been on duty for 7 hours 34 minutes. Prior to the flight he had had 12 hours rest.

Prior to the accident, Second Officer Perkins' flight time on this flight was 24 minutes. During the 24 hours prior to this flight, he had logged no flight time. His preceding 7-day and 30-day flight time totals were both zero.

Second Officer Perkins was a B-727 Lead Training Check Airman who reported directly to the B-727 Fleet Captain for United. He was actively involved in United's research and development efforts to upgrade wind shear training. He spent approximately 8 hours in the simulator, flying or observing various profiles as a research test subject in both vertical and horizontal wind shear situations.

WIND SHEAR PROFILES FLOWN DURING ANNUAL RECURRENT TRAINING

Captain Gore: January 1983: Iberia/Boston
January 1984: PA/New Orleans

F/O Rutter: (April 23-24, 1984) Unknown; if given as part of Day 3, training check airman Bob Posgate is fairly confident that he would have given the CAE Library profile -using strong crosswinds with turbulence on landing and takeoff. Flight operations training instructor Stan Reilly conducted Day 2. He alternates between wind shear No. 4 (Eastern Airlines at JFK) and wind shear No. 6 (Allegheny Airlines at PHL), giving one to the captain and the other to the first officer on landing.

S/O Perkins: February 1983: EAL/JFK
February 1984: AL/PHL

NOTE: The UO-109 proficiency form indicates the wind shear training was given to each crewmember on Day 2 or Day 3.

Local Controller (LC-1) Randy L. Hazzard

The local controller, age 25, is a full performance level (FPL) controller who is qualified to work all of the operating positions in the tower cab. In accordance with the structured staffing policy of the FAA, he has not been trained to control traffic in the radar control room (RAPCON). He possesses a second-class medical certificate, dated August 1983, with no limitations. While on active duty with the United States Air Force (USAF), he was assigned to the Stapleton Airport following the PATCO job action. He worked in this capacity for 1 year before reverting to civilian status. He remained at Stapleton and now has 2 1/2 years of control experience. He had 3 years' experience as a controller at military installations while on active duty with the USAF.

Tower Cab Supervisor William C. Fitch

The tower cab supervisor, age 46, has been a controller with the FAA for about 24 years. He had 4 1/2 years experience as a military controller with the USAF. He has been assigned to the Stapleton Airport for about 15 years. He transferred to Stapleton from the Los Angeles International Airport. He possesses a second-class medical certificate dated June 6, 1983, with no limitations. He possesses no pilot certificates.

APPENDIX C

AIRPLANE INFORMATION

Boeing 727-222, N7647U

The airplane, manufacturer's serial No. 19913, had been operated by United Airlines continuously since its delivery to the manufacturer on June 30, 1969. A review of the airplane's flight logs and other maintenance records showed that all applicable airworthiness directives had been complied with, and that all checks and inspections were completed within their specified time limits. The records review showed that the airplane had been maintained in accordance with company procedures and FAA rules and regulations and disclosed no discrepancies that could have affected adversely the performance of the airplane or any of its components.

The airplane was powered by Pratt and Whitney JT8D-7B turbojet engines rated at 14,000 pounds of thrust.

The following are specific statistical data pertaining to the airframe and engines:

