Crash on takeoff in microburst, Pan American World Airways, Inc., Clipper 759, Boeing 727-235, N4737, New Orleans International Airport, Kenner, Louisiana, July 9, 1982

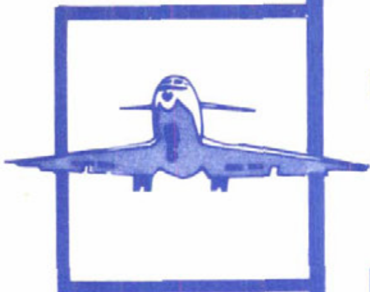
Micro-summary: **This Boeing 727-235 crashed shortly after takeoff, when it encountered a microburst.**

Event Date: **1982-07-09 at 1607:57 CDT**

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

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

PB83-910402

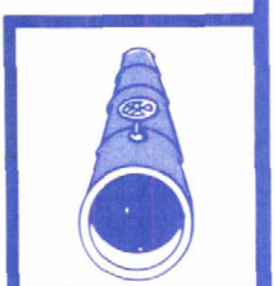


NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

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

UNITED STATES GOVERNMENT

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AIRCRAFT ACCIDENT REPORT

Adopted: March 21, 1983

PAN AMERICAN WORLD AIRWAYS, INC.
CLIPPER 759, BOEING 727-235, N4737,
NEW ORLEANS INTERNATIONAL AIRPORT
KENNER, LOUISIANA
JULY 9, 1982

SYNOPSIS

On July 9, 1982, Pan American World Airways, Inc., Flight 759 (Clipper 759), a Boeing 727-235, N4737, was a regularly scheduled passenger flight from Miami, Florida, to Las Vegas, Nevada, with an en route stop at New Orleans, Louisiana. About 1607:57 central daylight time, Clipper 759, with 7 crewmembers, 1 nonrevenue passenger on the cockpit jumpseat, and 137 passengers on board, began its takeoff from runway 10 at the New Orleans International Airport, Kenner, Louisiana.

At the time of Flight 759's takeoff, there were showers over the east end of the airport and to the east of the airport along the airplane's intended takeoff path. The winds at the time were gusty, variable, and swirling. Clipper 759 lifted off the runway, climbed to an altitude of between 95 feet to about 150 feet above the ground, and then began to descend. The airplane struck a line of trees about 2,376 feet beyond the departure end of runway 10 at an altitude of about 50 feet above the ground. The airplane continued on an eastward track for another 2,234 feet hitting trees and houses and then crashed in a residential area about 4,610 feet from the end of the runway.

The airplane was destroyed during the impact, explosion, and subsequent ground fire. One hundred forty-five persons on board the airplane and 8 persons on the ground were killed in the crash. Six houses were destroyed; five houses were damaged substantially.

The National Transportation Safety Board determines that the probable cause of the accident was the airplane's encounter during the liftoff and initial climb phase of flight with a microburst-induced wind shear which imposed a downdraft and a decreasing headwind, the effects of which the pilot would have had difficulty recognizing and reacting to in time for the airplane's descent to be arrested before its impact with trees.

Contributing to the accident was the limited capability of current ground based low level wind shear detection technology to provide definitive guidance for controllers and pilots for use in avoiding low level wind shear encounters.

1. FACTUAL INFORMATION

1.1 History of the Flight

On July 9, 1982, Pan American World Airways, Inc., Flight 759, a Boeing 727-235, N4737, was a regularly scheduled passenger flight from Miami, Florida, to Las Vegas, Nevada, with an en route stop at New Orleans, Louisiana.

At 1558:48, central daylight time, 1/ Flight 759 (Clipper 759) taxied from its gate at the New Orleans International Airport, Kenner, Louisiana, with 7 crewmembers, 1 nonrevenue passenger on the cockpit jumpseat, and 137 passengers on board. Before leaving the gate, the flightcrew had received Automatic Terminal Information Service (ATIS) message Foxtrot (F) which read in part, "...time one eight five five Zulu, 2/ weather, two thousand five hundred scattered, two five thousand thin broken, visibility six miles in haze, temperature niner zero, wind two four zero at two, winds are calm, altimeter three zero zero one...."

The company takeoff computation form completed by the flightcrew contained the following data: estimated takeoff gross weight -- 170,000 lbs; takeoff flap setting-- 15°; center of gravity/stabilizer trim setting -- 21.3 percent mean aerodynamic chord (MAC); takeoff temperature -- 33° C (91° F); wind -- 320° at 3 knots; and altimeter setting--29.98 inHg. The target engine pressure ratios (EPR) were 1.90 on engines Nos. 1 and 3, and 1.92 on engine No. 2. Critical engine failure speed (V1) and rotation speed (Vr) were 138 knots indicated airspeed (KIAS), and takeoff safety speed (V2) was 151 KIAS.

The flightcrew requested runway 10 for the takeoff and ground control cleared Clipper 759 to taxi to runway 10. At 1559:03, the first officer requested a wind check, and ground control informed the flightcrew that the winds were 040° at 8 knots.

According to the cockpit voice recorder (CVR), the flightcrew had completed its takeoff and departure briefings before turning onto the active runway for takeoff. At 1602:34, while Clipper 759 was taxiing to runway 10, ground control advised another airplane of low level wind shear 3/ alerts in the northeast quadrants of the airport and provided the relevant wind directions and speeds. This advisory was received on Clipper 759's radio.

At 1603:33, Clipper 759's first officer requested another wind check. Ground control replied, "Wind now zero seven zero degrees at one seven. . .peak gusts two three, and we have low level wind shear alerts all quadrants, appears to be a frontal (sic) passing overhead right now, we're right in the middle of everything." The captain then advised the first officer to ". . .let your airspeed build up on takeoff. . ." and said that they would turn off the air conditioning packs for the takeoff, which would enable them to increase the EPR's on engines Nos. 1 and 3 to 1.92.

At 1606:22, Clipper 759 informed the tower that it was ready for takeoff. At 1606:24, the local controller cleared the flight for takeoff, and at 1606:30, the first officer acknowledged the clearance. The acknowledgement was the last radio

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1/ All times herein unless otherwise noted are central daylight time based on the 24-hour clock.
2/ Zulu-Greenwich Mean Time (GMT); subtract 5 hours to convert Zulu to central daylight time.
3/ Wind shear: a change in wind direction and speed in a very short distance in the atmosphere.

transmission received from Clipper 759. At 1607:08, while the flightcrew was completing the final items on the takeoff checklist, the local controller cleared Eastern Flight 956 to land on runway 10 and advised ". . .wind zero seven zero (at) one seven. . .heavy Boeing just landed said a ten knot wind shear at about a hundred feet on the final." The CVR showed that this advisory was also received on Clipper 759's radio. About 1607:57, Clipper 759 began its takeoff. The CVR showed that (Vr) and (V2) were called out. Company personnel familiar with the flightcrew's voices identified the captain as the person making these callouts.

According to witnesses, Clipper 759 lifted off about 7,000 feet down runway 10, climbed in a wings-level attitude, reached an altitude of about 100 feet to 150 feet above the ground (AGL), and then began to descend. The pitch attitude of the airplane during the initial part of the takeoff and takeoff climb was described as "normal" or "similar to other" B-727's for this part of the flight. One of these witnesses, a flight data specialist and furloughed airline pilot, observed the takeoff from the tower cab, which is 126 feet high. He said, that Clipper 759 lifted off near the intersection of runway 10 and the center taxiway. He said, "rotation, liftoff, and initial climb segment appeared to be normal. I observed the airplane climb in a normal manner until it reached an altitude of about my eye level at which time I turned away."

Sixteen witnesses interviewed by Safety Board investigators described the airplane's pitch attitude as it crossed the airport boundary and before it initially struck trees. Two witnesses had a head-on view of the airplane during this portion of the flight. Both witnesses said that the airplane was in a noseup attitude, and one said that the noseup angle was "quite steep."

Six witnesses located at the American and Delta Airlines' concourses had a rear view of the airplane during this part of the flight. The consensus of these witnesses was that Clipper 759 was in a 7° to 10° noseup attitude as it descended toward the trees.

Eight witnesses had a profile view of Clipper 759 as it flew over the end of the runway and crossed the airport's east boundary. Two witnesses said that the airplane was in a nosedown attitude, one witness said that it was straight and level, and five said that the airplane was in a noseup attitude ranging from a "slight pitchup" to a 45° noseup angle. The witness who said that the airplane was at a 45° noseup angle also said that the nose was lowered as the airplane proceeded east ". . .as if the pilot was trying to gain increased airspeed." One of these five witnesses, an airline station agent, stated that Clipper 759 was in a noseup regular takeoff position when he first saw it, and that the nose then came down to a landing position. Another of these five witnesses, a professional pilot who was sitting in his truck just east of the end of runway 10, stated that as Clipper 759 passed in front of his truck, it was no higher than 100 feet AGL and that it ". . .had a very slight pitchup attitude." He said that the pitchup attitude was not ". . .what I am use(d) to seeing . . ." and that the attitude did not change as the airplane began a gradual descent and then disappeared from his view behind the line of trees.

Clipper 759 crashed into a residential area and was destroyed during the impact, explosion, and subsequent ground fire. One hundred forty-five persons on board the airplane and 8 persons on the ground were killed.

The accident occurred about 1609 during daylight hours at coordinates 29° 59' 15"N latitude and 90° 14' 08"W longitude.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	8*	137**	8***
Serious	0	0	9
Minor	0	0	0
None	0	0	7
Total	8	137	24

* Includes a nonrevenue passenger occupying the cockpit jumpseat.
** The coroner of Jefferson Parish, Louisiana, issued a "Certificate of Fatal Death" for a 7 1/2 month fetus which is not included above.
*** Persons on the ground.

1.3 Damage to Airplane

The airplane was destroyed by impact and the postcrash fire.

1.4 Other Damage

Six houses were destroyed; five houses were damaged substantially.

1.5 Personnel Information

The flightcrew and the Air Traffic Control (ATC) controllers were qualified in accordance with current regulations. (See appendix B.)

According to available information, the captain did not have any sleep or health problems. The captain had been off duty from July 5 until reporting for duty on July 9, 1982. He had about 7 to 8 hours sleep the night before, and arrived at the airport about 1230-1300 on July 9. The captain was described as being in good spirits.

Interviews with Pan American (Pan Am) pilots, training personnel, and supervisors revealed that the captain was considered to be an above average pilot. His judgment and ability to exercise command were rated as excellent. Several of these persons said that it was "comfortable" to fly with the captain because there was no question concerning his flying ability and judgment, and that there was never any doubt as to who was in command. In addition, National Airlines had commended the captain for his handling of an in-flight emergency involving a complete loss of A.C. electrical power and subsequent emergency landing at Houston International Airport, Texas. The emergency had occurred on January 1, 1979, before National Airlines had merged with Pan Am.

Except for a middle ear infection (otitis media), which had occurred on January 11, 1982, the first officer did not have any sleep or health problems in the recent past. He had returned from a flight on July 4, 1982. On July 6 and 7, he received recurrent training at the Pan Am training academy, and he was off duty on July 8. According to available information, the first officer had about 9 to 10 hours sleep the night before reporting for the flight and left for the airport about 1230 on July 9. At this time, he was described as being in good spirits.

Information received from the first officer's peers, company training personnel, and line captains who had flown with him revealed that he was considered to be a conscientious pilot with an excellent knowledge of the airplane's systems and company flight procedures and techniques. They described him as being quiet in the cockpit, but that he always could be "counted on" to supply information when it was needed.

Interviews concerning the second officer revealed that he had no sleep or health problems. He had returned from a flight on July 4, 1982, and was off duty until he reported for the flight on July 9. The second officer had about 8 to 9 hours sleep the night before and left for the airport about 1145 on July 9. The second officer's training records showed that he had passed all his proficiency checks without problems.

1.6 Aircraft Information

The airplane, a Boeing 727-235, N4737, was owned and operated by Pan American World Airways, Inc. (See appendix C.) The airplane's maximum allowable structural gross weight for takeoff was 172,000 lbs. The forward and aft center of gravity (c.g.) limits were 8 percent and 33 percent MAC, respectively; the company further restricted these c.g. limits to 14 percent and 29 percent MAC, respectively. Based on the existing outside air temperature at takeoff, the maximum allowable no-wind takeoff gross weight on runway 10 was 171,200 lbs. The airplane's takeoff gross weight and c.g. were recomputed after the accident using actual passenger weights and fuel loads. Based on this computation, Clipper 759's takeoff weight and c.g. were 171,139 lbs and 20.4 percent MAC, respectively; therefore, Clipper 759's takeoff weight was below the maximum allowable structural gross weight for takeoff and the maximum allowable gross weight for takeoff on runway 10.

N4737 was equipped with the Litton "Digiprox" ground proximity warning system (GPWS). Since Clipper 759 never attained 700 feet altitude, of the six available GPWS modes, only Mode 1, excessive descent rate below 2,500 feet, and Mode 3, descent during takeoff regime below 700 feet, were applicable to the accident. Mode 1 is engaged at 50 feet AGL. Between 50 feet AGL and 100 feet AGL, a descent rate of about 1,500 fpm will activate the warning cycle. Mode 3 is engaged at 90 feet AGL. Thereafter, a loss of 20 feet will activate the warning cycle. The aural warning for both Modes 1 and 3 is "whoop whoop pull up," and both modes are deactivated below 50 feet AGL.

N4737 was equipped with a Bendix model RDR-1E, monochromatic weather radar system. The system operated on X-band frequency at a 3.2-cm wavelength. The system is designed to display targets at three range selections--30 nautical miles (nmi), 90 nmi, and 180 nmi--and to display weather in two modes--normal and contour. In the normal mode, precipitation is displayed as luminescent green areas on the dark background of the cockpit display. The system is equipped with circuitry which measures the relative density of the precipitation areas and presents these areas on the indicator as three separate levels or shades of one target color. Very heavy precipitation rates, in excess of 12 mm/hr, 4/ are displayed in the brightest shade; the medium shade represents rates between 4mm/hr and 12 mm/hr; and the lightest shade represents a rate of less than 4 mm/hr. When the weather radar system is placed in contour mode, the contour circuitry, in effect, inverts the brightest shade of color and displays it as a black area surrounded by two lighter shades of color.

4/ 25.4 mm equals 1 inch. A precipitation rate of 12 mm/hr corresponds to about a National Weather Service level 3 weather echo.

The manufacturer's manual addressed attenuation effects of rain as follows, "severe rainfall within the antenna near field (100 feet) disperses the beam with a consequent reduction of radar range performance." The theoretical effects of attenuation by rainfall and water vapor between the radar antenna and the target have been calculated to be quite high for X-band radar as compared to radar operating at lower frequencies and longer wavelengths. 5/ Additionally, empirical evidence 6/ exists that radio magnetic waves of the X-band frequency are significantly more susceptible to attenuation by rainfall than are lower frequency waves of longer length. According to Medhurst, there were indications that the measured amounts of attenuation substantially exceeded the theoretical amounts, and he believed that further measurements were needed to reconcile the discrepancies.

1.7 Meteorological Information

The 1600 National Weather Service (NWS) surface analysis weather chart issued by the National Meteorological Center, Camp Springs, Maryland, showed the New Orleans area to be under the influence of a high pressure center located about 60 nmi off the Louisiana coast. There were no fronts or low pressure areas within 100 nmi of the airport.

The New Orleans area forecast issued at 0740, on July 9, 1982, by the New Orleans NWS office contained, in part, the following data and was valid between 1200 and 2000 of the same day: thunderstorms occasionally forming lines or clusters; thunderstorm tops to above 45,000 feet; "thunderstorms imply possible severe or greater turbulence. . .severe icing and low level wind shear."

The following terminal forecast was issued by the New Orleans NWS on July 9, 1982, and was valid between 1200 and 2200 of the same day: scattered clouds, variable to broken clouds at 3,000 feet; chance of overcast ceilings at 1,000 feet; visibility 2 miles; thunderstorms, moderate rain showers.

According to the NWS, there were no SIGMET's, convective SIGMET's, 7/ Severe Weather Warnings, Local Aviation Warnings, or Severe Weather Watches in effect for the time and area of the accident. At 1455, the Kansas City, Missouri, National Severe Storms Forecast Center issued convective SIGMET 38C for Alabama, Mississippi, and the coastal waters which called for thunderstorms with tops to 50,000 feet within an area from 40 miles northwest of Mobile, Alabama, to 20 miles north of Mobile, to 60 miles southeast of New Orleans. The SIGMET also stated that through 1655 these storms would show "little" movement. At 1501:28, the New Orleans clearance delivery transmitted SIGMET 38C to "all aircraft" and advised them to "monitor the VORTAC or check with flight watch for further information." This message was also broadcast on the New Orlean's tower approach and departure control frequencies.

5/ Skolnick, Merril L.: Radar Handbook, Chapter 24, McGraw-Hill Book Company, New York, 1970.

6/ Medhurst, R.G.: Rainfall Attenuation of Centimetre Waves: Comparison of Theory and Measurement, IEEE Transactions, Vol. AP-13. pp. 550-564, July 1965.

7/ A weather advisory concerning convective weather significant to the safety of all aircraft. Convective SIGMET'S are issued for tornadoes, lines of thunderstorms, embedded thunderstorms of any intensity level, areas of thunderstorms greater than or equal to VIP level 4 with an area coverage of 4/10 or more and hail 3/4 of an inch in diameter or greater.

The following surface weather observations were taken before and after the accident by observers under contract with and certified by the NWS at New Orleans International Airport:

> 1455: Type--record; 3,000 feet scattered clouds, estimated ceiling 25,000 feet broken clouds; visibility -- 5 miles, haze; temperature 91° F; dewpoint -- 75° F; wind -- 320° at 3 knots; altimeter setting -- 29.98 inHg; cumulus buildups overhead east to south.
>
> 1555: Type--record; ceiling -- measured 4,100 feet broken, 25,000 feet overcast; visibility -- 5 miles, moderate rain showers, haze; temperature -- 86° F; dewpoint -- 75° F; wind -- 070° at 8 knots; altimeter setting -- 29.98 inHg; remarks -- cumulonimbus overhead, rain began 1548.
>
> 1603: Type--special; ceiling -- measured 4,100 feet overcast; visibility -- 2 miles, heavy rain showers, haze; wind -- 070° at 14 knots gusting to 20 knots; altimeter setting -- 29.98 inHg; remarks -- cumulonimbus overhead.
>
> 1618: Type--special; ceiling -- estimated 4,100 feet broken, 25,000 feet overcast; visibility -- 2 miles, heavy rain showers, haze; temperature -- 82° F; dewpoint -- 75° F; wind -- 070° at 14 knots; altimeter setting -- 30.00 inHg; remarks -- visibility northeast 2 miles, cumulonimbus all quadrants, aircraft mishap.

The 1455, 1555, 1603, and 1618 surface observations were transmitted on the electrowriter and were received at the terminals in the tower and in the Pan American operations office at the airport. The electrowriter tape showed that the 1555, 1603, and 1618 transmissions were completed at 1556, 1604, and 1619, respectively.

The transmissometer traces for the touchdown, midfield, and rollout zones for runway 10 were obtained and converted to runway visual range (RVR) using a runway light setting of 3 and a 250-foot baseline. 8/ At 1600, 1610, and 1620, the midfield RVR's were 5,500 feet, 4,000 feet, and 6,000 feet, respectively. At 1600, 1610, and 1620, the rollout zone RVR's were 3,000 feet, 1,600 feet, and 1,200 feet, respectively; 1,200 feet was the minimum value recorded between 1600 and 1620.

Wind direction and velocity are measured at the airport's centerfield wind sensor; however, only the wind velocity is recorded. At 1605, 1610, and 1615, the recorded speeds were 20 knots, 16 knots, and 12 knots, respectively. Between 1605 and 1615, the minimum and maximum recorded wind speeds were 6 knots and 20 knots, respectively. In addition, at 1606:13, 1607:10, and 1609:03, the wind directions and velocities given to airplanes by the local and ground controllers were 070° at 17 knots, 070° at 17 knots, and 080° at 15 knots, respectively.

According to the weather observer on duty at the airport at the time of the accident, rainfall intensity is based on the following scale:

8/ Federal Meteorological Handbook No. 1, Surface Observations, January 1, 1982.

Rainfall	Rate
Light	Trace to 0.01 inches in 6 minutes.
Moderate	0.01 inches to 0.03 inches in 6 minutes.
Heavy	More than 0.03 inches in 6 minutes.

The recorded rainfall data at the airport indicated that between 1545 and 1615, about .2 inches of rain fell, and between 1615 and 1700, 1.6 inches of rain fell.

In response to a Safety Board request, a New Orleans television station provided the Board with rainfall data collected at seven locations in the vicinity of the airport. The data collected showed that on July 9, 1982, the rainfall logged on these seven rain gauges ranged from no rain to 2.8 inches. The observers of these gauges were not certified weather observers. Three of these observers were able to quantify the amount of rain that fell near the time of the accident. One observer stated, "at 6 p.m., I checked the rain gauge and found that 2.08 inches of rain had fallen between 3:30 p.m. and 6 p.m. I would estimate that most of that had fallen before 5 p.m." Another observer said that 2 inches of rain were measured between 1600 and 1645. A third observer estimated that the majority of the rain logged at his location (1.75 inches) fell just before, during, and immediately after the crash.

Weather Radar Observations.--The NWS radar systems are able to determine objectively radar weather echo intensity by the use of Video Integrator Processor (VIP) equipment. Based on this capability, the NWS has classified six levels of echo intensity and has assigned VIP numbers for each level. (See table 1.)

Table 1.--VIP levels and categories of intensity and rainfall rate.

VIP Number	Echo Intensity	Precipitation Intensity	dBZ*	Rainfall Rate (in/hr) Stratiform	Rainfall Rate (in/hr) Convective
1	Light	Light			
			30	0.1	0.2
2	Moderate	Moderate			
			41	0.5	1.1
3	Strong	Heavy			
			46	1.0	2.2
4	Very Strong	Very Heavy			
			50	**	4.5
5	Intense	Intense			
			57	**	7.1
6	Extreme	Extreme			
				**	

*dBZ: A measurement of radar reflectivity expressed in decibels.
**Stratiform rain with an intensity of very heavy, intense, or extreme does not occur. Rainfall rates for these intensities are, therefore, omitted here.

Although existing weather radar systems cannot detect turbulence, there is a direct correlation between the degree of turbulence and other weather features associated with thunderstorms and the intensity of the radar weather echo. The degree of turbulence and type of weather phenomona associated with these VIP numbers or storm levels have also been identified and categorized. The resultant data have been placed in tabular form and made available to pilots and controllers in various publications. The following table, excerpted from the Pilot/Controller Glossary of the Airman's Information Manual, presents the weather features likely to be associated with these VIP or thunderstorm levels:

Table 2.--Storm levels and associated weather phenomena.

Level	Phenomena
Weak (1) and Moderate (2)	Light to moderate turbulence is possible with lightning.
Strong (3)	Severe turbulence possible, lightning.
Very strong (4)	Severe turbulence likely, lightning.
Intense (5)	Severe turbulence, lightning, organized wind gusts. Hail likely.
Extreme (6)	Severe turbulence, large hail, lightning, extensive wind gusts and turbulences.

The NWS station at Slidell, Louisiana, about 30 nmi northeast of the New Orleans International Airport, has Weather Surveillance Radar (WSR) type-57 radar with VIP equipment. Radar weather observations taken at Slidell which were pertinent in time to the accident were, in part, as follows:

> 1531: Type--special: An area 3/10 covered by intense echoes containing thunderstorms with intense rain showers, no change in intensity over the last hour. The area was bounded by 323° at 175 nautical miles, 029° at 170 nautical miles, 082° at 200 nautical miles, 223° at 100 nautical miles, and 263° at 170 nautical miles. The cells were stationary. A maximum top of 50,000 feet was located at 060° at 40 nautical miles from the radar. NOTE: A special radar observation was taken because the maximum echo top was within 5,000 feet of the tropopause. The tropopause was reported as 52,000 feet on the radar log.
>
> 1635: Type--special: An intense echo cell containing a thunderstorm with intense rain showers was located at 230° at 31 nautical miles from the Slidell, Louisiana, weather radar antenna. The diameter of the cell was 11 nautical miles. The cell was stationary. The maximum top was 49,000 feet.

The departure end of runway 10 at New Orleans International Airport is located about 30 nmi from the antenna of the Slidell radar on a bearing of 237°.

The Slidell weather radar overlay and radarscope photography showed that radar echoes were located in the vicinity of the departure end of runway 10 before and during the time of Clipper 759's takeoff. At 1608, a radarscope photograph (frame 580) showed a VIP level 2 echo located approximately over the departure end of runway 10 and another VIP level 2 echo located about 4 nmi east of the airport. The same photograph showed VIP level 3 echoes located about 4 nmi north, 2 nmi west, and 6 nmi south of the departure end of runway 10.

According to the Slidell weather radar specialist, none of the weather radar echoes in the vicinity of New Orleans International Airport he observed either before or after the accident met the NWS Southern Region's special radar observation or severe weather criteria.

At 1510, the Center Weather Service Unit (CWSU) meteorologist in the Houston, Texas, Air Route Traffic Control Center (ARTCC) called the New Orleans tower on the FAA 300 system interphone and advised the controller of level 4 and 5 thunderstorms located south and southwest of the airport. He told the controller that these storms were moving northwest toward the airport and to "keep an eye on those thunderstorms." After the tower controller acknowledged receipt of the advisory, the CWSU meteorologist then advised the Houston Center's flow controller of these storms.

The CWSU meteorologist said that he saw the storms on the ATC's radar plan view display. Although this radar displays the area of precipitation, it cannot indicate the precipitation intensity. However, the meteorologist said that based on the 1435 radar observation from Slidell, he knew that the areas of precipitation being displayed on the ATC radar were isolated level 4 and 5 storms.

The CWSU meteorologist said that he did not issue a center weather advisory because the weather he was observing did not meet criteria requiring this type of advisory. Center weather advisories concerning thunderstorms are issued when convective SIGMET criteria are met. (See footnote 6.) The CWSU meteorologist also stated that he believed impact of the weather would be limited to the New Orleans International Airport and that the FAA interphone "represented the best and quickest way to provide the information to the affected FAA facility."

The CWSU meteorologist and Houston Center's flow controller both testified that the main purpose for the meteorologist's call to the New Orleans tower was to alert that facility to the possibility that these storms might affect arriving and departing traffic and that they could expect requests for route deviations from their traffic. The meteorologist and the flow controller said that in the absence of either a center weather advisory or convective SIGMET, there was no requirement to broadcast the information on ATC frequencies.

Flightcrew Weather Observations.--Between 1558 and 1627, four air carrier airplanes and one general aviation airplane departed New Orleans International Airport. In addition, during this period, another air carrier airplane taxied to runway 10 for takeoff but did not depart. All of these airplanes had weather radar, and their flightcrews used their radar to observe the weather near the airport. The air carrier airplanes were equipped with Bendix RDR-1-E monochromatic weather radar systems. The general aviation aircraft was equipped with a Bendix RDR-1100, X-band color radar. 9/

9/ Three different colors are used to display rainfall rates on the RDR-1100 display. Rainfall rates of more than 12 mm/hr are displayed in red, rates between 4 mm/hr and 12 mm/hr are displayed in yellow, and rates of less than 4 mm/hr are displayed in green.

Delta Airlines Flight 1622 departed from runway 10 at 1558. According to the flightcrew, the Bendix RDR-1-E weather radar was in normal mode and set on the 30-nmi range. The flightcrew stated that there was a cell directly over the airport which extended slightly north of runway 10 and that there were other storm cells at their 1230 position at a range of 25 nmi.

At 1601, Republic Airlines Flight 632, a DC-9-30, departed from runway 19. The flightcrew used the weather radar to scan the local area while taxiing from the gate. The radar was set on the 30-nmi range, and the antenna was tilted about 3° to 5° up. The flightcrew used both the normal and contour mode while scanning the area around the airport. According to the captain, thunderstorms were all around the airport; one was east-northeast of the airport, and numerous cells were to the south, southwest, and west between 5 nmi to 20 nmi from the airport. The captain stated that the largest radar echo was east-northeast of the airport and that the cell contoured when he switched to contour mode. The captain testified that the gradient in this cell "was very steep."

The Republic captain testified that during their takeoff roll they encountered heavy rain and wind shear about half way down runway 19 and the visibility became very poor. According to the crew, the airplane began to drift to the right and continued to do so even after left rudder was applied. The captain testified that rather than reject the takeoff and in order to avoid drifting off the side of the runway, he began to rotate the airplane and "prior to V1, I lifted the airplane off the ground. . . ." After liftoff, the captain called for the landing gear to be retracted, and while it was retracting, the stall warning stickshaker activated for a short time.

Flight 632's first officer said that the airspeed fluctuated between 100 KIAS and 110 KIAS during the takeoff roll. The captain, however, did not recall seeing this fluctuation. According to the first officer, V1 and Vr were 132 KIAS, V2 was 140 KIAS, and the captain rotated the airplane at 121 KIAS. The first officer said that as the airplane passed over the end of the runway, the airspeed went through V1, V2, and 160 KIAS "almost simultaneously." At 1602:17, the first officer called departure control and reported that "we had a wind shear on the runway." Departure control acknowledged; however, this pilot report (PIREP) was not passed on to the controllers in the tower cab. The PIREP did not follow the recommended format contained in paragraph 523 of the Airman's Information Manual (AIM). Consequently, the report did not provide the altitude at which the shear was encountered and the airspeed that was gained during the encounter.

At 1604, Texas International Flight 794, a DC-9-30, departed from runway 19. The radar was set to the 30-nmi range, and while awaiting takeoff, the flightcrew scanned the airport area using both normal and contour mode. The flightcrew observed storm cells 5 nmi to 6 nmi southwest of the airport, and the cells contoured. Their takeoff was made in light rain, and they did not encounter either turbulence or wind shear during climbout.

About 1558, N31MT, a Cessna Citation turbojet, was cleared to taxi to runway 19 for takeoff. When N31MT reached runway 19's apron, the pilot made a 360° turn and scanned the weather with the radar. About 1609:15, while holding on runway 19 awaiting takeoff clearance, the flightcrew scanned the area again with the radar. The pilot said that there were two storm cells about 2 nmi to 3 nmi east of the airport about 1/4 nmi apart, and another cell about 7 nmi southwest of the airport. Each cell was about 3 nmi to 4 nmi in diameter; they were depicted as sharp-edged red areas, and based on his interpretation of the edges of the red areas on the radarscope, the pilot believed they were either level 4 or level 5 radar echoes. Thereafter, N31MT was cleared to taxi to and takeoff from runway 01. At 1618, about 8 minutes after the accident, N31MT departed from runway 01. The pilot was asked if he ever considered runway 10 for takeoff. He testified that he did not "primarily because of the weather east of the airport."

N31MT's copilot's written statement corroborated his captain's statement and testimony. The copilot said that the radar painted numerous cells as large red areas outlined in green to the northeast, southeast, and south of the airport.

Southwest Airlines Flight 860, a B-737, left the terminal about 1549 and stopped on the end of the terminal ramp, abeam the east end of runway 10 to await takeoff clearance. The captain testified that at this time, his radar showed a storm cell above his airplane which "was between 5 to 6 miles wide extending 2 miles east of the airport." He said that the shower contoured and that the contour was located just to the south side of the departure end of runway 10. While in this position, the flightcrew watched Republic Flight 632 and Texas International Flight 794 take off. Thereafter, they were cleared to taxi to runway 01 for takeoff. After taxiing to runway 01, the captain aligned the airplane with the runway for takeoff and rechecked the weather with his radar. He said the cell described earlier was still in the area and that there was "little movement with heavy contour." While he was looking at the weather, the captain saw Clipper 759 pass over the departure end of runway 10. The captain stated that he thought the airplane was about 200 feet AGL, that the landing gear was retracted, and that the airplane was starting to turn to the left. Thereafter, he focused his attention inside his cockpit. The captain said that at the time he saw Clipper 759, the ceiling was about 3,000 feet, it was overcast, it was raining lightly, and the visibility to the east was about 3 nmi. Flight 860 subsequently departed from runway 19, at 1627.

U.S. Air Flight 404, a DC-9-30, taxied behind Clipper 759 to runway 10. While Clipper 759 was taxiing onto the runway, the captain of Flight 404 taxied to the apron and turned to a heading of 030° to look at the weather. When the airplane came to a stop on the 030° heading, the radar was set on the 30-nmi range. The captain testified that he "took a quick look. . . I did see precipitation or an outline of rain. I did not see a contour. So there was moisture present, but not heavy, from what I could tell from the radar." He further testified that he told his first officer, "we will see how Pan Am does and then we will take a look." After Clipper 759 departed, the captain taxied his airplane toward the runway, and while awaiting clearance to take the runway, heard that Clipper 759 had crashed. He shut his engines down to wait until the weather improved "so we really didn't get our radar turned around to runway heading to take a good look."

Witnesses' Weather Observations.--Forty-seven of the more than 100 witnesses interviewed by the Safety Board during this investigation provided descriptions of the weather conditions during the time period relevant to the accident. Fourteen of these witnesses were on the airport; 33 witnesses were outside of the airport boundaries.

Thirty-eight of the 47 witnesses, located at distances which ranged from 300 feet to 1 mile, saw Clipper 759 while it was airborne, the fireball after impact, or the smoke column rising from the crash site. Only two witnesses, airline support personnel, said that the rain obscured their view of Clipper 759 as it passed over the access road just inside the airport's eastern boundary.

Only 5 of these 47 witnesses described thunder and lightning. Two of the four witnesses who saw lightning said that it was not in the area of the accident site; one said that it occurred after the accident, and one said that the flash was coincident with the airplane's ground impact. Only one witness, who was driving on Williams Boulevard when she saw Clipper 759, heard thunder.

Of the 14 witnesses who were on the airport, 6 said that about the time Clipper 759 took off, the rain was light to moderate; 6 said that the rain was heavy; and 2 described the rain as very heavy. Four witnesses stated that the intensity of the rain increased after the accident. Only 7 of the 14 witnesses provided wind direction information: 2 said that the wind was from the east; 2 said that the wind was from the northeast; and 3 said that the wind was variable but did not state the direction of the wind.

Of the 33 witnesses who were located outside of the airport boundaries at the time of the accident, 31 were either in the area of the initial tree strike or near the crash site; the other two witnesses were over 1 mile north of runway 10. Only nine witnesses described the wind direction at the time of the accident. Seven said the wind was southerly; however, there was no consensus as to whether it was out of the southeast, south, or southwest. Two witnesses said the wind was from the north. Two of these witnesses said there had been a wind shift; one said the wind shifted from the north to the south, the other said that it shifted from the southeast to the northeast. Some of the witnesses described the winds as "swirling," "gusty," "strong," or "variable."

Although all 33 witnesses said that it was raining at the time of the accident, observations varied as to the intensity of the rain. Seven of the witnesses who described the rain as not very intense at the time of the accident said that the intensity increased after the accident.

Six of the 33 witnesses were on Williams Boulevard when Clipper 759 initially struck a north-south line of trees located along the east side of Williams Boulevard; three of these witnesses were driving south on Williams Boulevard and were 1,000 feet to 1,500 feet north of the airplane when they saw it fly across the boulevard. These three witnesses said that the rain was heavy to very heavy; one said that the rain was coming down "in sheets." None of these three witnesses stopped their cars during the rain. One of these witnesses testified that when Clipper 759 hit the trees, the wind was blowing from west to east, and "whole trees were swaying. . ." in the wind.

1.8. Aids to Navigation

Not applicable.

1.9 Communications

There were no known communications difficulties.

1.10 Aerodrome Information

New Orleans International Airport (Moisant), elevation 4 feet m.s.l., is located in Kenner, Louisiana, 14 miles northwest of New Orleans. (See appendix E.) The airport is certified in accordance with 14 CFR 139, Subpart D.

The landing area consists of three runways: 10/28, 01/19, and 05/23. Runway 10 is 9,228 feet long, 150 feet wide, and has a grooved asphalt and concrete surface. The runway has high intensity runway edge lights and centerline lights. Runways 01, 10, and 28 are served by Instrument Landing System (ILS) approaches, and runway 19 has an ILS back course approach.

1.10.1 Low Level Wind Shear Alert System

New Orleans International Airport has a Low Level Wind Shear Alert System (LLWSAS), which was functioning at the time of the accident. Pilots are notified that a LLWSAS is available by a note on the runway diagram chart of the airport's instrument approach charts. The runway diagram chart does not depict the location of the system's components.

The New Orleans LLWSAS consists of a centerfield vector-vane type wind sensor 10/ and five additional sensors located at or near the final approach courses to each runway (see figure 1). These five peripheral sensors are designated: northwest, 11/ northeast, east, south, and west. These sensors provide wind direction and speed data to a computer and five display units; one display unit is located in the tower cab, and four are located in the Terminal Radar Approach Control (TRACON). (See figure 2.) The New Orleans sensors, display units, and electronic gear are identical to those in all other LLWSAS's; this equipment has been standardized nationwide.

The top row of windows of the display unit in the tower show the centerfield wind direction, speed, and gust speed. The next five rows display wind information from the five peripheral sensors. When a peripheral sensor's average wind reading for 30 seconds shows a vector difference (direction and speed) of 15 knots or more from that of the centerfield sensor's wind reading, an aural alarm will sound and the digital information from the affected sensor or sensors will start flashing in the appropriate row or rows of the tower displays. 12/ The flashing will continue for five scans of the system's computer, or 37.5 seconds; the aural alarm lasts for two scans, or 15 seconds. The wind gust velocity will be shown in its appropriate window anytime the instantaneous wind speed retrieved from the centerfield sensor exceeds by more than 9 knots the average wind speed retrieved over the previous 2 minutes. Wind gust information is not shown on the readouts for the peripheral sensors. The digital readouts for the peripheral sensors will not appear in their appropriate windows in the tower displays unless an alert has occurred. However, a controller can obtain a wind readout for any of the five peripheral locations by pressing the appropriate blanking switch on the display unit. The readout will be retained until the controller again presses the blanking switch.

According to the manager of the Federal Aviation Administration's (FAA) Aviation Weather System Program, the FAA's criterion for the average spacing between

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10/ An instrument which measures both wind direction and velocity.

11/ The northwest sensor, for example, is located about 1 mile and on a bearing of about 341° from the departure end of runway 01. Although this sensor is not northwest of the center of the airport, it is northwest of the departure end of runway 01, and for the purpose of providing wind shear information, has been designated arbitrarily as the northwest sensor.

12/ The four TRACON displays show only the centerfield wind and gust information. They do not receive or generate wind shear alert information.

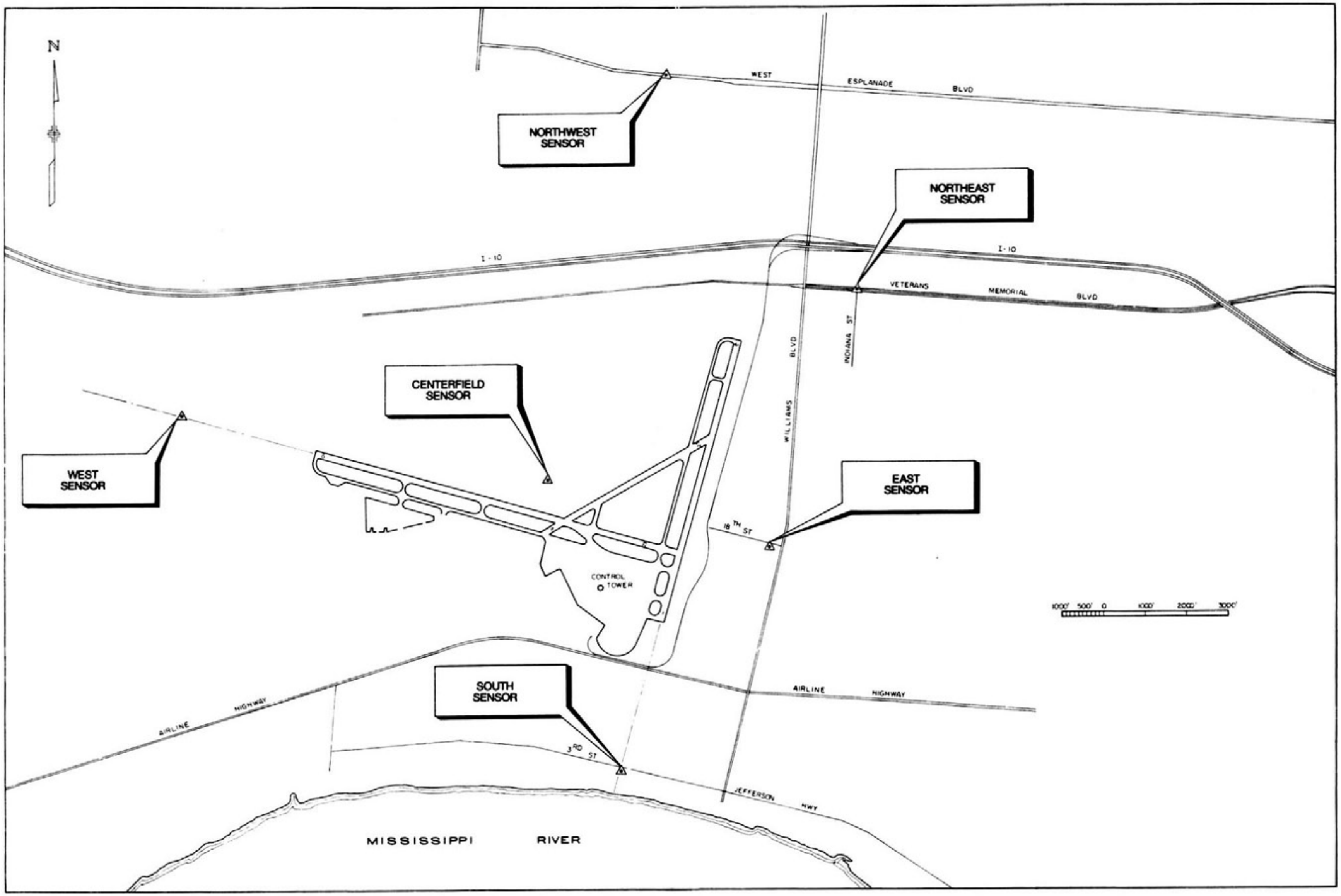

Figure 1.--Low Level Wind Shear Alert System at New Orleans International Airport.