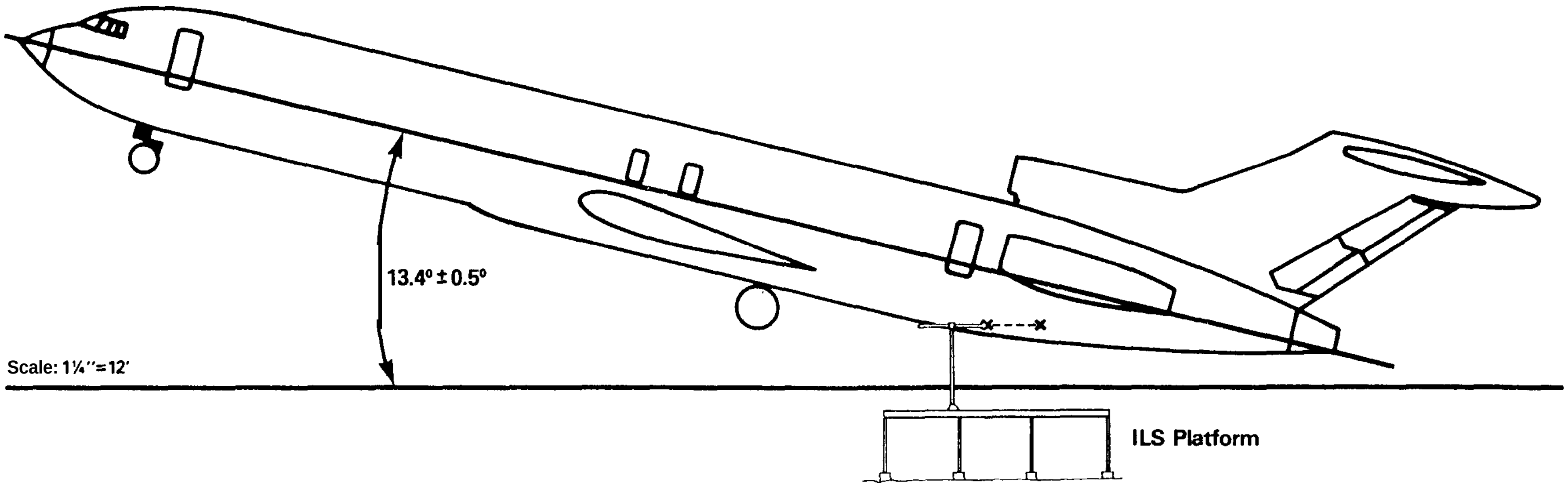
Airplane

Total Time	35,566 hours
Time Since Last Base Check -	826 hours

Engines	No. 1	No. 2	No. 3
Serial Number	655181	653399	655161.
Total Time (hours)	34,598	40,965	32,537
Hours Since Overhauled	34,598	40,965	32,537