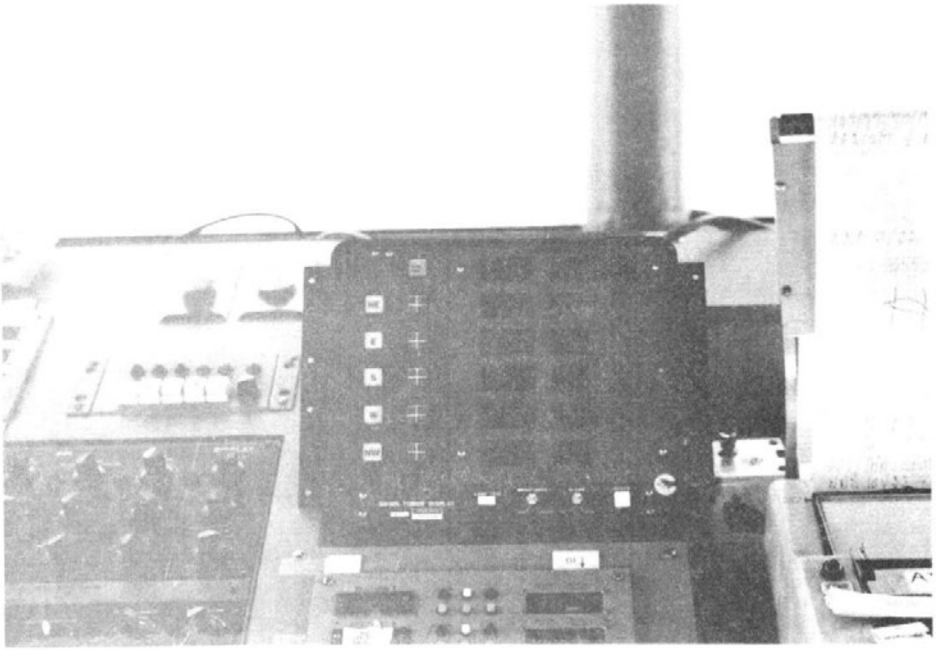

Figure 2.--Wind sensor display unit.

wind sensors is about 3 kms. 13/ Examination of the locations at New Orleans showed that, except for the spacing between the northwest sensor and the centerfield sensor (3.1 kms), the four other sensors were within 3 kms of the centerfield sensor. The manager testified that while uniformity of spacing between sensors is desirable, the location of these instruments is dictated by other factors. The sensors should be located where they will not be affected by terrain, trees, or other obstacles. In order to provide advance warnings to pilots, they should be located so that they can detect wind shears associated with weather systems which are moving toward the airport; therefore, in many cases they have been located outside the airport's boundaries. The FAA's program manager testified that although there were trees located to the north, east, and south of the east sensor, the sensors at New Orleans International Airport were located in accordance with established criteria and that there were no obstacles near any sensor that could affect their readings. He also noted that since weather systems can approach the airport from any direction, all sensors in the system are considered critical.

The LLWSAS was installed at the airport on August 30, 1979. Between September 1, 1979, and December 1979, the LLWSAS underwent testing and evaluation. The west sensor was part of the LLWSAS during this evaluation until November 15, 1979, when it was vandalized and rendered inoperative. On December 20, 1979, the LLWSAS was commissioned with the west sensor inoperative, and the west sensor remained inoperative until July 13, 1982, 4 days after the accident, when it was restored to service. (On July 20, 1982, the west sensor was again vandalized and rendered inoperative.)

13/ Kilometer, 1 km equals .54 nmi.

On July 9, 1982, the Automatic Terminal Information Service (ATIS) messages did not contain information indicating that the west sensor was inoperative. Paragraph 1222b of the FAA Handbook 7210.3F, Facility Operation and Administration states:

> b. When it is determined that a component or the whole LLWSAS has failed, take the following action:
>
> (1) If a component such as a remote sensor fails and the remainder of the system is functional, notify Airway Facilities. Inform users by broadcasting on the ATIS that the component is out of service.
>
> Example: "Low Level wind shear west boundary sensor out of service."
>
> (2) If there is a system failure rendering the LLWSAS unusable, notify Airway Facilities and NOTAM the system out of service.

According to the manager of the FAA's Terminal Procedures Branch, since the New Orleans LLWSAS was commissioned without the west sensor and since the west sensor did not become a component of the LLWSAS until July 13, 1982, the provisions of paragraph 1222b of FAA Handbook 7210.3F were not applicable at the time of the accident. The FAA's Aviation Weather System Program Manager testified that, given the circumstances of the accident, the effectiveness of the system was not reduced by the inoperative west sensor. However, he also testified that the system's overall effectiveness was reduced because "the airport is vulnerable from (weather) system encroachment from the west."

The LLWSAS has several limitations: winds above the sensors are not detected; wind shears beyond the peripheral sensors are not detected; updrafts and downdrafts are not detected; and if a shear boundary happens to pass a particular peripheral sensor and centerfield sensor simultaneously, an alarm will not occur. In addition, the dimensions of some meteorological phenomena -- downbursts or microbursts -- may be smaller than the spacing between the sensors and thus not be detected. The weather system program manager testified that "he would not expect a situation like that to occur and remain undetected for any long period of time." He said that if the downburst has strong downdrafts, the downward air turns horizontally as it approaches the ground and "a shear boundary is established. . . . you would expect that the weather would move out from its center point and eventually affect one of the sensors. It would be in fairly short order because the sensors are rather closely spaced."

According to the weather system program manager, the LLWSAS at New Orleans represents the state-of-the-art for this type of system. He stated that despite the limitations, the present system provides advisory information which "gives the pilot, in a timely fashion, additional information upon which to make a timely judgment on the approach to the airport or departure from the airport." However, he did not think that airplane operational limits could be developed based solely on information provided by the present LLWSAS. He testified that this information is advisory, an additional element of information upon which a pilot makes a judgment. He thought that it would be unwise "to base a go, no-go decision simply on the information received from the (LLWSAS) system."

At the time of the accident, there were 58 operational LLWSAS's in the United States. Except for the system at Stapleton Airport, Denver, Colorado, which was a data retrieval component of the Joint Airport Weather Survey Project (JAWS), none of these systems are equipped with data recording capability.

On July 10, 1982, the New Orleans LLWSAS was inspected by FAA technicians. All components of the system were operating within prescribed parameters.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 542 flight data recorder (FDR), serial No. 2641, and a Sundstrand V-557 cockpit voice recorder (CVR), serial No. 1832. The FDR and CVR were removed from the airplane wreckage and taken to the Safety Board's Washington, D.C., Laboratory to be examined and read out.

Although the exterior of the FDR was damaged substantially by impact forces and ground fire, the interior incurred only minor damage. The foil medium was removed from the recorder and magazine without difficulty. All parameters had been recorded in a clear and active manner, and there was no evidence of any recorder malfunction or abnormality. (See appendix E.)

The model 542 FDR scribes a continuous and permanent record of altitude, indicated airspeed, magnetic heading, vertical acceleration, and microphone keying on a metal recording medium. Correlation of the FDR data to GMT was accomplished by examining events common to the FDR data and the CVR and ATC transcripts. The FDR readout starts shortly after Clipper 759 was pushed back from its gate at the terminal and ends 10 minutes 3.3 seconds later when all traces became aberrant. The FDR's recording range, tolerances, resolution, and total stylus travel are depicted in table 3 below.

Because of the manner in which the FDR data were recorded and the airplane's relatively light initial impact with the trees, it was particularly difficult to correlate the timing of the FDR's scribed traces to each other. In order to insure timing accuracy, it was necessary to incorporate additional factual information into the interpretation of the FDR's scribed data. CVR, ATC, B-727 performance capabilities, and impact information were all used in evaluating the scribed FDR data.

The FDR readout showed that at 1607:57, the indicated airspeed began increasing and the vertical acceleration (G) trace became active.

About 1608:32, the altitude trace began to decrease. It continued decreasing at a fairly uniform rate until 1608:38 when the rate increased. At 1608:40, the trace reached its lowest point and then began to rise. The altitude trace showed that at 1608:54.5, Clipper 759 had climbed to 95 feet m.s.l., the highest altitude recorded. Thereafter, the altitude decreased and reached 0 feet m.s.l. at 1608:58.

The G trace remained essentially at or above 1.0 G until about 1608:47. Between 1608:47 and 1608:51, the trace decreased to 0.72 G's and remained at that value for about 4 seconds. Between 1608:55 and 1608:57, the trace increased from 0.73 G to 1.0 G.

Clipper 759 maintained a fairly constant magnetic heading of about 99° until about 1608:41. Thereafter, the airplane began a left turn, and at 1608:57, its magnetic heading was 92°.

A transcript of the CVR tape was made and begins before Clipper 759 was pushed back from its gate at the terminal and ends with the sound of impact at 1609:05. Using the time signal recorded on the FAA's ATC tape as a basis for comparison, the CVR tape timing was accurate to within 1 second over a period of 18 minutes 40 seconds.

Table 3.--Flight data recorder recording range, tolerances, resolution, and total stylus travel.

Parameter	Recording Range	Resolution	Tolerances	Total Stylus Travel This Flight
Pressure Altitude	-1,000 to 50,000 feet	20 feet	±100 ft sea level to ±700 ft at 50,000 ft	0.01 inch, from 0.167 inch to 0.177 inch with respect to the scribed reference line
Indicated Airspeed	0 to 450 knots	.6 knot	±10 knots	0.095 inch, from 1.757 inches to 1.852 inches with respect to the scribed reference line
Magnetic Heading	360 degrees	.2 degree	±2 degrees	0.836 inch, from 2.790 inches to 3.626 inches with respect to the scribed reference line
Vertical Acceleration	-3G to +6G	.015G	±0.2G	0.026 inch, from 4.260 inches to 4.286 inches with respect to the scribed reference line
Time	400 hours	.6 second*	±1% in an 8-hour period	The 10 minutes, 3.3 seconds of data contained in Attachment II was recorded on 0.998 inch of foil

*Based on average minute mark of 0.0992 inches per minute.

The recording from the cockpit area microphone (CAM) was distorted severely and had a high noise level. The recorder was examined at the manufacturer's facility in Redmond, Washington. Although the recorder tested satisfactorily, its erase head was inoperative. Consequently, a portion of previously recorded sounds and conversations remained as background noise on the tape. The mixture of this background noise with the newly recorded conversations produced a recording which contained high-pitch background sounds. In addition, the very loud sounds from the airplane's windshield wiper system during the takeoff roll further masked the distorted, low level, CAM sounds. (See appendix D.)

Most of the CAM sounds recorded before the windshield wipers were turned on were decipherable by filter adjustment and repeated listening. The final minute of the CAM transcript which was recorded after the wipers were turned on was prepared in the same manner. However, because of the poor quality of the recording, the CVR group could not reach a consensus concerning the content of sections of this final minute of the tape; therefore, these portions of the transcript are enclosed in parentheses.

The CVR transcript showed that while Clipper 759 was taxiing to runway 10, the captain and first officer reviewed rejected takeoff and fuel dumping procedures. At 1607:44, as Clipper 759 took the active runway for takeoff, the first officer asked, "Right or left turn after we get out of here?" At 1607:52, the captain said, "I would (suggest). . . .a slight turn over to the left."

At 1607:59, the first officer called for takeoff thrust, and at 1608:16, an unidentified flightcrew member called "(Eighty knots.)" At 1608:33, 1608:41, and 1608:43, the captain called "(Vr)," "Positive climb," and "(V2)," respectively. Correlation of the FDR and CVR data showed that at 1608:16, 1608:33, and 1608:43, Clipper 759's recorded airspeeds were 78 KIAS, 138 KIAS, and 158 KIAS, respectively. As stated earlier, the calculated Vr and V2 speeds for the takeoff were 138 KIAS and 151 KIAS, respectively.

At 1608:45, the captain said, "(Come on back you're sinking Don. . . .come on back.)" At 1608:57, the Ground Proximity Warning System (GPWS) activated and "Whoop whoop pull up whoop. . . ." was recorded. According to the FDR, at 1608:57, Clipper 759's recorded airspeed and altitude were 149 KIAS and 55 feet m.s.l., respectively.

1.12 Wreckage and Impact Information

Clipper 759 initially hit three trees located about 2,376 feet beyond the end of runway 10; the trees were oriented on a north-south axis. The swath angles through the trees indicated that the airplane struck the trees about 50 feet AGL in a 2° to 3° left-wing-down bank angle; pieces of airplane structure were found at the bases of these three trees. The airplane then struck a second group of trees located about 300 feet east of the first set of trees about 55 feet AGL in a 6° left-wing-down bank angle. Large segments of the left wing's leading edge devices and trailing edge flaps were found in the areas between the initial tree strike and the point where the left wing tip struck the ground. The airplane continued to roll to the left as it moved on an eastward track hitting trees and houses before coming to rest about 4,610 feet from the departure end of runway 10.

The airplane struck the ground in a left-wing-down bank of about 105° on a heading of about 089° M and was demolished during the impact, explosion, and subsequent ground fires. Except for the sections discussed herein, disintegration of the airplane's structure was so extensive that little useful information was obtained from postimpact examination of the wreckage.

Based on the positions of the applicable actuators, jackscrews, and actuator arms, it was determined that the landing gears were retracted, the trailing edge flaps were set at 15°, and the leading edge flaps and slats were extended. The horizontal stabilizer trim's jackscrew was intact and attached to its structure within the vertical stabilizer. However, the jackscrew had separated from the horizontal stabilizer and the ballnut was free to rotate; therefore, no useful measurement of the stabilizer trim position could be made.

One complete static discharge rod had separated from the trailing edge tip of the left horizontal stabilizer. This rod and portions of four additional discharge rods removed from the right horizontal stabilizer were analyzed at the Safety Board's Metallurgical Laboratory for evidence of lightning strike discharge. No evidence of localized arc burns was found on the rods, the attachment plates, or rod holders.

The EPR gauges, located on the pilot's center instrument panel, had been damaged by fire. The bug settings for the three engines were: No. 1 -- 1.92, No. 2 -- 1.98, and No. 3 -- 1.92. The gauges for the three engines indicated: No. 1 -- 1.50, No. 2 -- 2.90, and No. 2 -- 1.90. The three EPR gauge transmitters were removed from the airplane, sent to a FAA approved repair station, and examined under the supervision of a FAA maintenance inspector. The examination showed that all three transmitters indicated between 1.97 EPR and 2.0 EPR.

All three engines were found in the main wreckage area. The No. 2 engine was still attached to the airplane's empennage; the No. 1 engine and No. 3 engine had separated from their mounts. Damage to the engines indicated that all three engines were powered and rotating at impact. The engines were sent to Pan American World Airways' maintenance facility at John F. Kennedy International Airport, Jamaica, New York, where they were disassembled and examined under the supervision of the Safety Board. There was no evidence of any preimpact malfunction.

1.13 Medical and Pathological Information

All three flightcrew members sustained fatal injuries as a result of the accident. The pathological examinations disclosed no abnormal conditions and the toxicological tests were negative for alcohol, drugs, and carbon monoxide.

1.14 Fire

The airplane was subjected to severe ground fire.

1.15 Survival Aspects

The accident was not survivable because impact forces exceeded human tolerances.

1.16 Tests and Research

1.16.1 Heavy Rain Effects on Airplane Performance

The effect of rain on airplane aerodynamics has been an area of technical interest and speculation for years; however, only within the past 2 or 3 years have theories been developed regarding performance penalties, which quantify the hypothesized rain effects. The most definitive work in this area has been conducted by two research scientists of the University of Dayton Research Institute. Their research work was funded by the National Aeronautics and Space Administration (NASA) and the results were published in NASA Contractor Report No. 156885.

During the course of this accident investigation, the Safety Board examined the research data published by the research scientists, and then obtained the testimony of one of the senior research scientists who conducted the study to amplify further the data presented in these papers and reports.

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

Calculations have shown that the landing weight of a large transport type airplane operating under the most severe rainfall intensities would be increased no more than 1 percent to 2 percent. Since this increase in mass can be shown to have a negligible effect on airplane performance, this weight penalty is not considered significant.

The momentum penalty is considered to be more significant. An airplane flying in heavy rain will strike the raindrops in its path, thus causing the raindrops to accelerate to the velocity of the airplane. This process extracts energy from the airplane, causing the airplane to decelerate. The momentum penalty is dependent on the following factors: (1) airspeed, (2) rainfall rate, (3) raindrop size, (4) size distribution, (5) water content of the air; and (6) airplane configuration. With leading and trailing edge lift and drag devices, the airplane is intercepting more raindrops, and therefore the penalty is more severe when the airplane is in the landing or takeoff configuration. According to the senior research scientist, this penalty becomes significant at rainfall rates "approaching" 500 mm/hr. At those rates, the rainfall could reduce airspeed at a maximum rate of about one-half knot per second.

The most significant of the penalties is the aerodynamic penalty resulting from the formation of a water film on the surface of the wing, thereby roughening its surface. The senior research scientist indicated that the hypothesized roughness penalties originated in an experimental program conducted to determine the effects of frost roughness on airfoil lift and drag. These experiments for fixed elements which indicated that significant increases in drag and decreases in the stall angle of attack could occur for small amounts of roughness led to speculation that rain could roughen the surface of an airfoil and produce similar detrimental effects. The roughness can be attributed to the following factors: waves or ripples that form in the film because of wind stress action; raindrops that strike the film and crater the surface of the film; and a combination of waves and craters. The depth of the film, the waves, and the craters were measured and related to an equivalent sand grain roughness which was then used to determine the lift and drag penalties. The senior research scientist testified that the penalties for cratering and waviness "both turned out to be approximately of the same significance. We think that either one of these sources can give you increases of drag in the range of 10 to 20 percent and decreases in lift of 10 percent at lower angles of attack, depending of course on rainfall rate." He testified that the lift penalty increases as the angle of attack increases; therefore, the stall angle of attack will be decreased, and under certain conditions, aerodynamic stall could occur before the stall warning system could activate. The senior research scientist testified that the onset of significant roughness penalties would occur in a rainfall rate range of 150 mm/hr to 500 mm/hr.

The senior research scientist testified that the detrimental effects of roughness could be attributed to a change in boundary layer flow (the fluid layer adjacent to the airfoil surface). The surface roughness would cause the boundary layer to transition prematurely from smooth laminar flow to turbulent flow. This turbulent flow would produce an increase of skin friction drag, and due to the extraction of energy from the flow, would cause the flow to separate earlier than normal from the airfoil. He also testified that premature flow separation caused by the increased boundary layer friction coefficient would also occur for an entirely turbulent boundary layer on a high speed airplane. The senior research scientist testified that he was not aware of experimental work that showed that roughness in a turbulent boundary layer could cause mixing with high energy free stream air thereby delaying the detrimental separation effects.

The performance values cited in these studies were obtained totally by a theoretical analysis with no experimental wind tunnel or flight data supporting the results. Further, during the analysis of the momentum and roughness penalties, assumptions and extrapolations were made in order to equate the depth of the waves and the cratering of the water film surface to an equivalent sand grain roughness. While these assumptions and extrapolations appear to be both reasonable and conservative, their validity has not been determined positively; therefore, NASA Report No. 156885 included the following prefatory statement:

> The conclusions stated herein are those of the contractor and are not necessarily those of NASA. They are being published to direct attention to the problem of heavy rain and the aerodynamic performance of an aircraft.
>
> The theory proposed herein contains certain assumptions and extrapolations because suitable data do not exist. Because of this, the results and conclusions reported herein are in question. They are published, however, in the hope that other researchers will be inspired to suggest and to try new theoretical approaches and experimental programs to obtain needed verifications.

According to the testimony of the chief of NASA's Low Speed Aerodynamics Division Chief, NASA has reviewed the data contained in the rainfall study. Based on this review, NASA has concluded that there is not enough data to determine whether the estimates postulated therein were either reasonable or unreasonable. However, the NASA division chief believed that the results obtained during these early experiments warrant additional investigation under more controlled conditions.

According to the NASA official, the testing will have to be done in a wind tunnel. Flight test would be too dangerous. In order to find rain rates of the nature required, the airplane would have to be exposed to the possibilities of encountering hail, extreme turbulence, and other hazards. Since he did not think it was safe to consider a flight test, the alternative was to conduct multiple small scale wind tunnel tests. He testified that he thought that "we will see in the very near future several efforts underway to conduct small scale testing. But I think somewhere in the program we will have to come up with a scale of a test that is large enough to give us the confidence to say that we are there with the answer."

The NASA official also testified that although sand grain roughness tests did result in decreased lift and stall angle of attack, as stated by the senior research scientist, there were other cases in which roughness energized the boundary layer and produced beneficial results. Therefore, conclusions regarding roughness effect on an airfoil boundary layer need to be verified.

1.16.2 Joint Airport Weather Study Project

On September 17, 1982, the co-director of the Joint Airport Weather Study Project (JAWS) testified at the Safety Board's Public Hearing at Kenner, Louisiana, as to the status of the project and the results obtained to date.

The JAWS project was conducted under the auspices of the National Center for Atmospheric Research. The primary objective of the project was "to examine the basic and applied aspects of low level wind shear in the aviation context." The basic study areas were: space and time scales of thunderstorm wind events, origin and evolution of wind shear, structure of wind shear events, dynamic forcing of thunderstorm downdraft 14/ events, and the relationship between microburst and thunderstorm structure.

The following three areas of study have been undertaken concerning aircraft performance: (1) theoretical studies of aircraft performance in wind shear; (2) manned flight simulator tests of theoretical wind model studies; and (3) research flights with instrumented airplanes in thunderstorm environments.

The field or data collection phase of the project began May 15, 1982, and ended August 13, 1982. Consequently, the project co-director could only provide details as to how the data were obtained, the equipment used to obtain these data, and highlights of the project based on a preliminary survey of the raw data.

The field phase of the JAWS project was concentrated geographically around Stapleton International Airport, Denver, Colorado, and lasted 91 days. The most important of the data gathering tools was the pulse Doppler radar. Doppler radar can measure the velocity of the scatter echo of precipitation and other aspects of the atmosphere; it measures any component of motion perpendicular to the direction of its antenna. Three Doppler radars were located in a triangular array in the vicinity of Stapleton.

In addition, Doppler Laser Infrared Radars (LIDAR) were collocated at two of the pulse Doppler radar sites. The Doppler LIDAR radar has the same capability to measure motion as the pulse Doppler radar; however, it uses laser beaming instead of microwave pulsation to accomplish its function. Doppler LIDAR radar can measure precipitation and dust motion; however, it cannot penetrate cloud or fog, and it cannot perform in a perfectly clear atmosphere.

14/ Downdraft (downflow): a downward flow of air in the atmosphere.

Numerous ground instruments were positioned throughout the Stapleton area to complement the radars. These surface instruments measured and recorded wind speed and direction, rainfall, temperature, humidity, and pressure. Among these surface instruments was a pressure jump array system which measures and attempts to use rapid pressure fluctuations as a means of identifying wind shear.

The Stapleton LLWSAS, which has recording capability, was also included in the JAWS data gathering system. The average spacing between this LLWSAS's peripheral wind sensors and its centerfield wind sensor is about 6 km. A mesonetwork of portable wind sensors was also installed to provide additional surface wind data. The average spacing between the mesonetwork's sensors was about 3 kms.

Four airplanes were used in the data gathering process. One airplane, a Hawker Sidely HS-125, was equipped with three airborne wind shear detection systems: a ground air speed measuring and comparison system; a Smiths Industry Vertical Speed Energy Rate Indicator (VS/ERI); and forward looking Doppler LIDAR radar which measured the longitudinal component of the wind ahead of the airplane -- it provided about a 6-second "look - ahead" time. The project co-director testified that the HS-125 had flown about 30 hours in the wind shear conditions; however, the data had yet to be analyzed. Consequently, no firm findings or conclusions as to the effectiveness of these systems have been made.

The principal focus of the wind shear aspect of the program was the microburst. The microburst, fundamentally, is a simple atmospheric flow. It is a downdraft that upon reaching the surface must spread out horizontally producing a diverging radial flow in all directions. An airplane traversing the burst at a low height above the ground will encounter increasing headwinds as it enters the microburst, remnants of the downdraft near the center, then increasing tailwinds as it departs the area (see figure 3). According to the co-director, microbursts have been occurring for a long time; however, they were not identified until about 1977. In addition, because the microburst is so small and short-lived, it has been difficult to address scientifically and technologically.

The data obtained during the JAWS project have enabled its researchers to make some preliminary conclusions concerning the microburst. Data developed to date indicates that the microburst winds become significant when its diameter reaches about 1.6 kms to 1.8 kms. When the diameter reaches 4 kms, the winds begin to become insignificant again. During the project, outflow diameters which exceeded 4 kms were called downbursts. The co-director noted that, based on preliminary airplane performance work, when the outflow diameter exceeded 4 kms it is "less likely to be severe (as regards) aircraft performance. So we think the microburst is the feature we are most interested in the aviation context."

According to the co-director, the largest differential horizontal wind velocity measured was 80 knots. Although horizontal wind velocities of 40 to 60 knots were measured in many microbursts, there were many others within which the differential wind velocities were much weaker. The research data indicated that the average differential velocities observed in the stronger microbursts were about 50 knots.

The vertical velocities in 15 microbursts were measured by flying through their vertical shaft at heights of 2,000 feet AGL and 1,000 feet AGL. Airplane safety considerations precluded fly-throughs below 1,000 feet AGL. The co-director testified that "typically at 2,000 feet we are getting about 20 meters per second or 40 knots;

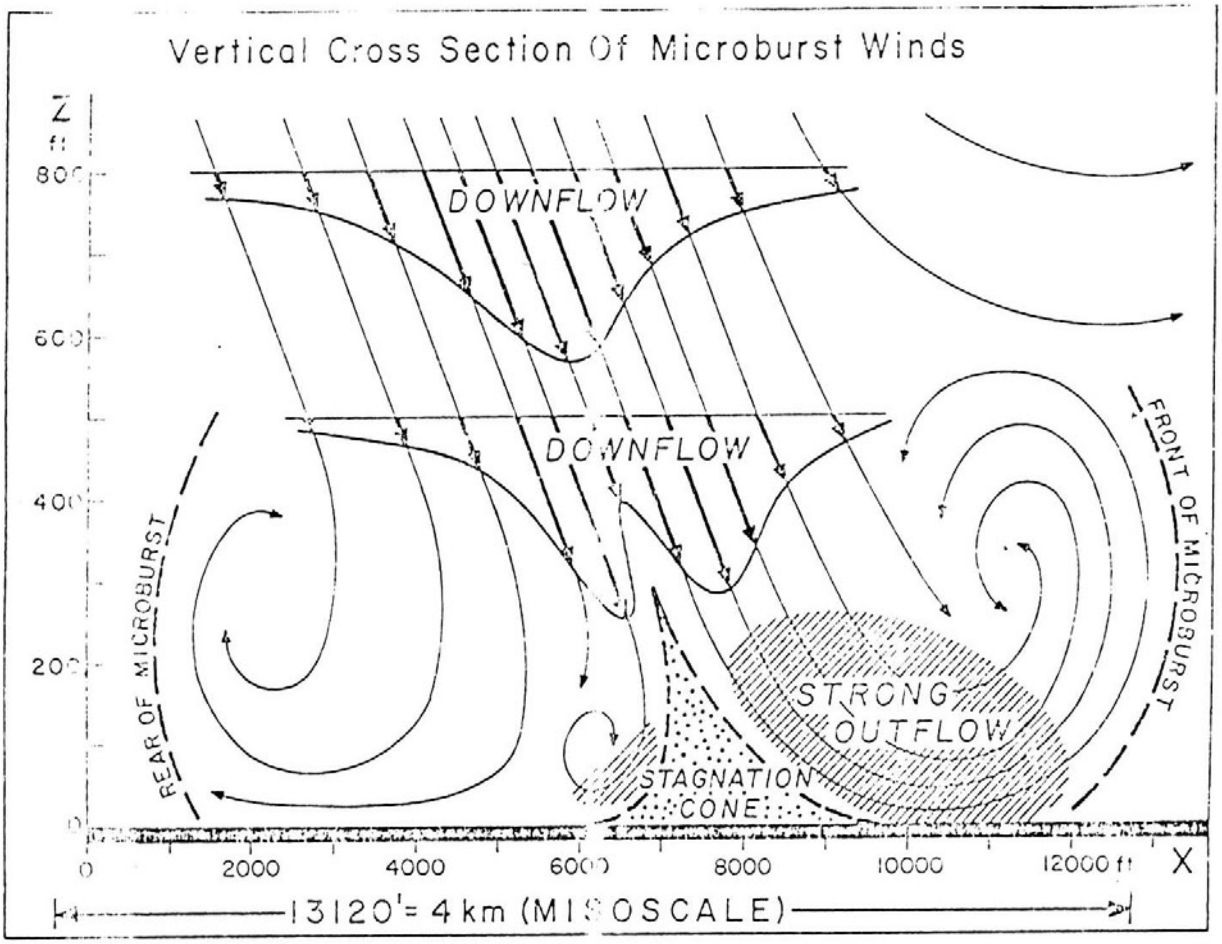

Figure 3.--Vertical cross-section of a microburst.
("Microburst Wind Shear at New Orleans International
Airport, Kenner, Louisiana, on July 9, 1982." p. 30, Dr. T. Theodore Fujita.)

at 1,000 feet it was down to 10 meters per second, or 20 knots." The co-director testified that although they had made "observations" of vertical velocities below 500 feet and 200 feet AGL, it was premature to address these observations in a quantitative sense.

During the JAWS project, the researchers attempted to correlate wind shear occurrences with rainfall rate and storm intensity. The project co-director testified that the "relationship is zero." The microburst appeared to be just as likely "to occur in a little or no-rain situation as in a heavy rain situation." He testified that the larger and more severe the thunderstorm becomes, the more likely it will be to produce a gust front. The preliminary data appears to indicate that there is no relationship between storm intensity and microburst generation.

The project demonstrated that the spacing between the LLWSAS's sensors at Stapleton (6 kms) was too great to capture the microburst on a regular basis. The LLWSAS did see the diverging outflows, but only after they reached a size to which the LLWSAS was capable of responding. The mesonetwork with a 3-km sensor spacing was more successful in seeing the microburst. The co-director thought that the LLWSAS could be improved by increasing the number of sensors and decreasing the distance between them.

The researchers have not yet evaluated the data from the pressure jump array system.

The co-director stated that the researchers believe that in a microburst, the horizontal outflow increases as the downdraft approaches the ground, and that the maximum horizontal winds occur at about 75 feet AGL. However, he could not provide any data as to the magnitude of the downdraft component that existed below 500 feet AGL.

The co-director testified that in the Denver area, "we had lots of microbursts with (horizontal wind) velocities of 50 knots or greater. Why do airplanes not crash all the time? The answer to that, in our opinion, is that the space time window for a microburst is very small. You have to encounter it below 500 feet, it is very small, (and) it doesn't last very long. Whereas they were fairly common in summer, you have to be in the wrong place at the wrong time to get in trouble."

The project co-director testified that while microbursts are common in Denver, they did not have any data concerning the frequency of their occurrence elsewhere. However, he thought "microbursts are rather common. If you go east and south from Denver, you are more likely to find microbursts imbedded in thunderstorms and less likely to have dry microbursts that you have in the west." He believed that the JAWS data, particularly as it related to detection and warning, was applicable anywhere. The microburst flow is "a simple, straight-forward flow, it is going to happen the same in Florida when a downdraft gets near the ground as it will in Denver."

1.16.3 Wind Analysis

Analyses of the surface and low level winds that might have existed on the New Orleans International Airport near and at the time of the accident were provided to the Safety Board by the National Oceanic and Atmospheric Administration (NOAA) and Pan American World Airways (Pan Am). The NOAA analysis, 15/ conducted at the request of the Safety Board, was based on its evaluation of large-scale meteorological patterns, Geosynchronous Operational Environmental Satellite (GOES) data, weather radar data, Clipper 759's FDR data, and a detailed examination of eyewitnesses' accounts of the weather.

The examination of the satellite data, weather radar data, and precipitation patterns showed storm cells in the vicinity of New Orleans International Airport at the time of the accident. Analysis of the weather radar data, in particular, showed a VIP level 3 echo directly over the airport at the time of the accident. Analysis of the radar data showed that between 1558 and 1614, the shape and action of the VIP level 3 echo over the airport was similar to those observed in association with microbursts in other research studies.

The outflow from the level 3 cell over the airport was too small to be detected by either the satellite or radar photography. Therefore, the magnitude and shape of the outflow was determined from the eyewitnesses' account of the weather and the airplane performance calculations based on Clipper 759's FDR data.

The NOAA analysis concluded that the available data "suggests that (Clipper) 759 flew through the center of a convectively generated downdraft shortly after lift-off. An analysis of the flight recorder data strongly supports the conclusion that the downdraft was a weak to moderate microburst." The analysis showed that Clipper 759 flew through "an adverse wind shear of 39 knots," and that the maximum downflow was 7 fps at 100 feet AGL. The analysis did not compute the location of the center of the microburst through which Clipper 759 flew; however, based on the eyewitnesses' accounts, the analysis suggested that it probably centered just north of the intersection of runways 10 and 19.

The analysis conducted for and funded by Pan Am 16/ showed that a microburst had impacted the airport and was in progress between 1608 and 1610. The center of the microburst was about 2,100 feet east of the LLWSAS's centerfield sensor and about 700 feet north of the centerline of runway 10. (See figure 4.) The Pam Am microburst was centered about 1,300 feet and on about a bearing 294° M from the center of the NOAA microburst.

The Pan Am analysis stated that the wind disturbance which affected Clipper 759 was "too small to be depicted by either satellite or radar photographs which were produced operationally." In order to perform an analysis of this small scale wind system, an iterative technique based on equations of motions was used. The technique required that assumptions of pitch attitude and wind components be made and compared to measured airplane performance and the constraints established by the physical evidence of the accident sequence. The assumed windfield of the microburst was also subjected to the constraints imposed by equations of continuity and weather data recorded and observed at the airport during the relevant time period.

15/ "Multi-Scale Analyses of Meteorological Conditions Affecting Pan American World Airways Flight 759" by F. Caracena and R. Maddox, NOAA, Environmental Research Laboratories, Boulder, Colorado, January 1983.
16/ Dr. T. Theodore Fujita, "Microburst Wind Shear at New Orleans International Airport, Kenner, Louisiana, on July 9, 1982." January 12, 1983.

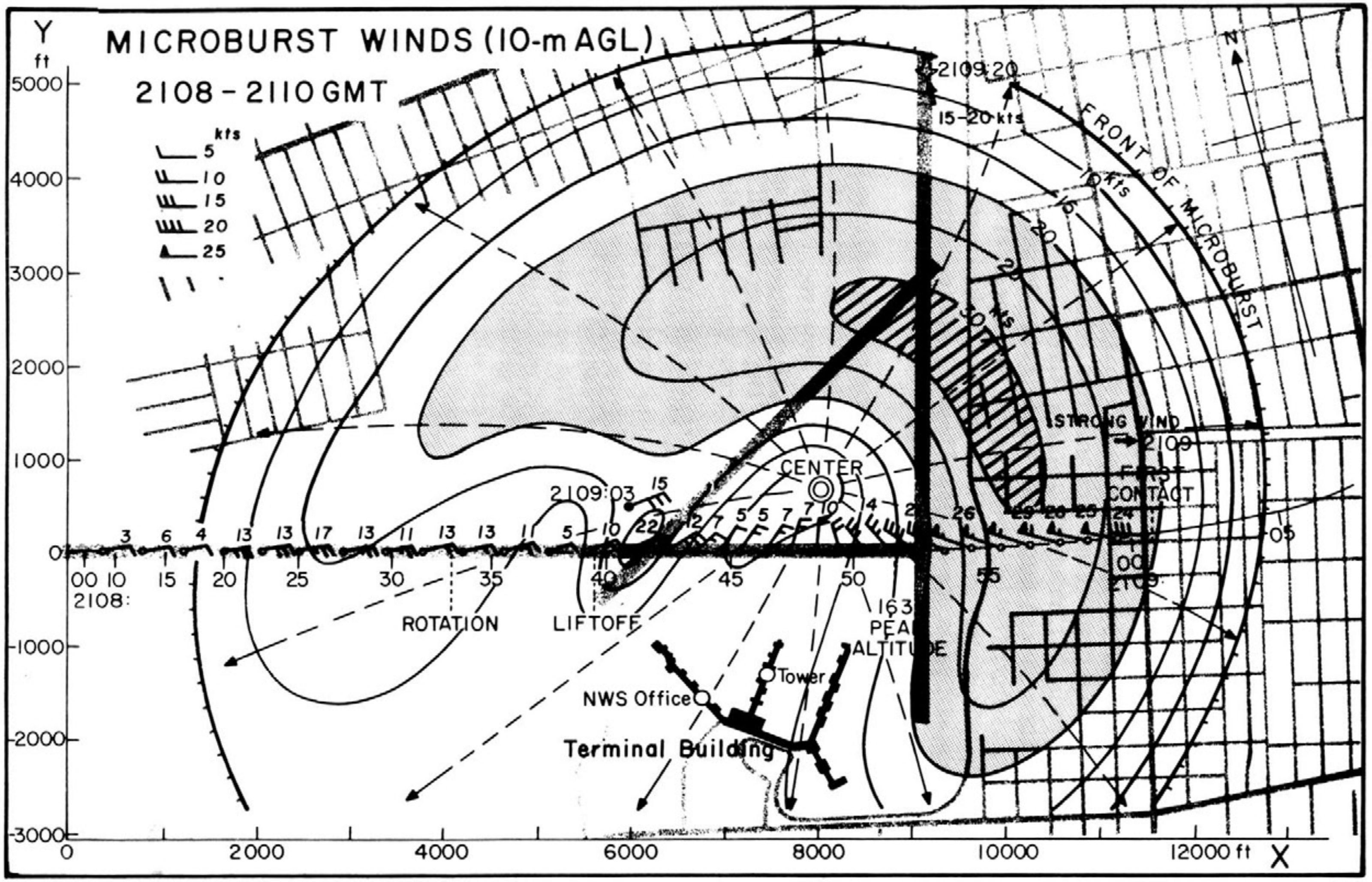

Figure 4.--Windfield of the microburst over the New Orleans International Airport (Moisant Airport) at the time of the accident. All wind speeds with barbs are reduced to the 30 ft (10 m) height above the runway with 0 to +1 ft elevation. Microburst was moving towards the northeast accompanied by strong west winds near the accident site and 15 to 20 knots southerly wind at the departure end of runway 19. (Page 28, "Microburst Wind Shear at New Orleans International Airport, Kenner, Louisiana, on July 9, 1982," Dr. T. Theodore Fujita.)

The computations used for this analysis showed that: (1) Clipper 759's maximum altitude of 163.2 feet AGL was reached at 1608:15, and the minimum altitude of 50.7 feet AGL was reached at 1609:00.2; (2) Clipper 759 had a 12° noseup pitch attitude and was climbing at 361 fpm when it hit the first tree; (3) the maximum headwind and tailwind encountered was 17 knots and 31 knots, respectively; (4) the maximum downflow speed was 7 fps or 4.1 knots; and (5) Clipper 759's pitch attitude gradually increased to 13° noseup, then decreased to 5° noseup before increasing again to 12° noseup.

1.16.4 Airplane Performance Analysis

The NOAA and Pan Am wind analyses indicated that Clipper 759 flew through a microburst and encountered, in rapid succession, an increasing headwind, a downdraft, and then a decreasing headwind (increasing tailwind). To analyze the effects of these rapidly changing winds on the flightpath of an airplane, the following forces which act on the airplane must be considered: lift, drag, weight, and thrust. In a dynamic situation, changes in the lift and the drag are most significant because they depend at any instant on the airplane's relative wind vector; that is, the direction and speed of the impinging air stream relative to the airplane's control axes. The airplane's weight can be considered a constant since it varies only as fuel is consumed. Thrust is related primarily to throttle position and to a lesser extent on airspeed and the properties of the engine inlet air.

The analysis is simplified by resolving the components of these forces along the airplane's vertical and longitudinal axes. As long as the components of the forces are balanced, the airplane will remain in unaccelerated flight. However, if the forces become unbalanced either by the pilots manipulation of the throttles or flight controls or by a change in the environment surrounding the airplane, the airplane will accelerate or decelerate until a new flightpath is established and the forces are again balanced.

When the airplane flies into a vertical wind, the angular change in the direction of the total wind vector, with respect to the airplane's path relative to the ground, changes the angle of attack which causes a change in both lift and drag. If the vertical wind's direction is downward, angle of attack is reduced and the lift and drag will decrease causing the airplane to accelerate downward. The basic stability of the airplane will cause it to pitch up initially; however, the ultimate effect on the airplane's flightpath will be an increase in the descent rate relative to the ground. If the flight controls remain fixed, the airplane will restabilize in the air mass which is now descending with respect to the ground. Thus, the change in the airplane's rate of descent relative to the ground will equal the vertical speed of the wind and, if longitudinal wind does not change, the airspeed will remain approximately constant. The pilot can compensate for this condition by increasing the airplane's pitch attitude and by adding thrust to establish a climb relative to the descending air mass. He will thereby maintain the desired flightpath.