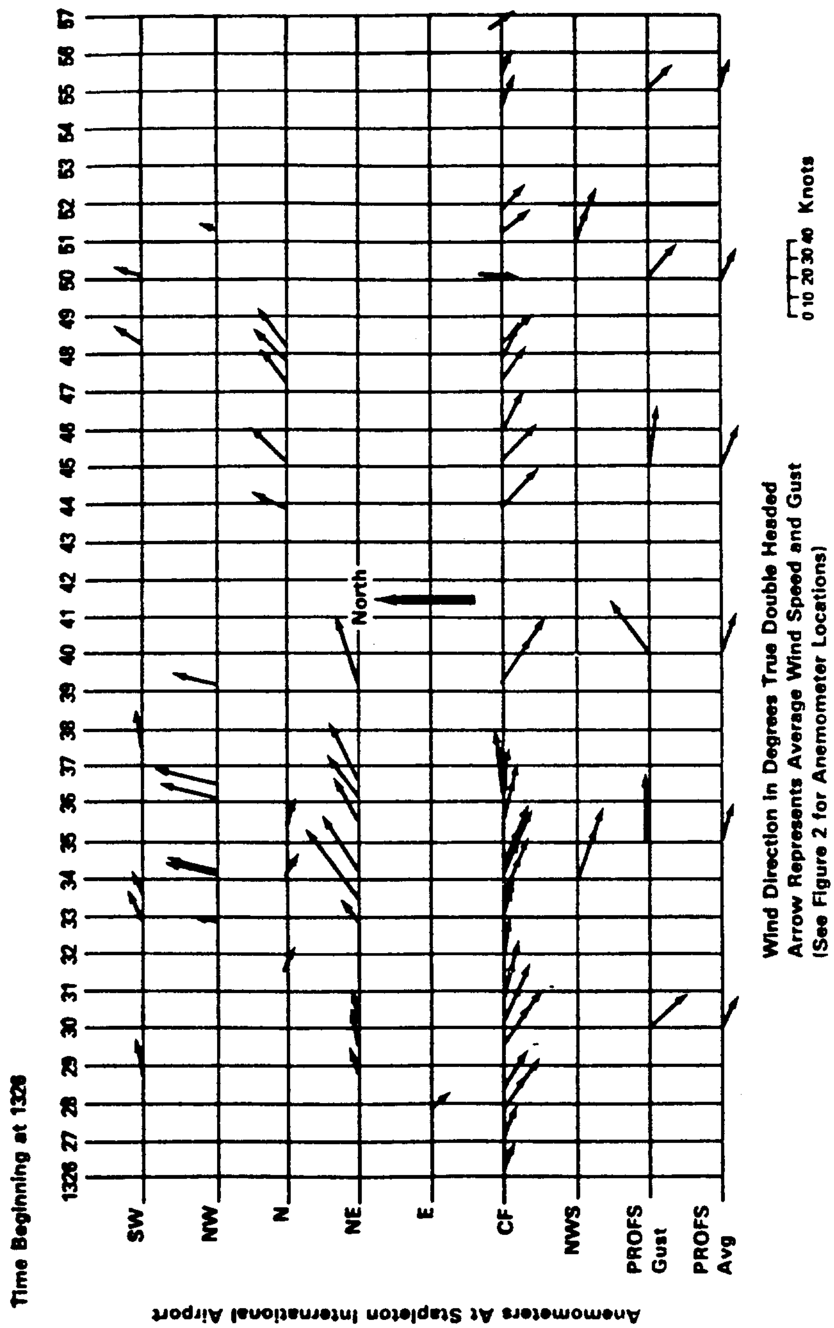
APPENDIX D

AIRPLANE BODY/PITCH ATTITUDE DIAGRAM



APPENDIX E

WIND ANALYSIS CHART



APPENDIX F

ACCIDENTS INVOLVING TRANSPORT CATEGORY AIRPLANES WITH WIND SHEAR AS A FACTOR

July 27, 1970	Flying Tigers DC-8; Okinawa, Japan; 4 fatalities-Approach encounter with heavy rain.
May 18, 1972	Eastern Air Lines DC-9; Ft. Lauderdale, Florida; nonfatal-Hard touchdown after encounter with heavy rain.
December 12, 1972	Trans World Airlines B-707; New York, New York; nonfatal-Descent below ILS glideslope; struck approach lights.
July 23, 1973	Ozark Air Lines FH-227-B; St. Louis, Missouri; 38 fatalities--Crashed 2 miles short on ILS; heavy rain and stong winds.
October 28, 1973	Piedmont B-737; Greensboro, North Carolina; nonfatal-Long, fast touchdown in heavy rain.
November 27, 1973	Delta Air Lines DC-9; Chattanooga, Tennessee; nonfatal-Struck short of runway; heavy rain.
December 17, 1973	Iberia Airlines DC-10; Boston, Massachusetts; nonfatal-Struck approach lights and sea wall after frontal wind shear.
January 30, 1974	Pan American B-707; Pago Pago, American Samoa; 96 fatalities-Struck short of airport; heavy rain and wind shear.
June 24, 1975	Eastern Air Lines B-727; New York, New York; 112 fatalities--Struck short of airport; heavy rain and wind shear.
August 7, 1975	Continental B-727; Denver, Colorado; nonfatal; Crashed after encounter with microburst on takeoff.
November 12, 1975	Eastern Air Lines B-727; Raleigh, North Carolina; nonfatal-Crashed short of runway during ILS approach; heavy rain.
April 27, 1976	American Airlines B-727; St. Thomas, Virgin Islands; 37 fatalities-Long, fast touchdown; terrain wind shear at flare.
June 23, 1976	Allegheny Airlines DC-9; Philadelphia, Pennsylvania; nonfatal-Crashed on runway during go-around encounter with thunderstorm.
June 3, 1977	Continental B-727; Tucson, Arizona; nonfatal-Struck powerlines and poles after takeoff wind shear.
July 9, 1977	Pan American B-727; Kenner, Louisiana; 153 fatalities; Crashed after takeoff encounter with heavy rain and wind shear.
June 13, 1984	USAir DC9-31; Detroit, Michigan; nonfatal-Crashed on runway after encountering a thunderstorm on approach.

APPENDIXG

EXCERPTSFROM FLIGHTOPERATIONSMANUAL ANDOPERATIONSBULLETINS

UNITED AIRLINES

POLICIES - GENERAL

1. Conduct United Airlines flight operations activities in compliance with Federal Aviation Regulations end Company policies and procedures stated in this manual. Appropriate Federal Aviation Regulations required for day to day operations are incorporated throughout the text of this manual. Copies of FAR Parts 1, 91 and 121 are maintained at each domicile (usually at the FOSR position) for reference by Flight Officers desiring 6 more thorough review of these Regulations. Dispatch also maintains several copies and can provide answers by radio or telephone to questions on FAR's which may not be included in the FOM. Remember, however, NO REGULATION OR POLICY IS A SUBSTITUTE FOR THE EXERCISE OF GOOD JUDGMENT.