When an airplane flies into an area where the direction of the horizontal wind changes abruptly, the indicated airspeed will change. The change is equivalent to the abrupt change in the relative wind. Both lift and drag will also change abruptly and thus produce an imbalance in the forces acting along the airplane's longitudinal and vertical axes.

If the airplane flies into an increasing headwind, the relative wind will increase. The indicated airspeed, lift, and drag will increase; the airplane's nose will pitch up; and the vertical speed will change in the positive direction. If the wind speed continues to change, the airplane will appear to have a positive increase in performance. When the wind speed stabilizes, if thrust has not been changed, the longitudinal forces will be unbalanced because of the increased drag. The airplane will decelerate and eventually will return to equilibrium at its original airspeed. When equilibrium is regained, however, the airplane's speed relative to the ground will have been changed by the amount of change in the longitudinal wind component.

If the airplane flies into a decreasing headwind, the effect will be the opposite. The indicated airspeed will decrease, lift will decrease, the airplane's nose will pitch down, and the vertical speed will change in the negative direction.

As illustrated above, passage through either a downdraft or a decreasing headwind can be singularly hazardous; however, when combined, the two conditions produce an even more critical situation. A microburst contains both a downdraft and a decreasing headwind. The severity of the effects produced by an encounter of this type will depend on the magnitude of the changes in wind speeds and the abruptness with which these changes occur. Obviously, the higher the speed changes and the shorter the time interval involved, the greater the effect on the airplane's flightpath.

At the Safety Board's request, the Boeing Company analyzed the information from Clipper 759's FDR to determine the probable horizontal and vertical wind velocities affecting its takeoff performance. The computations performed during this analysis were based on the following general assumptions: the weight and configuration of the airplane at takeoff; the weather conditions at New Orleans at the time of takeoff; engine and airplane performance parameters derived from Boeing Company documentation; the elapsed time and distance between brake release and initial impact of 63.9 seconds and 11,524 feet, respectively. The thrust levels used from brake release to initial impact were those expected from average in-service engines. Finally, although the examination of the EPR transmitters after the accident indicated that the engines' thrust had been increased above the takeoff thrust setting during the departure, the effect of a thrust increase above the 1.92 EPR takeoff thrust setting was not considered during these computations.

A fundamental problem in the analysis of the segment of the flight beginning with airplane rotation and ending at initial impact was the design limitations of the foil type FDR installed on Clipper 759. Data concerning flight control inputs, engine thrust inputs, longitudinal acceleration, and airplane pitch angles were not recorded. As a result, data that would have furnished precise measurements depicting pilot energy management techniques during the takeoff flare maneuver and throughout the remainder of the flight were not available. Therefore, assumptions concerning these data were required in order to solve the equations of motions relevant to this analysis.

The analysis was divided into three segments: ground roll to rotation; the takeoff flare maneuver which included rotation, liftoff, and climb to 35 feet AGL; and the flight from 35 feet AGL to initial impact at 50 feet AGL. Thirteen cases were developed during the analysis to explore the variations in airplane performance resulting from the fast and slow rates of rotation; the different rates of climb between liftoff and 35 feet AGL; and the different altitude - time histories from 35 feet AGL to initial impact. In order to insure that the airborne segment of the flight was completed within the distance constraints imposed by the physical evidence of the accident sequence, different ground speed assumptions were required. Comparison of the theoretical performance produced by these assumptions with the airplane's FDR's measured performance parameters yielded the speeds of the horizontal and vertical wind components along the airplane's flightpath.

Ground Roll to Rotation.--The ground roll to rotation phase was identical in all 13 cases. Takeoff groundspeed and distance from brake release to Vr was determined from equations of motion. A time history of horizontal wind during the takeoff ground roll was computed by taking the difference between the airplane's computed groundspeed and the FDR's indicated airspeed corrected to true airspeed. These computations showed that the horizontal wind along Clipper 759's takeoff path began as an increasing tailwind, switched from an 8-knot tailwind to a headwind of 8 knots at about 2,600 feet (27.5 seconds from brake release), then diminished to a 4-knot headwind at Vr (4,560 feet and 37 seconds from brake release).

Rotation, Lift Off, and Climb to 35 Feet AGL.--Because of possible variations of pilot energy management techniques during rotation and the climb to 35 feet AGL, the actual airplane flightpath during this phase of the flight could differ with respect to time. Therefore, the 13 cases analyzed herein contain a range of possible assumptions which, based on experimental flight test data or energy-work computations for a circular flightpath, were consistent with possible variations of pilot technique and airplane performance capabilities.

The horizontal winds affecting this part of the flight were derived by comparing the ground speed from rotation to 35 feet AGL with the true airspeed; the analysis assumed that vertical winds did not exist below 35 feet AGL.

Thirty-Five Feet AGL to Initial Impact.--The 13 time-histories of vertical and horizontal wind components and airplane pitch attitudes for the flight from 35 feet AGL to impact were derived from computations using airplane equations of motion in conjunction with known and assumed quantities. Since the variations of the takeoff flare maneuver resulted in the airplane reaching the 35 feet AGL point at different times, ground distances, and ground speeds, the remaining segment of the flight had to be structured in a manner which satisfied the remaining altitude, distance, and time constraints to the point of initial impact. Two methods were then used to construct altitude-time histories which met the above constraints. In cases I through VIII, the altitude-time histories were structured to resemble the shape of the FDR's pressure altitude trace with a peak altitude of 100 feet AGL and tree contact at 50 feet AGL. In cases IX through XIII, the altitude-time histories were established by integrating the FDR's vertical acceleration data. The integration procedure used in cases IX through XIII produced altitude profiles which reached 160 feet AGL; however, the 50 feet AGL height of initial tree impact could not be obtained using these methods. Therefore, these altitude profiles were adjusted downward from their peak values to coincide with the known impact altitude.

The ground speed assumptions for each of the 13 cases were made in order to satisfy the distance and time constraints between the point the airplane reached 35 feet AGL and the initial impact point.

Pitch attitude calculations were made possible when the solution of the airplane's equations of motion produced a value for the rate of climb relative to the air (R/Cair). Calculations could then be made to estimate the pitch attitude of the airplane at any point during the flight.

The analyses of these 13 cases showed that the horizontal wind changed from a headwind or slight tailwind at 35 feet AGL to an increasing tailwind which then diminished slightly before initial contact with the trees. The vertical wind increased from a slight downdraft at 35 feet AGL to a maximum downdraft as the airplane reached 100 feet AGL; the downdraft then diminished as the airplane descended and approached the impact point. The maximum horizontal wind changes -- cases I, II, and III -- ranged from 2.6 knots to 3.4 knots per second over a 10-second to 15-second period. The maximum vertical wind component -- cases IV, VII, and IX -- ranged from 60 to 70 feet per second at about 100 feet AGL to 120 feet AGL. Computed pitch angles ranged from peak values of 25° noseup -- cases IV, VII, and IX -- to minimum values between 5° noseup and 10° noseup for the rest of the cases.

The performance analysis also determined that Clipper 759's stall speed (Vs) and stickshaker speed (Vss) were 122 KIAS and 138 KIAS, respectively.

1.17 Other Information

1.17.1 Air Traffic Control Procedures

During the time period relevant to the accident, both the ground and local control positions in the New Orleans International Airport's tower were manned by developmental controllers. 17/ Both developmental controllers were monitored by controllers who were fully qualified at the respective positions. The controllers conducting the training were wearing headsets and could override the developmental controllers' transmissions at any time such action was required. The training and the manner in which the training was being administered was in accordance with the procedures contained in the applicable FAA Handbooks and General Notices (GENOTS).

The New Orleans TRACON is equipped with Air Surveillance Radar type 8 (ASR-8), and the antenna is located on the airport. The TRACON has Automated Radar Terminal Service III (ARTS III) capability. The tower cab has a Bright Radar Indicator Tower Equipment type IV (BRITE IV) display and a diagonal Conrac display. 18/ The two tower displays repeat the displays shown on the TRACON's radarscopes. Although the ASR-8 radar is primarily designed to display air traffic to controllers, the equipment will show precipitation echoes; however, it does not have the capability to differentiate between various levels of precipitation. The same limitation also applies to the tower's BRITE and Conrac displays.

The five controllers in the tower either stated to investigators or testified that it was raining on the airport when Clipper 759 departed. The senior controller in charge of the tower said that he saw that weather was being painted in the center of the BRITE scope; however, he said, "it didn't appear significant enough to affect aircraft operations." The five controllers said that the weather at the time of the accident was typical of thunderstorm weather which occurred during a summer day at the airport. NWS data showed that during the past 17 years there was an average of 13.47 days in July wherein thunderstorms occurred at the airport.

According to the TRACON chief, the tower controllers are qualified to take visibility readings and provide wind shear information from the airport's LLWSAS. They may describe precipitation as heavy or light, but they are not certified weather observers.

17/ A qualified air traffic control specialist who is being trained for a new position or procedure for career development.

18/ A black and white television repeater manufactured by the Conrac Corporation, Stamford, Connecticut.

ATIS Procedures.--According to paragraph 1230b(3) of FAA Handbook 7210.3F, "Facility Operation and Administration," ATIS broadcasts shall be updated upon receipt of any new official weather regardless of whether there is a change of values. "Make a new recording when there is a change in other pertinent data such as runway change, instrument approach in use, new or canceled NOTAM's, SIGMET's, PIREP's, etc."

At the time Clipper 759 taxied from the terminal gate, ATIS "F" was the current message. ATIS "F" was issued at 1358:50 and reflected the 1355 surface weather observation. The 1455 surface weather observation was issued and received in the tower cab at its electrowriter terminal. While the weather on this observation was essentially the same as the 1355 weather, the remarks section noted, "cumulus buildups overhead east to south." At 1555, another surface weather observation was received in the tower and was followed at 1603 by a special weather observation. At 1604:45, ATIS "G" was issued and reflected the 1603 special weather observation which noted in its remarks section "low level wind shear in all quadrants. . . ."

According to facility procedures, the ground controller is responsible for updating the ATIS messages. The ground controller, who was monitoring the developmental controller at that position, testified that an ATIS message should have been issued when the 1455 weather observation was received. It was not. When questioned as to why it was not issued, he testified, "It is just an oversight, basically."

The supervisory ground controller testifed that the tower did not issue an updated ATIS message when it received the 1555 observation because the visibility observed from the tower differed from that contained in the 1555 weather observation. The controllers advised the weather station of the variance and then waited for the corrected observation. The next observation received was the 1603 special, and this was included in ATIS "G". The Pan American Systems Manager for Flight Standards was asked, "In your estimation, is there any other weather information that the crew of Clipper 759 could have been given but. . . .wasn't?" He answered, "They were given all the NWS information that was available. There was no SIGMET's issued pertinent to the departure. So it was not that they were missing any weather information. They were given, according to ATC testimony, the wind shear alerts that existed at the time they were taxiing out. An updated ATIS might have been more valuable, but I really don't think that that was an operational factor here. If there was additional data on the magnitude or location of the. . . .echoes that were being observed by the Slidell site or the Houston center weather coordinator, this may have been of some value."

Dissemination of LLWSAS Information.--The procedures for dissemination of information derived from a LLWSAS are presented in paragraph 981 of FAA Handbook 7110.65C, Air Traffic Control. Paragraph 981 reads, in part, as follows:

> 981. LOW LEVEL WIND SHEAR ADVISORIES
> At those locations equipped with Low Level Wind Shear Alert System, the local controller shall provide wind information as follows. . . .
> a. If an alert is received, issue the centerfield wind and the displayed field boundary wind.
> 981.a. Example.--
> "Centerfield wind, two seven zero at one zero. East boundary wind, one eight zero at two five."

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 in accordance with 980.b. followed by the field boundary wind most appropriate to the aircraft operation.

981.b. Example.--

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

Thus, according to the FAA Handbook 7110.65, the local controller is responsible for disseminating LLWSAS information. Examination of the ATC transcripts of the New Orleans tower's ground and local control positions showed that both the ground and local controllers had provided wind shear advisories to airplanes during the time period relevant to the accident.

The developmental controller working the ground control position and the controller supervising his performance both stated in their original interviews that the ground controller was required to provide LLWSAS advisories. During the public hearing, the supervisory ground controller contradicted his earlier statement. He testified that he could not speak for the developmental controller, but his statement had been misconstrued. He testified that it was not the responsibility of the ground controller to issue LLWSAS alerts "it is the local controller's responsibility." He added, "I personally, if I considered it advantageous to the pilot, I would give it (Wind shear alert). . . .I cannot speak for ground controllers at Moisant. But as I said, it is mandatory actually by local control."

Between 1602:33 and 1609:03, three wind shear alert advisories were issued by ground control:

1602:33	(To Cessna Citation N31MT) Winds zero six degrees at one five, peak gust two five, low level wind shear alert at northeast quadrant three three zero degrees at one zero, northwest quadrant one three zero degrees at three.
1603:36	(To Clipper 759) Winds now zero seven zero degrees at one seven, peak gust. . . .two three, and we have low level wind shear alerts all quadrants. Appears to be a frontal (sic) passing overhead right now, we're right in the middle of everything.
1609:03	(To Delta Flight 169) Taxi to runway one niner, wind zero eight zero at one five, low level wind shear from the northeast two two zero at four; from the east three one zero at six; from the south one six zero at three. . . .

The supervisory ground controller issued these three advisories because, at the time, the developmental controller was "cutting" a new ATIS message.

The supervisory ground controller recalled his remarks about "frontal passage," and "right in the middle of everything." He testified that it was "an off the cuff type remark. I am not a meteorologist. It was just to advise them that you can expect certain conditions when a frontal (sic) is passing." With regard to his second remark, he testified, "I was referring to the fact that I was looking at the main bang (the center) of the radar for a different purpose, but I noticed that the main bang was surrounded by ground clutter which indicated a lot of rain right there at the airport."

The supervisory ground controller also noted that "low level wind shear data is given out when it occurs. It is not always constant. It would be no factor to them such as telling an aircraft as soon as they are on the frequency that it exists and they won't be ready for departure for five and six minutes later, there would be no longer a use for that."

Examination of the transcript of the local control position showed that four wind advisories were transmitted. Three of these advisories -- at 1602:08, 1604:11, and 1604:28 -- were based on readings from the LLWSAS display in the tower; the fourth -- at 1607:10 -- was generated by a PIREP received from a landing B-707.

The first three advisories were issued to Texas International Flight 794. At 1602:05, Flight 974, while awaiting takeoff clearance from runway 19, requested a wind check. At 1602:08, the developmental local controller answered, "Centerfield wind zero five zero at one five gusting to two five, northeast quadrant wind three two zero at one zero, northwest quadrant wind one three zero at four." (The vector differences between the centerfield wind and the northeast and northwest quadrant winds were over 15 knots.)

At 1604:06, Flight 794, after being cleared for takeoff, requested another wind check, and at 1604:11, the developmental local controller answered, "Centerfield wind zero six zero at one six, all quadrants lightening (sic) up an amount of wind shear." At 1604:28, the developmental local controller broadcast, "No wind shear registering in south quadrant," and at 1604:33, Flight 794 answered, "Okay, Texas (unintelligible)."

The developmental controller working the local controller position was being monitored by the senior controller in charge in the tower cab. The senior controller testified that the developmental controller made most of the transmissions before the accident, but that he made most of the transmissions thereafter.

At 1607:10, the tower's clearance delivery issued a clearance to a helicopter and informed the pilot that the current weather was "measured ceiling four thousand one hundred overcast, two miles in heavy rain showers and haze, and the wind is zero seven zero degrees at sixteen, wind shear all quadrants, gusting to twenty knots. . ." The clearance was delivered by a flight data specialist who had "plugged in" to the clearance delivery position just before issuing the clearance.

The flight data specialist who issued the clearance said that he had been on his coffee break but remained in the tower cab while off duty. He said that the traffic level had increased and he "plugged in" to assist the on-duty flight data specialist at the clearance delivery position. He was positioned between the clearance delivery and ground control positions and his 15-foot long headset cord allowed him to move about the tower cab. (See figure 5.) He stated that the LLWSAS's aural alert can be heard throughout the entire cab; however, he could not see the LLWSAS's display wind readouts

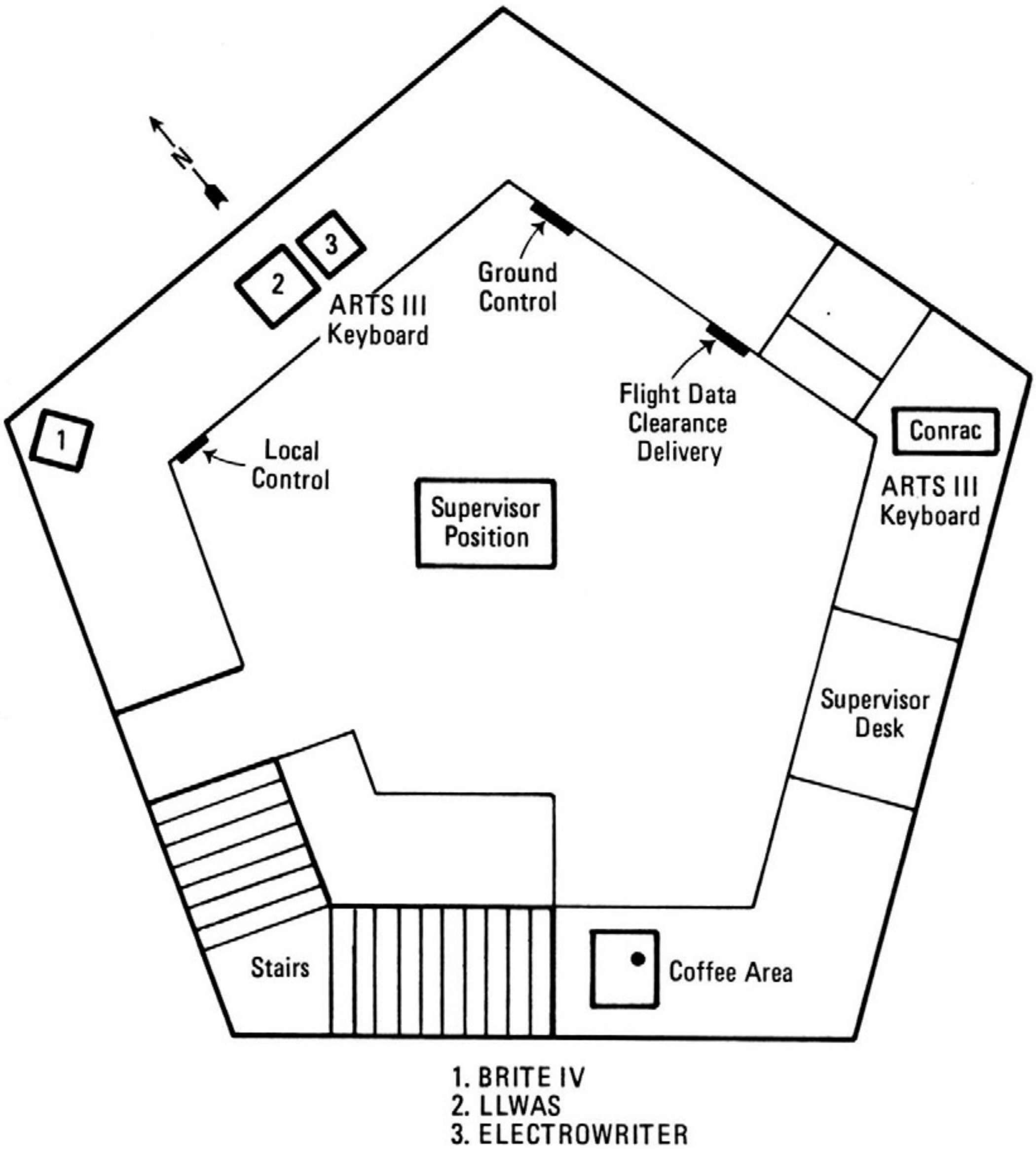

Figure 5.—New Orleans International Airport tower cab layout chart.

or visual flashing alerts without moving from the clearance delivery console. He also said that centerfield wind information was available at the ground controller's console. These gauges are connected to the NWS wind sensor which is adjacent to the LLWSAS's centerfield sensor.

The flight data specialist stated that the weather contained in the clearance he gave the helicopter was taken from the electrowriter terminal on the ground control console. He stated that the wind shear advisory was based on his observations and what he had heard in the tower cab before he "plugged in" at the clearance delivery console; he did not look at the LLWSAS display nor did he recall hearing a wind shear alert while he was delivering the clearance. Except for the gust value, the wind speed contained in the clearance was different from that reflected on the electrowriter weather transmission. The flight data specialist stated that he could not remember whether he got the wind speed fom the gauges on the ground control console or from the LLWSAS display.

According to the senior controller, the LLWSAS display was configured to present both an audio and visual alert. He testified that the volume of the audio alert could be adjusted; however, he did not know if the audio alert feature could be eliminated.