2. Each manual holder is required by FAR and UA to keep his manual up-to-date at all times. Accomplish this by entries on the "Record of Revisions" sheet in the front of each manual, by prompt insertion of new and revised pages, by requesting any missing revisions (or portions of revisions), and by carefully checking the manual against checklists distributed by DENTK.

3. Manual holders directly engaged in flight operations activities are expected to be sufficiently familiar with the contents of this manual to pass an examination on the manual as required by FAR.

Safety First

4. To insure compliance with these policies and procedures, give full consideration to United Airlines' RULE OF FIVE:

SAFETY
SERVICE
PROFITABILITY
INTEGRITY
RESPONSIBILITY

Safety Policy

5. SAFETY IS THE MOST IMPORTANT OPERATING RULE OF ANY TRANSPORTATION SYSTEM. It is an essential ingredient to all measurements of success. It is a RESPONSIBILITY *OF* EVERYONE connected with a transportation system.

To achieve appropriate Safety standards, we must control loss. Loss control means prevention of injury or damage to people and property - both on the ground and in the air. To achieve safety through "loss control", efforts must be directed toward prevention of loss-producing situations before they occur.

Safety, therefore, requires each of us to exercise the highest degree of cue in all operations to minimize the possibilities of accidents resulting in injury or damage.

To accomplish the above Safety Philosophy, United shall operate under a sound, well-established policy of responsibility toward loss control.

The Company's six point loss control policy is as follows:

A. Safety shall be considered by management and employees to be an integral and vital part of the successful performance of any job.

B. Safety is a paramount put of good operating practice and, therefore, a management function which will be given priority at all times.

C. Direct responsibility for' the safety of an operation will rest with the supervisor of that operation. The Captain of a flight is the supervisor of tht operation. See Paragraph 14.

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D. Each individual employee is personally responsible lo perform his duties giving primary concern to his own safety as well as that of his fellow employees, our customers and the property and equipment entrusted to his care.

E. Supervisory efficiency and ability will be judged by accident prevention performance as well as by other standards.

F. Management at all levels shall provide means for prompt corrective action in the elimination of unsafe acts, conditions, equipment or mechanical hazards.

Sterile Cockpit

6. FLIGHT CREW MEMBER DUTIES FAR 121.542 prohibits flight crew members from performing any duties during a critical phase of flight except those duties required for the safe operation of the airplane.

A. Critical phases of flight are defined as all ground operations involving taxi, takeoff and landing, and all other flight operations conducted below 10,000 feet, except cruise flight.

B. Specific activities prohibited during critical phases of flight include:

1) Radio calls for arch nomafety related purposes as ordering galley supplies and confirming passenger connections;

2) Announcements to passengers promoting the company or pointing out sights of interest;

3) Paperwork unrelated to the safe operation of the flight;

4) Eating meals and drinking beverages;

5) Engaging in nonessential conversations within the cockpit and nonessential communications between cabin and cockpit crews;

6) Reading publications not related to the proper conduct of the flight; and

7) No flight crew member may engage in, nor may any pilot in command permit, any activity during a critical phase of flight which could distract any flight crew member from the' performance of his cc her duties or which could interfere in any way with the proper conduct of those duties.

C. PA announcements or cockpit entry by Flight Attendants which are not safety related are permitted during ground holding in designated areas such as a "penalty box" while waiting for a gate.

D. Company Communications Except for emergency calls, Dispatch will not SELCAL nights be below 10,000 feet. Generally, this will be the first 15 minutes after takeoff and the last 15 minutes before landing. However, passive messages may be sent to the airplane via ACARS during this time for the flight crew to accept when the critical phase of flight has passed.

7. COCKPIT CONTACT Below 10,000 feet, Flight Attendants should not contact the crew except for items which could affect the safety of the flight. Plight Attendants will assume the airplane to be above 10,000 feet JO minutes after takeoff. Plight Attendants will assume the airplane to be at 10,000 feet or below 10 to 15 minutes before scheduled landing.

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4. TORNADOES AND HAIL A majority of hall echoes appear on the scope with characteristic fingers, hooks or scallops protruding from the main thunderstorm echo. On a color radar, there is also a Ngh correlation between red echoes and hall or tornadoes. Tornado identification is less reliable but it is known that some tornadoes produce a protrusion much like the shape of a figure six. Other tornadoes have no characteristic Identification.

5. TERRAM MAPPING The radar is not to be used as a terrain avoidance tool; however, it may be used lo terraln mapping to establish the relative position of the airplane to high terrain, large bodies of water and other easily distinguishable ground features. (Terrain echoes may be Improved by reducing gain, if provided.)

Wind Shear

6. CONDITIONS In order to successfully cope with shear, it la important that the fllght crew be aware of those conditions which can cause It. The following should be considered:

   A. Thunderstorm activity in the aiport area can produce shear In both the takeoff and approach paths. This may be true even though the storm may be farther than 10 miles from the airport.

   B. Frontal activity in the vicinity of the airport can produce dangerous shear conditions. This is particularly true of warm fronts. When a temperature difference of 10' or more exists across the front and its speed is SO knots or more, there is an excellent potential for low level shear.

   C. Temperature luverslons may produce shear conditions.

   D. Airport location may be conducive to the developmed of wind shear conditions. Airport runways that are near an ocean shore line, in mountain valleys, have a severe dropoff at one or both ends, or are protected by trees or buildings have an increased potential for shear.

   E. Virga or rain shafts from Ngh based cumuliform clouds in the viclntty of high altitude airports can be tell-tale signs of wind shear.

7. ALERTS The flight crew may be alerted to the possibility of shear by one of the following:

   A. Pilot reports, whether received directly or through an ATC function, will alert the crew to anticipate shear. Reports which give airspeed gain/loss are the greatest value.

   B. Low level wind shear alert systems (LLWSAS), which are installed at many major airports, provlde information on wind velocity and direction at several points around the perimeter of the airport. This Informatlon is automatically compared with the value measured at a ceder aeld point and when a significant difference is sensed, an alert will be transmitted to the controller, who will in turn relay the information to aircraft at regular intervals so long as the condition exists.

   C. Comparison of reported surface wind velocity with wind being encountered on approach; if this Information is available. INS may be used to determlne ground speed or wind during the approach.

   D. Visual cues such as blowing dust, rings of dust, dust devils, trees blowing in several directtons, and other ground blown debris.

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8. TAKEOFF 11 strong wind shear is known or suspected to exist along the take-off path, serious consideration should be glven to delaying the takeoff or to selecting another runway which will provide a takeoff path which wlll not be affected by the shear. If the performance and runway llmlts permit, a lesser flap setting should be selected and speed for rotation and lnltlal climbout should be increased by an amount equal to the known gust factor or reported shear velocity. Airspeed should be monitored carefully for the earliest indication of wind shear. Speeds 20 knots - 30 knots above V_2+10 wlll provide the best rate of climb capability but it may be necessary to trade airspeed for altitude during severe wind shear at low altitude.

If strong wlnd shear is encountered below 500 feet the following procedure should be followed:

A. Thrust - lmmedlately advance throttles to full forward (firewall).

B. Pitch Attitude - Simultaneously maintain or Increase as necessary to avoid ground contact. Airspeed may be reduced toward stick shaker speed as necessary. Do not lower the nose to accelerate (or regaln the lnltlal airspeed) until terrain and obstacle clearance is assured.

C. Maintain present configuration. Do not change flap or gear posltlon until terrain and obstacle clearance is assured.

9. APPROACH If strong wind shear is known to exist on the final approach, especially below 500 feet, serious consideration should be glven to delaying the larding. If the approach must be made through known or suspected tailwind shear (decreasing alrspeed), the approach speed should be adjusted upward (20 knots maximum addltlon) by the amount of loss expected ln the shear. Frequently a headwind shear (increasing alrspeed) precedes a tailwind shear. During this 6ltuatlon it may be prudent to adjust the target speed upward (20 knots maximum addition) by the amount of the headwind shear. Consideration should be glven to maklng the approach wlth a lesser landing flap setting when a choice is available.

A stabilized approach wlth engines spooled up is important and will permit an early recognition of wind shear. Prompt throttle reaction to speed change must be lnltlated wlth the recognition that an equal and opposite throttle and pitch movement may be required shortly as the aircraft energy reacts to the shear condition.

When using auto-throttle, manual backup of the throttles should be used to overcome any lag or resulting over control by the auto function. While it is desirable to keep the aircraft in trim on stabilized approaches, when operating in shear conditions, stabilizer movement should be held to a mlnlmum. Above all, do not hesitate to execute a go-around lf not on speed and proflle below 500 feet.