The senior controller testified that it was not tower policy for the ground controller to provide wind shear advisories and that, even if ground control had broadcast a wind shear alert, the local controller also would have transmitted the LLSWAS alert to an airplane. He testified that when Clipper 759 was cleared for takeoff, there was no LLWSAS alert in progress; therefore, an LLWSAS advisory was not issued to the flight. He also testified that he could not recall a pilot refusing a takeoff solely on the basis of a LLWSAS advisory.

In addition to the LLWSAS alerts, two PIREP's were received concerning wind shear. According to the Airman's Information Manual (AIM), which is not a regulatory publication, a PIREP concerning a wind shear encounter should include the amount of indicated airspeed either gained or lost, and the altitude at which the airspeed excursion occurred. The AIM recommends that pilots who cannot report wind shear in these specific terms should describe the effect the shear had on his airplane. For example, "Gulfstream 403 Charlie, encountered an abrupt wind shear at 800 feet on final, max thrust required." At 1600:13, N58RD, a B-707 heavy, after landing on runway 10, informed local control, "Eight R D, you got a ten knot wind shear on one zero at two hundred feet." According to the senior controller, the developmental controller "wasn't exactly familiar with how to relay this information. . . ." to landing airplanes. Therefore, when Eastern Flight 956 reported inbound over the outer marker, he took over the radio and at 1607:10 transmitted to the Eastern flight "the wind zero seven zero at one seven, heavy DC eight or heavy Boeing just landed said a ten knot wind shear at about a hundred feet on the final." Flight 956 thanked him for the information.

At 1602:17, Republic Flight 632, after contacting departure control, reported "we had a wind shear on the runway." Departure control replied, "I understand." This PIREP was not relayed to the tower cab and the local controller. According to the departure controller, he made "a statement in the TRACON in a loud voice that Republic reported a wind shear on the runway." He did not relay the information to the local controller because the tower had LLWSAS display which depicted that data to the tower controllers and the local controller would be relaying the LLWSAS wind information to arriving and departing traffic.

With regard to providing LLWSAS advisories, the senior controller testified, "If there was a wind shear at the time he was ready for takeoff, he is going into position, starts taking off, rolling, there is a wind shear, he is going to get it." He also testified that if the LLWSAS alert had occurred 3 to 4 minutes earlier and no longer existed when the airplane was ready for takeoff, he would not provide the airplane with a wind shear alert advisory.

Convective Weather Advisories.--At 1510, the CWSU meteorologist at the Houston ARTCC advised the New Orleans tower of level 4 and 5 thunderstorms located south and southwest of the airport. The senior controller testified that the recipient of the phone call briefed him on its contents and that he verified that this information had been relayed to the team supervisor in the TRACON.

The senior controller testified that after he received this weather information, he looked at his BRITE IV display in the tower. The BRITE display was operating in the 20-nmi range configuration and, "At that time there was no evidence of any severe level 4 or 5. Again our radar doesn't show levels of intensity or the fact that there are even thunderstorms, just areas of precipitation. At that time, there was no significant indication of what (the) center had just passed to us, that it was within 20 miles of Moisant, not to my experience." The senior controller also testified that there was no "weather reading radar" in either the tower or TRACON.

According to the senior controller, the advisory from the Houston ARTCC "is passed to us for planning purposes, anticipating deviation requests from pilots for different routes, and so forth." It also alerts them to the possibility of a failure of commercial power and to be ready "to turn on standby power equipment."

The senior controller testified that there was no requirement to relay the weather information from Houston to the pilots. The only weather data they are required to relay were SIGMET information and hourly and special weather observations; the hourly and special weather observations are provided to the pilots "on the ATIS."

The senior controller said that SIGMET's are received on the Flight Data Entry and Printout (FDEP) terminal in the TRACON. The team supervisor is responsible for insuring that each position in the facility receives the SIGMET and that each position broadcasts the SIGMET once.

Procedures for handling SIGMET's are presented in paragraph 1220, FAA Facility Handbook 7210.3F, and paragraph 41 of the ATC Handbook. Paragraph 1220 requires the facility to establish procedures to insure that SIGMET information is collected and disseminated promptly. The facility is authorized to select which SIGMET information is pertinent to its area and then disseminate the selected information to other terminal ATC facilities within "your terminal area."

Paragraph 41 of the ATC Handbook requires that the selected information be broadcast on all frequencies once as a SIGMET alert. It establishes guidelines for this requirement and the procedures and formats for the broadcast.

1.17.2 Pan American World Airways Performance Requirements and Flight Operation Procedures

Pan American World Airways' (Pan Am) performance requirements and flight operations procedures are presented in Pan Am's Flight Operations Manual (FOM), the 727 Aircraft Operating Manual (AOM), and the Route and Airport Manual (RAM).

On January 19, 1980, National Airlines, Inc. was merged with Pan Am. During the merger, the flightcrew procedures of both airlines were reviewed by Pan Am. These procedures were compared and revised where applicable; the resultant procedures were incorporated into the present Pan Am FOM and AOM. Thereafter, crossover training was conducted for the former National flightcrew personnel to familiarize them with the contents of the revised manuals.

Dispatch Procedures.--The evidence showed that Clipper 759 had been dispatched from Miami in accordance with Pan Am's dispatch procedures.

According to the Pan Am operations agent at New Orleans, Clipper 759's captain and first officer came into the operations office while the flight was on the ground in New Orleans. The operations agent prepared the flight folder for the flightcrew. When the folder was complete, both he and the captain signed the teletype copy of the dispatch release which had been transmitted to New Orleans by the Miami dispatch office. According to the dispatch agent, his signature on the teletyped release form signified that "all the information requested for the flight (New Orleans to Las Vegas) has been assembled and is present and accounted for." In addition to the release form, computer flight plan, and a preliminary load sheet, the flight folder prepared in New Orleans contained the 1415 Gulf Coast and Pacific State Surface Aviation Weather Reports and the 1425 Southwestern States Surface Aviation Weather Reports.

The operations agent testified that additional weather information was displayed on clipboards mounted on a carousel on the operations office's counter and that these data were available for flightcrew review. In addition, the electrowriter terminal and ATIS radio receiver were on the same counter and both were operating so that the flightcrew could obtain the data required to prepare their takeoff computation form.

The operations agent said that the office received the New Orleans surface weather observations on the electrowriter from the weather station, on the weather circuit teletype machine, and over the ATIS receiver. The teletype copy of these observations is also placed on the appropriate clipboard which is then placed on the counter carousel. According to the operations agent, it was the office's practice to "retain it on the carousel for two hours." The agent was asked, "if the 1455 weather sequence was never put on the ATIS, would the crew have obtained the information in any event merely by referring to the carousel?" He answered, "Yes."

Takeoff Procedures.--Pan Am's RAM presented the runway weight information for takeoff at New Orleans International Airport. Based on the data contained on Clipper 759's takeoff computation form and on the RAM's runway weight information chart for New Orleans International Airport, runway 10 was the only runway available to Clipper 759 for takeoff. Also, according to the runway weight information chart, runway 10 was obstacle limited. The limiting obstacle was a tree 78 feet high, 2,250 feet east of the departure end of the runway, and 200 feet to the right of the extended centerline of the runway.

As set forth in the AOM, the procedures call for the flying pilot to ease off the brakes and advance the throttles smoothly to the vertical position. "This will produce about 1.40 EPR. Allow the engines to stablize, then check for balanced EPR." Thereafter, the flying pilot will advance the throttles to near takeoff EPR, call for takeoff thrust, and the flight engineer will trim the engines to the takeoff EPR setting. The nonflying pilot is required to make the 80 knots, Vr, V2, and positive climb callouts. "If V1 and Vr are different, V1 must be called also."

The rotation maneuver should be a smooth continuous pitch change to the V2+10 climb attitude. Therefore, the AOM recommends, "At Vr rotate smoothly to the target climb attitude. The airplane should reach the target climb attitude and V2+10 simultaneously." The AOM recommends that after liftoff and during the initial climb, the pilot monitor the airspeed and "adjust the pitch attitude to maintain V2+10, to a maximum of 18 degrees nose up (pitch attitude)."

The AOM states that horizontal wind gradients and vertical wind components are not figured in takeoff gross weight calculations, but they have a significant effect on the airplane's performance over the ground. The AOM presents the following warning notes to the flightcrews:

> If significant wind shear is suspected, consider the alternatives of taking off in a different direction or delaying the takeoff until conditions are more favorable.
>
> If shear is suspected and the takeoff is not obstacle limited, a speed in excess of V2+10 may be used for the initial climb to provide additional protection from decreasing headwinds or downdrafts.

Weather Avoidance and Wind Shear Information.--Pan Am's FOM and 727 AOM also present information and guidance to flightcrews concerning wind shear and convective weather. The Meteorology section of the FOM contains a discussion of wind shear and the LLWSAS.

The material concerning the LLWSAS is essentially limited to a description of the system, how it functions, and the type report to be expected from controllers at airports with a LLWSAS. Except for noting that the system is "primarily designed to indicate the presence of horizontal wind shear," the discussion does not describe the other limitations of the system. However, the discussion of the system's capabilities does inform the flightcrew that the lowest, or minimum, wind vector difference required to produce a LLWSAS alert is 15 knots. The FOM states that the LLWSAS wind information "is strictly informational and no action is required unless deemed appropriate by the pilot."

A detailed description of thunderstorms and the wind conditions generated by these storms is also included in the FOM's Meteorology section. These data include a description of the rain cold front or gust front and the conditions associated with this phenomenon. The description of the conditions associated with the gust front states, in part:

> A surface wind shift often accompanies the gust front but may lead the front by up to 5 miles. The gust front moves faster that the thunderstorm from which it was created and may lead the thunderstorm radar echo by 5 to 10 miles.
>
> Vertical wind shears of 10 knots per 100 feet extending from the surface to several hundred feet above the ground may occur just behind the nose (of the gust front).
>
> Horizontal wind shears of 40 knots per mile have been measured while crossing perpendicularly through the gust front, and the shear may be even greater in thunderstorm squalls.

The FOM also notes that, "At large airports the tower may be unaware of gust front activity in the approach or departure corridor and winds which are vastly different from those reported by the tower could be encountered."

Neither the FOM nor the AOM contain any description of microbursts or downbursts and the weather conditions associated with these two phenomena.

The Severe Weather Avoidance section of the FOM contains Pan Am's severe weather avoidance policies. The FOM states, in part, "the following precautions should be observed in avoiding turbulence, wind shear, and hail associated with thunderstorm activity:"

1. Departure and Arrival

   When significant thunderstorm activity is approaching within 15 miles of the airport, the captain should consider conducting the departure or arrival from a different direction or delaying the takeoff or landing. Use all available information for this judgment, including pireps, ground radar, aircraft radar, tower reported winds, and visual observations. Gust fronts in advance of a thunderstorm frequently contain high winds and strong vertical and horizontal wind shears, capable of causing an upset near the ground.

   A gust front can affect an approach corridor or runway without affecting other areas of the airport. Under such conditions, tower-reported winds and the altimeter setting could be misleading.

The Normal Operation, Landing section of the Pan Am 727 AOM lists five weather conditions that indicate the possibility of wind shear during the approach; one of these conditions listed is, "Thunderstorm in the immediate vicinity of the airport." The AOM then presents a detailed description of the effects a decreasing or increasing headwind shear may have on airplane performance during a landing approach and the recommended pilot techniques to counter the effects of these types of shears should they be encountered. Although it is not stated explicitly in the AOM, these shears would produce a similar effect on airplane climb performance during takeoff; consequently, portions of this part of the AOM presentation are relevant to the takeoff regime. The AOM states, in part, that the initial airplane reaction to a decreasing headwind (or increasing tailwind) is a drop in airspeed and a loss in altitude. "It is important that the pilot promptly add thrust and increase pitch to regain airspeed and glidepath. Do not consider 18 degrees a pitch limit in this case."

<u>Airplane Weather Radar System Procedures</u>.--The AOM contains recommended procedures to obtain the optimum performance from the Bendix RDR-1-E weather radar. According to the AOM, the radar may be operated in normal mode during taxi and should be used to analyze surrounding weather conditions before takeoff. This search is usually made using a 150-nmi to 180-nmi range. The AOM also recommends that the 30-nmi range be used to analyze local weather before takeoff. The manual states that the target return should be optimized by manipulating the antenna tilt. "A one half degree change in tilt can produce significant changes in target definition." The contour mode may be selected to provide additional information concerning the intensity of precipitation echoes.

Vertical scanning of storms is described as important particularly before takeoff and during climbout, and the AOM states, in part, "Echoes received at high angles of antenna tilt during low altitude flight indicate the presence of mature storms. . . ."

The AOM also discusses the effect of attenuation stating, in part, "Very light rain may be undetected; but interposed between the airplane and a distant weather target, it produces scattering and attenuation of the radar signal in transit, both out and back. This often causes distant weather targets to fade or disappear temporarily when light rain lies in the path of the radar beam."

During the public hearing, a Pan Am Regional Chief Pilot and the Systems Director of Flight Standards described the use of the airplane's weather radar system before takeoff. The chief pilot testified that after the airplane was aligned with the takeoff runway, the flightcrew "would have tilted the antenna up 5 to 7 degrees or so to get out of ground clutter. . . .and scan the area."

The director of flight standards testified that, according to Pan Am policy, "The crew is instructed to turn the weather radar on while taxiing out, to scan the departing area, particularly vertically by using up (antenna) tilt and to make a decision on takeoff based on their analysis of the aircraft weather along with a myriad other factors we have already discussed."

1.17.3 **Wind Shear Training**

FAA Advisory Circular.--On January 23, 1979, the FAA issued Advisory Circular, AC 00-50A, "Low Level Wind Shear," which contains descriptions of the low level wind activity generated by weather fronts, thunderstorms, and the outflow pattern produced by a "downburst cell." The Circular contains precautionary measures to avoid wind shear and flight techniques to counter wind shear effects. Since there was no weather front near New Orleans at the time of the accident, our summarization of the material herein has been limited essentially to low level wind shears associated with convective type weather and the effect of wind shear on takeoff performance.

The Circular states that wind shear can be found on all sides of a thunderstorm cell, in the downdraft directly under the cell, and in the wind shift line or gust front ahead of the cell. This gust front can precede the actual storm by 15 nmi or more; therefore, the Circular concludes "if a thunderstorm is near an airport of intended takeoff or landing, low level wind shear hazards may exist."

The Circular warns that "Airplanes may not be capable of safely penetrating all intensities of low level wind shear. Pilots should, therefore, learn to detect, predict, and to avoid severe wind shear conditions. Severe wind shear does not strike without warning. It can be detected. . . ." The Circular cautions pilots to be alert for the possibility of wind shear in the departure or arrival areas if thunderstorms are observed or forecast at or near the airport, and to examine the approach or takeoff area with the airplane's radar to determine if thunderstorm cells are in the vicinity of the airport. A departure or approach should not be flown through or under a thunderstorm.

The Circular also urges pilots to utilize the LLWSAS at the airports, where available, to assess the potential for wind shear. An example of severe wind shear alert would be the following: "Centerfield wind is 230 degrees at 7 knots; wind at north end of runway 35 is 180 degrees at 60 knots." In this case, a pilot departing on runway 35 would be taking off into an increasing tailwind condition that would result in significant losses of airspeed and consequently altitude.

Thereafter, the Circular presents a detailed discussion concerning airplane performance in wind shear. It describes the effect of a downdraft on the airplane's angle of attack, and states,

> When an airplane flies into a downdraft, the relative wind shifts so as to come from above the horizon. This decreases the angle of attack, which in turn decreases lift, and the airplane starts to sink rapidly. In order to regain the angle of attack necessary to support the weight of the airplane, the pitch attitude must be significantly increased. Such a pitch attitude may seem uncomfortably high to a pilot. The wing produces lift based on angle of attack -- not pitch attitude. Caution should be observed when a pilot has traversed a downdraft and has pitched up sufficiently to stop the sink rate. If that pilot does not lower the nose of the airplane quickly when it exits the downdraft, the angle of attack will become too large and may approach the stall angle of attack.

The Circular notes also that jet transport manufacturers have pointed out that their airplanes still have substantial climb performance (generally in excess of 1,000 fpm) at speeds down to stall warning or stickshaker speed (Vss). Boeing performance data indicate that a B-727-200, at 185,000 pounds with all engines operating, at sea level, and at standard day conditions can produce, at Vss, about a 1,300 fpm rate of climb. 19/

The Circular presents the effects of an energy trade -- airspeed for altitude or altitude for airspeed -- in a low level wind shear. It states, in part:

> Trading Altitude for Speed: A pilot caught in a low level wind shear who finds he is slower than the normal airspeed (even though he has gone to max power) could lower the nose and regain speed by trading away altitude. . . .However, data shows that the penalty for doing this is severe; i.e., a large sink rate is built up and a great deal of altitude is lost for a relatively small increase in airspeed. Therefore, at low altitudes this alternative becomes undesirable. It is preferable to maintain the lower airspeed and rely on the airplane's climb performance at these lower speeds than to push the nose over and risk ground contact. . .
>
> Trading Speed for Altitude: Conversely, a pilot caught in a low level wind shear may pull the nose up and trade speed for altitude. . . .If the speed is above V2 or Vref 20/ (as applicable) then this trade may well be desirable. If at or below V2 or Vref such a trade should be attempted only in extreme circumstances. In doing so the pilot is achieving a temporary increase in climb performance. After he has traded away all the airspeed he desires to trade, he will then be left with a permanent decrease in climb performance. In addition, if ground contact is still inevitable after the trade, there may be no airspeed margin left in which to flare in order to soften the impact. Wind shear simulations have shown, however, that in many cases trading airspeed for altitude (down to Vss) prevented an accident.

19/ Boeing Airliner Magazine, January 1977, "Hazards of Landing Approaches and Takeoffs in a Wind Shear Environment," Page 15.
20/ Vref is 1.3 stall speed (Vs). V2 is 1.2 Vs.

However, there are difficulties associated with flying at or near Vss. According to the Circular, these include:

(1) The pilot often does not know Vss.

(2) The stickshaker mechanism may be miscalibrated. . . .

(3) The downdraft velocity may vary, which requires a change in pitch attitude to hold speed.

(4) It is hard to fly a precise airspeed in turbulence which is often associated with wind shear.

(5) Turbulence might abruptly decrease the airspeed from Vss to Vs.

(6) Pilots have historically had little training in maintaining flight at or near Vss.

The final sections of the Circular are devoted to procedures for coping with wind shear encounters during takeoff and landing. According to the Circular, "The worst situation on departure occurs when the airplane encounters a rapidly increasing tailwind, decreasing headwind, and or downdraft. Taking off under these circumstances would lead to a decreased performance condition. . . ." since it will cause a decrease in indicated airspeed. The airplane will initially pitch down "due to decreased lift in proportion to the airspeed loss." The pilot techniques recommended in the Circular to counter the effects of this type wind shear on takeoff require the pilot to trade airspeed for altitude. On encountering the shear, the pilot should apply maximum rated thrust, rotate the airplane to high noseup pitch attitudes -- "15° to 22° are to be expected during this maneuver" -- and, if necessary to prevent an unacceptable descent rate, maintain the noseup pitch attitude even though the airplane decelerates below V2. The speed tradeoff should be ended when the stickshaker is encountered. Thereafter, the airplane should be flown at a pitch attitude that will maintain an indicated airspeed just above stickshaker speed. The Circular notes, in part, that, "Postaccident studies have shown that, under similar circumstances, had flight techniques of an emergency nature (such as those outlined above) been used immediately, the airplane could have remained airborne and the accident averted."

The Pan Am director of Flight Standards testified that the company reviews all FAA Advisory Circulars and "almost exclusively adopt them into the aircraft operating manual. . . .or the flight operations manual. We don't issue the advisory circulars, per se, to the airmen because we want the airmen's attention to be focused on the Pan American manual system so that there is a single source document and not a myriad of loose advisory circulars. But we insure that the thrust and intent of the advisory circular is incorporated into the manual." He testified that Pan Am accepted and incorporated in their manuals and training procedures the data contained in circular AC00-50A.

Training Courses.--Beginning in 1977, Pan Am presented "Wind Shear," Course No. WSR, to all flightcrews in their annual recurrent ground training course. The presentation defined wind shear, reviewed the causes of this event, and included methods of forecasting wind shear. It also detailed airplane reaction to wind shear and presented corrective measures to counter the effects of wind shear. From 1980 to July 31, 1982, this course was not presented to the flightcrews; however, during the latter half of 1981, the Pan Am ground training course included a review of five accidents and the review included "wind shear procedures." The flightcrew of Clipper 759 saw this program.

In addition, the director testified that the company safety magazine "Cross Check," which is distributed to all flightcrews, published 20 articles in recent years "regarding wind shear encounters, (and) accident reports of aircraft that have been involved with wind shear."

The flightcrew of Clipper 759 were former National Airlines personnel. National Airlines, before it merged with Pan Am, included a slide/tape presentation "Hostile Environment" in its annual ground training program. The program, which was begun in 1978, presented wind shear data to its flightcrews, wind shear effects on airplane performance, and recommended pilot techniques to counter wind shear effects. The Pan Am chief pilot, who had occupied the same position with National Airlines before the merger, testified that the National Airlines B-727 AOM contained procedures concerning a wind shear encounter during departure, and that the procedure suggested "taking off with a little higher than normal speed if obstructions and so forth would allow that. It also suggested pulling the airplane up to something less than normal climb-out airspeed in an effort to stop the sinking situation. The procedure is relative to the wind shear circular that came out. It is almost verbatim to that procedure that is spelled (out) in that."

<u>Simulator Training</u>.--In 1975, National Airlines programmed their B-727 flight simulators to provide wind shear training. According to the chief pilot, "The wind shear program that was inserted in the former National Airlines simulators was (a) 180 degree change in wind direction over a 6-second period and (the magnitude of the wind) was at the discretion of the check airman."

The wind shear exercise was not graded, it was "purely for schooling purposes." Therefore, the check airman, although not always, quite frequently warned the flightcrews that they were going to receive a wind shear during a certain part of the simulator flight. This demonstration was given as part of the flightcrew member's recurrent simulator training in lieu of a proficiency check and "this particular exposure would have been given to them once a year."

According to the chief pilot, the wind shear exercise could have been conducted on an approach and landing, on a departure, or on both. During the exercise, the check airman evaluated the flightcrew's ability to recognize the type of wind shear encountered and to take appropriate and timely action to counter the effects of the wind shear.

According to National Airline's training records, the captain of Clipper 759 flew a wind shear training exercise during his recurrent simulator training in 1979. There is no requirement for the first officer to receive "hands on" wind shear training in the simulator, and there is no record that he did.

Pan Am's B-727 flight simulator training program is conducted in a manner similar to the manner in which National's was conducted. Since the maneuver is not a graded item and since no entries are made in the airman's training folder to denote that he has accomplished the maneuver, Pan Am's training personnel could not state whether either the captain or first officer of Clipper 759 had performed this maneuver during their last recurrent simulator training periods.

The Pan Am director of flight standards was asked if the company provided recommended flight techniques to counter a decreasing headwind shear during departure. He testified, "The wind shear procedures as described in Pan Am's aircraft operating manual for the 727, as a matter of fact, for all our airplanes, notes that when encountering decreasing headwinds. . . .the pitch (angle) should be increased, to whatever pitch and power are required. Those are the words that are in the manual, whatever pitch and power are required." He testified that the simulators were programmed to provide this training "when shear became a known operational factor in airline operation in the 1970's."

1.17.4 Low Level Wind Shear Detection Systems--Air and Ground

Ground Detection Systems.--The FAA has been involved in the testing and development of ground based wind shear detection systems since 1972. The LLWSAS's in operation at 58 airports in the United States represented the state-of-the-art at the time of the accident. However, the FAA has tried to improve this system since its inception.

In 1980, a pressure jump array system was integrated with the LLWSAS at Hartsfield International Airport, Atlanta, Georgia. Because of the lack of necessary weather conditions, the results were inconclusive. Therefore, the FAA decided to reevaluate the pressure jump system during the JAWS project. According to the manager of FAA's Systems Research Aviation Weather Branch, one problem with the pressure jump system is "false alarms. The system goes off without wind shear."

Beginning in the early 1970's, the FAA tested acoustic, laser, frequency-modulated and pulse Doppler microwave systems for use in wind shear detection systems. The acoustic Doppler system propagates sound waves vertically into the atmosphere to extract low level wind velocities. This system did not meet the FAA's reliability standards. In addition to the transmitted noise, it was very sensitive to other noise. Airplane noise, high wind velocity over the receivers, and even bird sounds would distort the signal.

Laser Doppler systems were found to be range-limited and their capabilities were further decreased by low visibility environments such as fog, clouds, and heavy rain. Frequency-modulated microwave Doppler systems also appeared to be range-limited.

The pulse Doppler microwave radar was evaluated during the JAWS project; additional data concerning the performance of this system was collected at the National Severe Storms Laboratory (NSSL) at Norman, Oklahoma, and at five other pulse Doppler radar sites in the United States. Based on the evaluation of the data collected to date, FAA's weather research branch manager testified that the pulse Doppler microwave radar system is now the chief candidate for use as a low level wind shear warning system and as the Next Generation Radar (NEXRAD).

The weather research branch manager testified that, for aviation purposes, the FAA wants the NEXRAD to (1) monitor air traffic airspace from 6,000 feet m.s.l. to 70,000 feet m.s.l. throughout the continental United States and in Alaska, Hawaii, and Puerto Rico; and (2) to measure low level shear in precipitation out to 30 nmi from the antenna. The 30-nmi cutoff was established because of the earth's curvature; at 30 nmi, the radar beam is already too far above the surface to detect either the microburst or downburst.

The weather research branch manager testified that the NEXRAD network consisting of some 140-plus radars should be available by 1991. The initial evaluation of the siting criteria showed that the 140-plus radars in the continental United States would protect nearly the entire en route airspace system and "70 percent of the terminals we are concerned with. . . ." Additionally, based on thunderstorm exposure and high traffic density, there are about 40 high priority terminals which are not protected by the proposed (NEXRAD) network, and, according to the weather branch manager, the FAA will have to examine the option of protecting those terminals.

The weather research branch manager testified that the LLWSAS was designed to detect gust fronts not microbursts, and that it would be at least 3 years before the present system could be replaced by another type of wind shear alert system. He thought that the present LLWSAS could be improved, and that after the JAWS' project data are analyzed, the FAA will have to determine what can be done to improve its performance and make it a more viable system.

Airborne Detection Systems.--Between 1975 and 1979, the FAA sponsored a major research program to test and develop airborne displays and instrumentation for aiding a pilot in coping with wind shear on approach and landing and on takeoff. Although general aviation airplanes were included in the program, the discussion herein has been limited to those portions of the program relevant to large transport airplanes. The projected end results to be derived from the program were:

(1) Determination of optimum pilot aiding concepts for detecting and coping with wind shear.

(2) Complete performance specifications for cost-effective airborne equipment to display accurate and timely groundspeed information in the cockpit.

(3) Selection of and recommendation for use of wind shear systems.

The program to develop wind shear detection equipment (Task 2) was made a part of the FAA's All Weather Landing System (AWLS) project. Task 2 began in June 1975 and ended in July 1979 with the issuance of Report No. FAA-RD-117 (RD-117), "Airborne Aids For Coping With Low Level Wind Shear." The program was conducted by SRI International, and the following organizations participated: Bunker Ramo Corporation, Collins Division of Rockwell International, Douglas Airplane Company, NASA Ames Research Center, and the Boeing Commercial Airplane Company.

In order to accomplish the goals of the program, more than 21 wind models were developed and used in various combinations during piloted simulation tests. The profile severity of these models was classified as low, moderate, and high, and they were representative of the type wind shears generated by atmospheric boundary layer effects, frontal systems, and thunderstorms. Report RD-117 states, "In the high severity wind profiles, the two wind components (vertical and horizontal) combined adversely to produce complex wind shears possessing greater hazards; in the low-severity wind profiles, no shear in the vertical component was present. Higher severity profiles were also found to contain reversals in wind shear direction." Of these more than 21 wind models used, 7 were chosen and recommended to the FAA as candidate standard wind profiles for system qualification.

Task 2 consisted of a series of piloted flight simulation tests supported by analytical and experimental studies of airplane response to wind shear and the meteorological phenomena that produce low level wind shear. Approach and landing tests were conducted under various conditions of visibility, with different levels of approach instrumentation (full ILS and localizer only), in both wide-body and non-wide-body jet transport flight simulators, and in a B-727-200 flight simulator with a Head Up Display (HUD). The simulation experiments were conducted using simulators of good quality and a significantly large number of experienced pilots. Baseline values for each maneuver were established by requiring each pilot to fly the test wind profile using conventional airplane instrumentation. Report RD-117 states, "A major conclusion, over all the tests, was that conventional instrumentation was found inadequate for coping with wind shear during approach and landing. The percentage of acceptable approach outcomes under these conditions was generally less than 50 percent."

Many instruments and techniques, including HUD, were tested. Groundspeed-airspeed comparison and energy rate management instrumentation systems were tested; Report RD-117 noted that both produced approach and landing results which exceeded baseline values.

With the use of a modified flight director system (MFD-delta-A), which consisted of an acceleration and groundspeed augmented flight director, acceleration-margin criterion for advising go-around, and minimum-height-loss go-around pitch steering, the effects of wind shear on aircraft performance during approach and landing were greatly minimized. Report RD-117 states that results for both the precision and nonprecision approach demonstrated a substantial and operationally significant increase in the safe management of low-level shear encounters when the pilot aiding features of the MFD-delta-A system were available. With this system, pilots on precision approach were able to make within-limit touchdowns or execute successful go-arounds during all of the more hazardous high-severity shear encounters. On the nonprecision approach, this level of performance was achieved on all but one of the high-severity shear encounters. In all tested levels of wind shear severity, and for both the precision and nonprecision approach, the MFD-delta-A system showed a major improvement over baseline values as well as approaching the expected top level of performance (which corresponds to the simulator results with no shear). Report RD-117 concluded that the

> ...system performed well enough and ranked high enough in acceptability to be recommended as a solution to the wind shear problem on approach and landing. We do not mean to imply, of course, that MFD-delta-A is the only solution nor even that it is the most economical solution. We can only say that it is the system that has been found to work, and that the line of development taken (starting with minimal changes to the airplane instrumentation and introducing more complexity only when needed for improved performance) implies that it should be reasonably cost effective.

Report RD-117 stated that pilot workload, as reflected by pilot judgments of mental and physical effort involved in managing the wind shear encounter, was not significantly increased over baseline values when the MFD-delta-A system was used. The most noticeable effects on workloads were associated with the severity level of the shear. The report concluded that "with sufficient training and familiarization, pilots will accept an approach-management technique calling for deliberate variation in command airspeed to cope effectively with the low level shear environment."

Report RD-117 stated that the test HUD formats were generally helpful for both detecting wind shear effects and for providing guidance for control actions, "however, test results showed no substantial improvements over baseline performance in either approach outcomes or approach management during the shear encounters."

Takeoff performance was also evaluated during the Task 2 program. Five wind shear profiles were developed especially for the takeoff tests; four were thunderstorm wind fields characterized by a substantial headwind shearout (decreasing headwind—increasing tailwind) during the first 500 feet of the climbout. On three of these thunderstorm shears, the headwind shearout was accompanied by a downdraft in excess of 10 knots. The fifth profile represented a frontal type wind shear with a milder headwind shearout occurring in combination with a downdraft of less than 5 knots.

The takeoff simulations were performed in a DC-10 flight simulator, at sea level elevation and on a standard day. Low compressor (N1) takeoff setting was 102 percent, and the pilot executed a normal rotation and climbout. All takeoff sequences were flown using the MFD-delta-A system. Report RD-117 states, however, that the only element of this system considered appropriate "to the takeoff situation was the modified flight director pitch steering commands developed for go-around guidance." Four takeoff and climbout control strategies were used:

(1) Follow standard DC-10 pitch steering command immediately after rotation; this was the baseline.

(2) Pitch up to 15° at rotation and thereafter attempt to establish and maintain V_2+10 by reference to the airspeed indicator, with no pitch-steering command available; hereafter referred to as "no flight director" (NOFD).

(3) Follow the modified pitch-steering command immediately after rotation; hereafter referred to as "MPD at lift-off" (MPD).

(4) Use baseline procedure for rotation and initial climb and switch to MPD when shear effects are encountered; hereafter referred to as "MPD option" (MPD opt).

Three pilots flew 60 data runs, and contrasts between alternate climbout control strategies were based on 15 runs using each control strategy. In all instances when severe wind shear effects were encountered, the throttles were advanced to an overboost condition of 113 percent. Report RD-117 states in part,

> The outcomes of the takeoff attempts were remarkably consistent for the three pilots and, for the most part, showed little difference across the four control strategies. Encounters with the combined headwind shearout and low level downdraft were extremely hazardous for both the baseline and the test systems. Crashes were recorded on all of the test runs under these conditions. . . . Encounters with the milder thunderstorms profile with no downdraft and with the frontal shear were comparatively benign; none of the pilots had any difficulties climbing through these conditions using any of the four control strategies.

Computer model studies conducted during this program showed that the hazard on takeoff is at least as great as that on approach and that the range of possible control actions in response to shear on takeoff is much more limited. The airplane is already being flown at high pitch attitudes, and the throttles are positioned to almost full thrust (they may already be there). The computer studies indicated that there are realistic wind profiles in which even operation at the limit of airplane capability "is not enough to prevent ground contact." The simulation tests confirmed the computer studies, and the Report stated, "The overall picture given by the takeoff outcome data was that individual wind shear effects were dominant and that none of the aiding techniques tested could cope efficiently with the combined effects of a headwind shearout and downdraft during the first 500 feet of the climbout." The Report then states, "The tests showed that there are realistic wind shear conditions that, occurring on takeoff, exceed the aerodynamic and thrust capability of the airplane. An attempt to make a normal takeoff in such a situation, even when aided by a minimum-height-loss pitch-steering algorithm, cannot be retrieved by pilot action."

On May 3, 1979, the FAA issued Advance Notice of Proposed Rulemaking 79-11 (ANPRM 79-11) which discussed, in part, research and development of wind shear detection and guidance equipment. The ANPRM invited public participation to determine whether there is a "valid need to amend Part 121 and require wind shear detection equipment."

The majority of those responding to the ANPRM believed that regulatory action under 14 CFR 121 would be either premature or unnecessary. ANPRM 79-11 was closed out and a Notice of Proposed Rule Making (NPRM) was never issued. Moreover, since 1979, the FAA has not directly funded a continuation of airborne instrumentation development and testing programs. Although the FAA's National Airspace System Plan, dated December 1981, contained a project to define airborne techniques to traverse wind shears, the project plan called only for a final report in 1986 which would contain acceptance criteria for airborne systems. According to a FAA Systems Research and Development Service project manager, the funding of additional testing or simulation activities is contingent upon the discovery of new hazardous wind shear profiles in the JAWS project.

Shortly after the Clipper 759 accident, the FAA issued a draft Advisory Circular 120 (AC-120), "Criteria For Approval of Airborne Wind Shear Detection Systems." The draft AC presents guidelines to "operators holding operations certificates issued under Parts 121, 125, and 135 of the Federal Aviation Regulations" to obtain operational approval of airborne wind shear detection systems. The draft AC describes acceptable simulation criteria, wind field modeling data, and minimum performance parameters for system evaluation. The circular is strictly advisory and does not require the use of wind shear detection and guidance systems on air carrier airplanes. Comments regarding the draft AC are presently being reviewed by the FAA; the decision to issue the final version of the AC will be made early in 1983.

1.17.5 Human Performance Data

The captain was hired by National Airlines on August 16, 1965; the first officer was hired on December 20, 1976. Since their respective dates of hire, both the captain and first officer had been based at Miami, Florida. The evidence showed that, for the most part, they had flown routes which traversed the southern tier of the United States and the Gulf Coast States. According to NWS data, convective or thunderstorm type weather activity is common to this part of the United States during the summer. 21/ The evidence also showed that the captain had flown through New Orleans numerous times; during the 90 days before the accident, the captain had made five landings and takeoffs at the airport. Thus, the evidence was conclusive that both the captain and first officer were familiar with the air mass type thunderstorm weather that was affecting the New Orleans area and airport on the day of the accident. The evidence also indicated that they most probably had landed and had departed from airports under weather conditions similar to that which existed at New Orleans International Airport on July 9, 1982.

The Pan Am FOM states that when thunderstorm activity is approaching within 15 miles of the airport, the captain has, among other considerations, the option of delaying takeoff or landing. According to a former National Airlines Chief Pilot, the procedures concerning severe weather avoidance, particularly those relating to the captain's option to delay a takeoff or landing, were identical to those contained in the present Pan Am manuals. According to Pan Am supervisory personnel, the exercise of this option is based on the captain's evaluation of the airplane's performance capability, runway conditions, wind, and weather. The Pan Am Director of Flight Standards testified that captains "routinely do not takeoff in bad weather and delay and cancel flights." There was no evidence that management exerted any pressure on its flightcrews to keep to schedules in disregard of weather or other safety considerations.

2. 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 powerplants that would have affected its performance.

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

The ATC controllers on duty in the New Orleans tower at the time of Clipper 759's departure were certificated properly, and each controller had received the training and off-duty time prescribed by FAA regulations. The developmental controllers being trained at the ground and local control positions in the tower were qualified to receive the training at those positions; the controllers monitoring the developmental controllers at the local and ground control positions were qualified to supervise this training, and the training was conducted in accordance with applicable regulations and GENOT's.

21/ Twenty-eight years of NOAA climatological data reflecting the mean number of days with thunderstorm occurrences during June, July, and August showed the following: New Orleans—41 days, Miami—44 days; Fort Myers, Florida—50 days; Pensacola, Florida--45 days,* and Mobile, Alabama--57 days. "Climate of the States" Vols. 1 and 2, 1974, published by the Water Information Center, Inc., Port Washington, New York. (*Based on 2 years of data.)

Accordingly, the Safety Board directed its attention to the meteorological, airplane aerodynamic performance, and operational factors which might have caused the airplane to descend and crash. The meteorological evidence relevant to this accident included: the weather data provided to the flightcrew in their flight folder, the weather conditions existing at the New Orleans International Airport before and at the time of Clipper 759's departure, the weather information provided by ATC to the flightcrew, and ground and airplane weather radar systems. For continuity and clarity, aspects of the latter two weather related areas -- the processing and dissemination of weather information by ATC and ground and airplane weather radar systems -- will be discussed during an examination of operational factors.

2.2 Meteorological Factors

2.2.1 Flight Folder

Examination of the flight folders prepared and given to the flightcrew at Miami and New Orleans showed that they contained the required weather documents. The area and terminal forecasts were both current and substantially correct. The flightcrew did not have a copy of SIGMET 38C; however, this SIGMET did not affect the New Orleans International Airport or Clipper 759's route of flight, and there was no requirement to provide them with a copy.

2.2.2 Weather Conditions at Airport

Since the evidence showed that Clipper 759 began its takeoff roll at 1607:57 and that the initial impact with the trees occurred about 1609:01, the Safety Board's examination of the weather was centered on, but was not limited to, the time period between 1607:57 and 1609:01.

Convective Weather Activity.--At the time Clipper 759 was preparing for takeoff, convective weather radar echoes were located both over and to the east of the departure end of runway 10. The 1608 weather radarscope photograph from Slidell, Louisiana, showed a VIP level 2 echo located nearly over the departure end of runway 10 and another VIP level 2 echo about 4 nmi east of the airport. The weather radar "sees" a VIP level 2 echo at an intensity level of 40 dBZ. However, due to intervening rain, atmosphere, and clouds, the two-way attention of the radar beam would have been about 4 dBZ. 22/ Therefore, the nonattenuated echo intensity of these cells was probably 44 dBZ; a 44 dBZ intensity corresponds to a level 3 storm cell.

Between 1601 and 1609, the pilots of four airplanes -- Republic Flight 632, Texas International Flight 974, Cessna Citation N31MT, and Southwest Airlines Flight 680 -- saw three weather cells either over or near the New Orleans International Airport on their respective airplane weather radar systems. All four airplanes were on the east side of the airport when these observations were made. One of the weather cells was over the departure end of runway 10, another was within 2 nmi to 5 nmi east-northeast of the airport, and the third cell was 5 nmi southwest of the airport. Based on their observations of their radar, all four pilots testified that these weather cells were level 3 or higher. Based on this evidence, the Safety Board concludes that level 3 storm cells were located over the airport and just east-northeast of the departure end of runway 10 during Clipper 759's takeoff.

22/ Federal Meteorological Handbook No. 7, June 1981, Chapter 3, p. 24. Wexler, R, Atlas, D, Radar Reflectivity and Attenuating Rain; Journal of Applied Meteorology, Vol 2, pps. 276-280.

The statements of the witnesses, controllers, and the airport weather observer showed that a thunderstorm was not in progress at the airport either just before or during the time of Clipper 759's departure. Further, based on the same sources, the weight of the evidence showed that a thunderstorm was not in progress in the area just east of the departure end of runway 10 during this same time period.

Rainfall Rates.--The rainfall rates during Clipper 759's departure were also calculated from various data sources. A rain gauge located about 3,000 feet southeast of the departure end of runway 10 showed that, between 1608 and 1609, the rainfall rate increased to a value of about .5 in/hr. The rainfall rate was probably heavier east of the departure end of runway 10. The radar reflectivity in this area, as stated earlier, was 44 dBZ. The relationship between radar reflectivity and rainfall rate is expressed in the following equation: $R = (Z/55)^{.625}$, where R equals rainfall rate, and Z equals reflectivity expressed in millimeters to the sixth power per cubic meter ($mm^6\ m^{-3}$). 23/ Substituting 44 dBZ into this equation yields a rainfall rate of 1.8 in/hr (45.7 mm/hr) east of runway 10.