If strong wind shear is encountered below 500 feet, the following procedure should be followed:

A. Thrust - Immediately advance throttles to full forward (6rewall).

B. Pitch Attltude - Simultaneously maintain or Increase as necessary to avoid ground contact. Airspeed may he reduced toward stick shaker speed if necessary. Do not lower the nose to accelerate (or to regain the initial airspeed) till terrain and obstacle clearance is assured.

C. Maintain present configuration. Do not change flap or gear position untll terraln and obstacle clearance is assured.

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B-727 PLIGHT MANUAL - HANDBOOK
BULLETIN #106
JUN 17/83
FROM: SFOEG - NEW AIRCRAFT AND OPERATIONAL BNGINBBRING

Please insert fallowing the BULLETINS teb. Record on the Bulletin Checklist.

WHAT% THE LATEST INFORMATION ON WIND SHEAR?

Background

A gmat deal has been learned about low level wind shear in the last two years. As a result of ● tudiea such as the JAW8 project in the Denver area kat summer we art re-evaluating our policies regarding wind shear.

Experience shore that encounters with eevem low level wind shear are rem. but tragedies like the New Orleena accident demonstrate that they can be fatal.

Pilots and meteorologists hart only recently learned ● bout weather phtnomene which art mftrmd to u downbunts. Downbumta am descending columns of air varying in diameter from less than a mile to mom tban four miles which gtnerate very strong horizontal wind shear as well as strong downdnfta. This wind shear is now referred to as DOWNBURSTS, MICROBURSTS, or MACROBURSTS. Dry downbursts (those occurring outside of cloud activity) can be es severe es any found within htavp rain or thundtratorma. <An 85-knot ahaar was recorded within the conflnta of the north/south runways et Denver Stapltton hat summer). Tht microburat can cause the moat vicious wind shear. It is a violent, downward blast of air, that apptars suddenly, often without warning out of a benign looking sky.

It is important to understand the tffecta of wind shear, ● apeciellly when maneuvering at low altitude with a htadwind shear (increasing airspeed) or the more dangerous tailwind shear (decreasing airspeed). Yhroburata can have a profound effect on an airpknt even when the flight peth is offset from tht vertical downdraft.

To htlp pilots avoid severe wind shear we will provide inforautior. in the following areas :

1. Pomcaating ● trong wind shear.
2. Alerts end visual clues to ◆)(■♎ ● hter.
3. Procedures to fallow if ● trong wind shear is encountered unexpectedly at low altitude.

Forecasting

Cluta that ● trong ● hear may be expected include:

1. Thunderstorm ● ?tivity in tht area.
2. Strong frontal activity with surface temperature differences ● cmaa the front over 10°F or frontal movement over 30 knots.
3. Temperature invtraiona.

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4. Airport location near an ocean shore line or in mountain valleys.
5. PIREPS of wind shear. Wind shear event8 usually are not isolated, expect more in the area.

Resources Available

1. When airports have low level rind shear alert systems (LLWSAS) it will be noted on the first approach page (airport plan view). At thou airports, the tower will normally ● dvi8e pilot8 any time a peripheral sensor's average wind reading for 30 seconds shows a vector difference (direction 8nd speed) of 15 knot8 or more from that of the centerfield sensor's wind reading. However, even if not ● dvi8edbythetower.don't hesitateto● [illegible] aperipheralwind.
2. Reports of surface wind directions end velocities that vary considerably in a short period of time.
2. Airplane instrument indications. Compare wind8 at 1.500-2.000 feet with surface wind8 reported. Use the INS/IRS/ONS to maximum advantage. Recheck on the approach.
4. Thunderstorms in the area - observed visually or when displaying heavy precipitation on the cockpit radar.
5. Evidence of 8 gustfront - such a8 blowing dust (A downburst will sometimes create a dirtinctire circular dust pattern).
6. Surface temperatures in excess of 80° and 8 temperature/dewpoint spread of 40° or more and virga beneath high based, high attitude cumulus clouds.

Takeoff in a Wind Shear Environment

1. Consider runway selection which will take you away from the shear.
2. Select a lesser flap setting, runway condition8 permitting.
3. Improved climb performance by accelerating to a speed of V_2 plus 20-30 knots before encountering the shear.
4. The noise abatement takeoff profile should NOT be flown.

Approach to Landing in a Wind Shear Environment

1. Increase the target approach speed by the expected airspeed loss.
2. The ● pproech should NOT be flown if an ● ir8peed loss of 20 knots or more is anticipated.
3. Consider uaing a lesser flap setting for the approach.
4. If the first indication of shear is 8 sudden increase in performance (i.e. ballooning above glide path) this may be followed soon by a rapid airspeed loss and an additional loss of performance due to a downdraft. Consider maintaining the increased ● ir8peod initially in anticipation of the subsequent airspeed loss - resist the tendency to retard throttle8 to rapidly return to target ● ir8peed.

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5. If the initial increase in airspeed is significant, 20 knot8 or more, and encountered below 1.000 feet AGL, an immediate go-around, using full throttle, is indicated.
6. With tailwind shear, up to full throttle may be required quickly to prevent loss of airspeed below Vref. Along with the thrust increase there is a need for a nose-up rotation to minimize departure from the glide path.
7. If the ● ppro8ch become8 destabilized at any point, a go-around la indicated.

Policy

United's poilicy is to avoid encounters with wind shear on takeoff and landing by delaying takeoff-or aborting the ● ppro8ch when strong wind 8heu is known or suspected. We define strong wind shear 88 that invdving 8n indicated airspeed change of 20 knots or more.

Summary

Be prepared: Use all available weather forecasts and current information to anticipate wind shear. When shear is anticipated, a thorough briefing of the plan of action will make it possible to take full advantage of the crew and airplane capabilities.

Give and request rind shear PIREPS:

1. Location and altitude of the shear encounter.
2. Airspeed gain or loss and magnitude of change.
3. Airplane type.

Act promptly: If a severe wind shear is inadvertently encountered close to the ground and ground contact appear. imminent,

1. THRUST - Advance throttle8 immediately to full forward (firewall)
2. PITCH - Increase as necessary to ● vdd ground contact. Speed down to stick shaker may be used.
3. CONFIGURATION - Do not change flaps or gear position until terrain and obstacle clearance is assured.

It is important to stay on instruments. Flying close to stick shaker 8hould be resorted to below 500 feet if ground contact appear8 imminent. High pitch attitudes may be required to control the flight path in downdraft conditions.

In light of the recent knowledge gained about the frequency ● nd severity of rind shear, the wind shear discussion in the Flight Operations Manual is being revised and a new videotape will soon be at all domiciles. In the near future, all flight manuals will be revised to include a wind shear discussion and suggested procedures for each fleet. In the interim. the new videotape 8hould be viewed and the POM rind shear discussion reviewed along with the content8 of this bulletin.

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B-727 FLIGHT MANUAL - HANDBOOK
BULLETIN #121
MAY 17/84 4
FROM: DENTK - FLIGHT STANDARDS AND TRAINING 77MAY84 82 57

Please insert following the BULLETINS tab. Record on the Bulletin Checklist.

NM ACDO 31

YORB ON WINDSHEAR

With the spring and summer thunderstorm seasons bearing down on us once again. let's review some previous information on windshear plus some recent finding8 on the subject. The June, 1983 Bulletin is still valid and rhould also be reviewed at this time.

AVOIDANCE: STILL YOUR BRRT BBT

Once it ha8 bun determined that a severe windshear exists or is probable, the safest policy is to delay the takeoff, or the approach to landing. Recall that we define a severe windshear as one causing an airspeed change of 20 knots or more below 500 feet.

There are many sources that can alert us to potential windshear conditions. Several are found in Dispatch. Weather reports and forecasts provide an initial warning of the possibility of windshear, and include reports of frontal and thunderstorm activity. mountain wave, and virga. Also, be aware of potential problem8 when temperatures am above 80°F, and also with temperature dew point pmad8 of 40°F or more.

When en route, the most important sources of information am visual: Specifically, blowing dust or debris, dust rings, rain shafts or virga, or thunderstorm dghtingr. Radar la mat important in helping us to avoid thunderstorms and heavy precipitation. PIRBPS am also extremely useful tools which we rhould request as often a8 practicable, and in turn support with our own reports when turbulence or low level windshear is encountered. A meaningful PIREP includes specifics such an "United 611, a 727, ncwuntemd moderate turbulence oo final between 500 feet and 200 feet with an airspeed loss of 20 - 25 knots." Any reported airspeed loss or gain of 20 knots or more rhould be considered severe windshear.

Remember also that many of our airports are served by LLWAS (Low Level Windshear Alerting System). A NOTB on the airport plan view on the back side of the first ppmaoh plate (11-1) will advise if the airport ha8 a LLWAS system. The following airports on our system have LLWAS installations:

Albuquerque	Dayton	Los Angeles	Oklahoma City	Sarasota
Baltimore	Denver	Louisville	Omaha	Tampa
Birmingham	Des Moines	Memphis	Orlando	Tulsa
Baton	Detroit	Miami	Philadelphia	Washington (IAD)
Buffalo	Ft. Lauderdale	Milwaukee	Phoenix	Washington (DCA)
Charlotte	Houston	Minneapolis	Pittsburgh	West Palm Beach
Chicago	Indianapolis	New Orleans	Raleigh-Durham	Wichita
Cincinnati	Kansas City	New York (JFK)	Rochester	
Cleveland	Knoxville	New Yak (LGA)	St. Louis	
Columbus	Las Vega8	Newark	Salt lake City	
Dallas/Ft. Worth	Little Rock	Norfolk	San Antonio	

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With LLWAS, the tower ● howld report the different winds once the threshold is exceeded (usually a difference of 15 knots betrnn the airport perimeter sensors and centerfield reading). Remember: Bven though *the* tower is net reporting the different LLWAS winds, 8 digital readout of the winds in proximity to your takeoff or approach area is ● v8U8ble at all times in the tower and can be quickly relayed to you at your request.

RECOGNITION

To successfully fly through an Inadvertent windshear on takeoff. the presence of the windshear environment must be recognized. In all of the known low level windshear-caused takeoff accidents, the pilots did recognize the shear condition, but too late to successfully fly out of it. The key, therefore, is early recognition, and instinctive action. It's almost a given, that if recognition is late and a descent has already started in a severe windshear/downburst environment, successful recovery is not likely.

Several clues are ● v8B8ble to help us move up on the recognition point. In order of importance they are:

1. Airspeed decay
2. Change in pitch attitude
3. Change In rate of climb on the IVSI
4. "Seat of the pants" sinking feeling
5. High ● tiek force8
6. Altimeter rate slowing
7. GPWS raring

Once any or all of the above clue8 reveal 8 windshear on takeoff, It becomes desirable to prevent the vertical speed from going below zero. Simply stated, with a given amount of energy (thrust) available, you will more likely succeed in maintaining 8 positive climb rate than in arresting 8 descent 8nd returning to 8 positive climb.

COORDINATION

Human factor8 research has shown that pilot8 frequently "tunnel in" (gun barrel vision) during periods of apprehension, uncertainty, and high stress. The pilot flying may only be looking at one or two instruments (attitude and airspeed) and not be ● w8re of the flight path of the plane. It is essential for the pilot(s) not flying to monitor the vertical speed and altimeter, and Inform the pilot flying of the flight path by calling out Impending 8nd negative vertical speeds. The pilot not flying should also call out unwanted airspeed in- (above stickshaker) *during* periods of descent, when ground contact is 8 concern.

ESCAPE

Having now determined that performance is deteriorating and 8 windshear ● nvlronaent has been encountered. what ● heuld be done? During the past few months, DBNTR pilots have flown Boeing-recommended takeoff windshear recovery techniques developed in the Boeing ● I81ul8tora. At the same time. a full-ape&rum windshear model installed in the DENTK ● imulatora was ● xtendvely flown and our tests have validated the Boeing conclusions. Here are those findings:

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1. THRUST - ADVANCE THROTTLES IMMEDIATELY TO FULL FORWARD

It is essential to obtain full rated takeoff thrust. Overshoot (to the firewall) is permissible for short periods of time.

2. PITCR - INCREASE AS NECESSARY TO AVOID GROUND CONTACT - SPEEDS DOWN TO STICKSHAKER MAY BE USED

On takeoff. initial pitch attitude should be between V_2 engine out pitch and V_2 + 10 ● U engine pitch. commensurate with the degree of danger. Thereafter, pitch may be increased slowly (up to stickshaker) whenever the flight path (vertical speed) is negative. Pitch must be lowered in small increments at onset of ● tickmhaker to maintain intermittent ● ttckahaker and ● rold exposure to inadvertent stall. High stick forces should be anticipated. The pilot not flying rhonld monitor vertical ● peed and altimeter and should call out all impending and negative vertical speeds.

3. MAINTAIN CONFIGURATION

Do not change flaps or gear position until terrain and obstacle clearance is ● OOM[illegible]

Classroom and simulator briefings about windshear will continue to be en essential part of our training program at DENT-C. Information and procedures will continually be modified u new information is gained from industry sources end oar orn investigative efforts.