Several witnesses located on the airport saw Clipper 759 from the point of liftoff to the tree line east of runway 10. The average distance from the witness locations to the tree line was about 4,000 feet (1.22 kms). The rainfall rate at the departure end of runway 10 was calculated using this visibility. The relationship between visibility and rainfall rate is expressed in the following equation: $SM = 18.8I^{-0.69}$, where SM equals visibility in kilometers, and I equals rainfall rate in millimeters. 24/ Substitution of 1.22 kms into the above equation yields a rainfall rate of about 2.1 in/hr (53.3 mm/hr) at the departure end of runway 10.

At the time Clipper 759 took off, the average rollout RVR on runway 10 was 2,000 feet (.61 km); substituting .61 km into the visibility and rainfall rate equation yields a rainfall rate of 5.7 in/hr (144 mm/hr) for the area near the departure end of runway 10.

Wind Direction and Speed.--Although the Safety Board used both meteorological data and witness statements, it was not possible to determine precisely the horizontal and vertical wind components affecting Clipper 759's takeoff.

Between 1607 and 1609, the NWS wind trace showed that the average wind was about 16 knots. The NWS anemometer is located within 100 feet of the LLWSAS's centerfield sensor. At 1604:11, 1606:13, 1607:10, and 1609:03, the local and ground controllers using the centerfield sensor reported winds of 060° at 16 knots, 070° at 17 knots, 070° at 17 knots, and 080° at 15 knots, respectively. Therefore, at the time Clipper 759 took off (1607:57), the centerfield wind was approximately 070° at 16 knots.

At 1609:03, about 2 seconds after Clipper 759 struck the trees on Williams Boulevard, there was a LLWSAS alert involving the east sensor; the ground controller reported the centerfield wind as 080° at 15 knots and the east sensor wind as 310° at

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23/ Federal Meteorological Handbook No. 7, Weather Radar Observations June 1981.
24/ Bartishvili, I.T., Meteorologicheskaia Dal Nost Vidimosti V Zone Dozhdia (Meteorological Visibility Range in a Rain Zone) Trudy, Nauchno - Issledovatel, skii Gidrometeorologicheskii Institute, Tiflus No. 5 1959, pps. 115-123.

06 knots. A wind of 080° at 15 knots results in a 14-knot headwind component in relation to the runway 10 centerline; a wind of 310° at 06 knots results in a 5-knot tailwind component. Since the tree line on Williams Boulevard is 300 feet beyond the east sensor, the airplane experienced approximately a 19-knot decreasing headwind shear within a distance of 5,850 feet.

According to a witness, just before and at the time of initial impact, the wind was blowing from west to east and was causing whole trees to move. According to Table A-10-5, Federal Meteorological Handbook No. 1, "whole trees in motion. . . ." corresponds to a wind speed of 28 knots to 33 knots. Assuming a wind direction of 310° and a 30-knot velocity at the tree line, and assuming a centerfield wind of 080° at 15 knots, the magnitude of the decreasing headwind shear between the centerfield sensor and Williams Boulevard was 40 knots.

All the LLWSAS's sensors were located within acceptable tolerances to meet the criteria established in the test and evaluation program. However, according to FAA Reports No. RD-80-45 and No. NA-80-1, "The Low Level Wind Shear Alert System," May 1980, tests have shown that anemometers located above the mean height of nearby trees, but in a clear zone near the trees, frequently sense low winds when ambient wind flows over the trees before impinging upon the sensor. This is caused by forest-produced diffluence. Even if the criteria contained in the two reports cited above are used to determine sensor height, there will be some residual influence on the measured wind as a result of the upstream obstruction. Although the east sensor had been placed in accordance with established criteria, there are trees to the north, east, and south of the sensor. Since the northwest wind would have had to flow over trees before impinging upon the sensor, the retrieved 6-knot speed could have been lower than the actual speed.

The wind directions and speeds noted by the witnesses and the readings of the LLWSAS's sensors as reported by the controllers in the tower around the time of the accident were characteristic of a divergent flow emanating from convective cells. Due to the divergent flow near the surface, Clipper 759 probably encountered downdrafts from near the departure end of the runway to the initial contact with the tree line on Williams Boulevard. However, an accurate description of the downdrafts is not possible.

Preliminary analysis of data from the JAWS project showed downward velocities in convective activity on the order of 10 fps at 100 feet AGL. In addition, a recent study based on an analysis of 14 months of meteorological tower wind observations in Oklahoma indicated that "vertical motions in particular downdrafts of any consequence to pilots are virtually nonexistent below about 100 meters (328 ft)." 25/ This study states that at 26 meters (85 feet), the maximum updrafts and downdrafts are about 4 meters per second (13 fps) and that "downdraft magnitude is inversely proportional to horizontal spatial extent."

Based on the equation of continuity, a horizontal surface divergence of .1 per second yields downdraft velocities of 10 fps at 100 feet AGL and 5 fps at 50 feet AGL. At the time of the accident, the horizontal surface divergence near the departure end of runway 10 was probably less that .1 fps; therefore, at 100 feet AGL and 50 feet AGL, the downdrafts in this area were probably less than 10 fps and 5 fps, respectively.

25/ "Characterization of Winds Potentially Hazardous to Aircraft," Craig Goff, Journal of Aircraft, Vol. 19, No. 2, February 1982.

In summary, the meteorological evidence showed that at the time Clipper 759 was preparing for takeoff, there were VIP level 3 weather cells located over the eastern part of the airport and east of the departure end of runway 10; however, lightning and thunder were not occurring in either area.

Clipper 759's takeoff began in light rain; it encountered increased rain during the takeoff roll and even heavier rainfall after liftoff. Between the points of liftoff and initial impact, the calculated rate increased from 0.5 in/hr to about 2.0 in/hr; however, theoretical maximum rainfall rates near the departure end of the runway and east of the runway's end could have approached 5.7 in/hr.

At rotation and liftoff, Clipper 759 was operating in a headwind; between liftoff and initial impact with the trees, the wind changed to a tailwind. The minimum and possible maximum magnitudes of this decreasing headwind shear were on the order of 19 knots and 40 knots, respectively. The performance studies showed that Clipper 759's average liftoff time occurred 43 seconds after brake release; consequently, the time from liftoff to initial impact was 20.9 seconds. Given a 20.9-second flight time from liftoff to initial impact, the possible minimum and maximum rates of decreasing headwind shear between these two points were .9 knots/second and 1.9 knots/second, respectively. In addition, between liftoff and initial impact, the airplane would have experienced a downdraft of between 10 fps to 5 fps.

Portions of the wind data referred to in this analysis are based on the ground controller's 1609:03 wind shear alert advisory. The evidence showed that Clipper 759 lifted off about 1608:40, and hit the trees about 1609:01. The Safety Board could not determine either the precise time the LLWSAS alert began or how long it had been in progress before the ground controller issued the 1609:03 advisory. Given the retention features of the LLWSAS display, the alert could have begun as early as 1608:25.5; therefore, the Safety Board concludes that the winds causing this wind shear alert also affected Clipper 759's takeoff and initial climb.

Based on its analysis of all the available meteorological data and its analysis of the data contained in the NOAA and Pan Am wind analyses, the Safety Board concludes that the winds emanated from a microburst which was centered about 2,100 feet east of the centerfield sensor and 700 feet north of the centerline of runway 10 (see figure 4). Based on the microburst windfield, the Safety Board also concludes that during the flight from liftoff to initial impact, Clipper 759 most probably experienced about a 38-knot decreasing headwind shear and about a 7 fps downdraft at 100 feet AGL.

2.3 Airplane Aerodynamic Performance

During the analysis conducted by Boeing Company and the Safety Board's performance group, 13 hypothetical flight profiles were developed to establish the environmental conditions affecting Clipper 759's takeoff. The 13 cases were necessary in order to explore airplane performance produced by fast and slow rotations, rapid and slow climb rates to 35 feet AGL, and the various assumed wind patterns required to get the airplane from 35 feet AGL to the impact point at 50 feet AGL within the constraints of total distance traveled and elapsed time. These possibilities had to be considered because of the total lack of recorded parametric information required to make direct wind evaluations.

Examination of the 13 cases showed that only two cases -- I and III -- exhibited reasonable downdraft magnitudes at 100 feet AGL. Case I was based on a fast rotation rate; case III was based on a slow rotation rate. Given the facts that (1) the captain advised the first officer to let the airspeed build up on takeoff; (2) a slow rotation would allow the airspeed to build up; and (3) only case III correlates with the actual FDR vertical acceleration typical of a slow rotation, the Safety Board examined case III further.

The horizontal wind data developed in case III showed a 16-knot headwind at liftoff. Thereafter, over the next 14 seconds, a tailwind shear of about 35 knots occurred. During the last 5 seconds before tree impact, the tailwind diminished from about 20 knots to about 10 knots. The derived vertical winds showed a steadily increasing downdraft from the 35 feet AGL point to about 5 seconds before impact. At this point, the downdraft remained at about 25 fps until tree contact. While the downdraft velocity exceeded that normally noted at 100 feet AGL by about 14 fps, the horizontal wind shear falls within 3 knots of the parameters developed in the meteorology analysis (see figure 6).

The maximum altitude reached in case III was 95 feet AGL, and the pitch attitudes during the latter part of the flight were on the order of 12° to 13° noseup. The witnesses who saw Clipper 759 on takeoff estimated that it climbed to an altitude of about 100 feet AGL to 150 feet AGL before descending. The majority of the witnesses who estimated a pitch attitude indicated that Clipper 759 was in a noseup attitude throughout its flight to the impact point. While three witnesses described pitch angles higher than 15°, the majority of the witnesses described Clipper 759's pitch attitude as lower than 15°. At least two witnesses said that the nose was lowered as Clipper 759 approached the tree line. Thus, the witnesses offer some corroboration of the pitch attitude and altitudes presented in case III. Based on the evidence, the Safety Board concludes that case III is a reasonable representation of the environmental conditions encountered by Clipper 759 on takeoff, although the downdraft velocity exceeds values expected to satisfy a downdraft continuity constraint.

Using case III as a reasonable and conservative approximation of environmental conditions, a hypothetical assessment of different airplane energy management techniques with available airplane capability can be made by comparing the available rate of climb of the airplane to the computed downdraft values over a selected period of time or distance. For example, in case III, at 58 seconds after brake release, had the airplane's climb capability been used to establish and maintain a 25-fps rate of climb relative to the air which could have been done by increasing the airplane's pitch attitude to maintain the indicated airspeed that existed at that time, the airplane theoretically could have maintained 95 feet AGL and the decreasing tailwind would have caused the indicated airspeed to increase. This hypothetical evaluation is based on a static analysis of the airplane's instantaneous performance capability; the evaluation does not include any allowance for pilot recognition, perception, and reaction times.

The major difference between the derived windfields in the Boeing performance analysis and those reflected in the Pan Am and NOAA wind analyses was the wind speed of the downdraft at 100 feet AGL. In addition, the airplane pitch attitudes reflected in the Pan Am analysis were different from those shown in the Boeing analysis. In the Boeing performance analysis, the speeds of the horizontal and vertical wind components and their spatial relationship to each other were adjusted by assuming groundspeed time histories which insured that the airplane's flight met the constraints imposed by the physical evidence of the accident sequence. Airplane pitch attitudes were

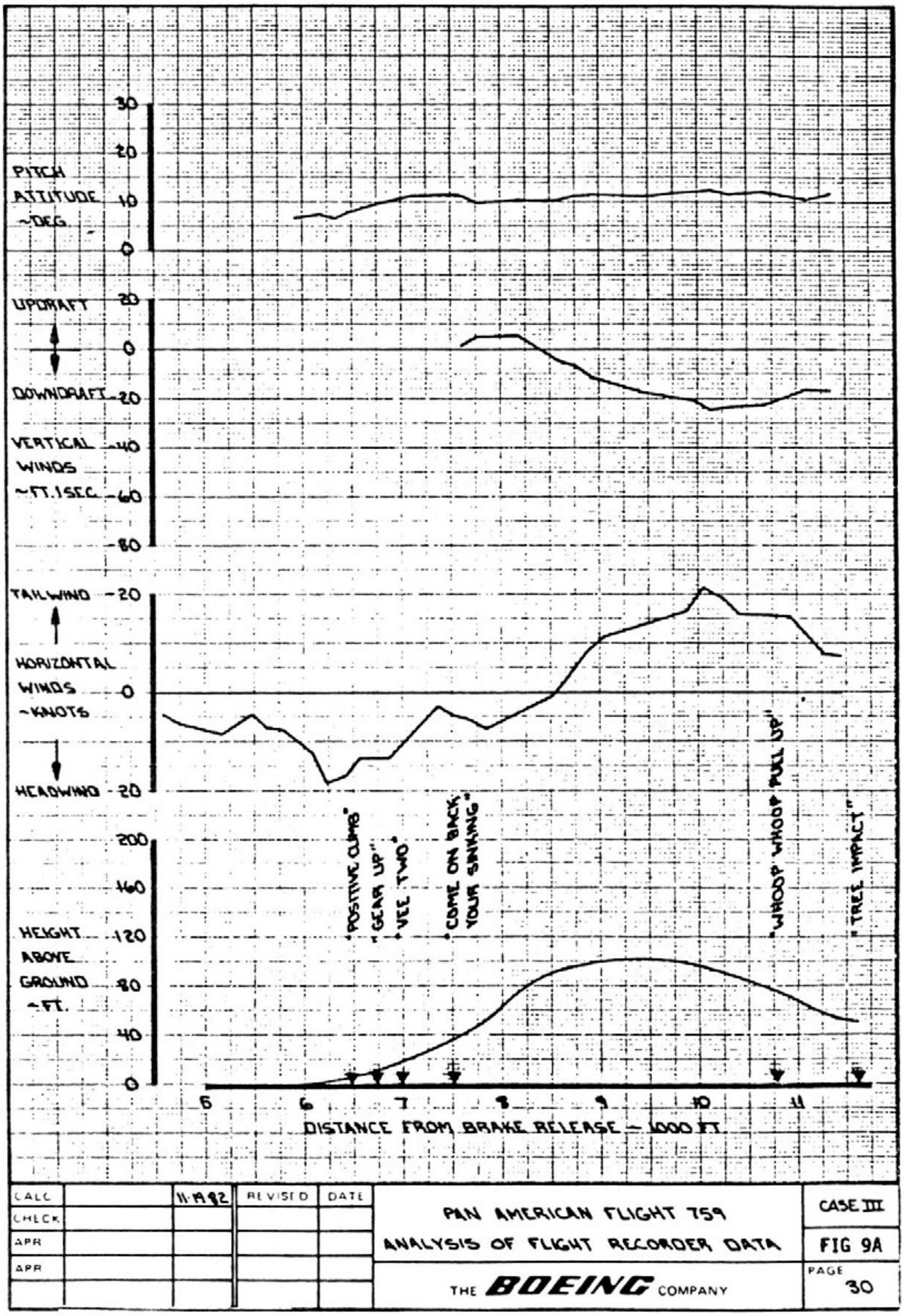

Figure 6.--Boeing's analysis of flight recorder data, case III.

derived from the airplane's measured performance parameters combined with the motion equation results for the assumed groundspeed profiles. No attempt was made to adjust the derived airplane pitch angles to produce a windfield that would fall within reasonable environmental parameters. Consequently, while the horizontal wind shear demonstrated in case III is reasonable, the 25 fps downdraft at 100 feet AGL is not; a 25 fps downdraft at 100 feet AGL would produce a diverging outflow on the order of 100 knots. It was obvious that surface winds of this magnitude did not occur during this accident.

The Pan Am and NOAA wind analyses were based on similar assumptions to those used in the airplane performance analysis; however, an additional constraint was satisfied. The horizontal and vertical wind speeds were adjusted to assumed values which, when inserted into the equation of continuity, yielded outflow wind speeds which were consistent with those recorded or observed in the area of the airport at the time of the accident. The assumed airplane pitch angles shown in the Pan Am analysis reached a 13° noseup angle, was then decreased to 5° noseup, and was thereafter increased to 12° noseup. (Assumed pitch angles were not reflected in the NOAA analysis. However, since the assumptions and equations used in the NOAA analysis were essentially identical to those used in the Pan Am analysis, the Safety Board concludes that the pitch angles shown in the Pan Am analysis would be equally applicable to the assumed horizontal and vertical wind speeds used in the NOAA analysis.) Except for the 7 fps downdraft speed, the wind speeds contained in the Pan Am and NOAA analyses approximated those contained in case III of the airplane performance analysis. The variation of the downdraft speed resulted from the application of the equation of continuity constraint. Since the application of this constraint produced downdraft speeds that were substantially less at 100 feet AGL than the downflow speed reflected in case III, the Safety Board's determination that the environmental wind conditions of case III did not exceed the airplane's performance capabilities is equally, if not more, applicable to the horizontal and vertical wind speeds reflected in the Pan Am and NOAA microburst windfields.

There is tangible evidence which appears to substantiate the airplane's theoretical capability to negotiate the derived environmental conditions. The swath through the two groups of trees at the impact site indicated that at impact Clipper 759 was in level flight or in a slight climb. The evidence also showed that during the last 5 to 6 seconds before impact, Clipper 759's airspeed had increased 18 KIAS. Had the pilot been able to recognize and react to the changing flight path immediately, this increase in kinetic energy might have been used to decrease the rate of descent and perhaps level the airplane more quickly.

The swath through the two groups of trees also indicated that the pilot may have recognized the wind shear but too late to avoid the trees; however, the fact that the wind shear was encountered immediately after takeoff and during the initial climb made it more difficult for the pilot to detect the wind shear. Normally during the passage through a downburst or microburst, the airplane will first encounter an increasing headwind, a downdraft, and then a loss of headwind (or a sudden tailwind). An airplane which approaches a microburst or downdraft either during cruise flight or during an approach to landing is generally in stable flight conditions when the phenomena is encountered; i.e., the airplane's flight attitude and airspeed are stabilized. Under these flight conditions, the changes in airspeed, pitch attitude, and performance produced by the airplane's passage through the divergent windflow would be more apparent to the pilot than they would be immediately after takeoff and during initial climb. During takeoff, the airplane is accelerating to reach the minimum level of performance to initiate flight. The pilot's actions are predicated upon his reaching target airspeed values. Under this condition, he is not in a position to recognize that the rate of airspeed increase is the result of an increasing headwind as well as the airplane's inertial acceleration. He responds to the airspeed to achieve liftoff and achieve his normal initial climb pitch attitude. Thus, the airplane is not likely to attain a performance margin during takeoff into a downburst or microburst to cushion the effect of downdraft and headwind loss. The slower the entry airspeed the longer the exposure to downdraft, and the more significant the angle of attack change resulting from the combined downdraft and headwind loss. The magnified aerodynamic performance penalty combined with the absence of altitude available for recovery present an extremely severe hazard. If the airplane is theoretically capable of maintaining level flight during the microburst penetration, the avoidance of ground impact is contingent upon rapid recognition of the situation and reaction by the pilot. It would necessitate a rapid pitch change to a perhaps unaccustomed attitude to immediately decrease the airplane's descent flightpath angle.

There are several factors to consider when evaluating the pilot's performance in such a situation. First, the pilot of an airplane taking off in the outflow of a downburst or microburst is less likely to recognize that he is encountering such a phenomena than a pilot approaching this condition in other phases of flight where outflow entry effects would be more apparent. Second, the airplane is trimmed for takeoff so that the aerodynamic forces developed by the wing and horizontal stabilizer balance the airplane's weight at the normal takeoff and climbout airspeeds with minimal forces required on the pilots control column. As the airplane lifts off in the outflow and approaches the downflow area of the microburst, it experiences a decrease in the horizontal headwind overlayed by an increasing downdraft. The resultant reduction in airspeed and angle of attack caused by the effects of the decreasing headwind and increasing downdraft reduces the aerodynamic forces acting on the wing and initially produces a pitchup caused by the longitudinal stability of the airplane. Ultimately, the force imbalance causes the airplane to descend, and as the horizontal wind change is encountered beyond the center of the microburst (an increasing tailwind), the resulting loss of airspeed would continue to cause the airplane to descend and pitch down until enough lift force was produced to restore the vertical force balance. Theoretically, airspeed acceleration, because of the descending flightpath, would restore the force balance at the trim angle of attack and eventually result in a restoration of the climbing flightpath. However, on takeoff or final approach, it is unlikely that enough altitude is available for such a self-corrected flightpath change to be completed. Therefore, to avoid or minimize altitude loss near the ground, the pilot must recognize the reduction in airspeed and the pitching tendency of the airplane immediately and apply back forces on the control column to rotate the airplane to the higher than normal pitch attitude.

Furthermore, if the pilot does not react immediately and the descent is permitted to develop, even greater corrective actions will be needed to develop a positive load factor to arrest the descent. AC 00-50A has stated that a noseup pitching rotation to the stickshaker angle of attack may be required to prevent ground impact. However, it is imperative that the pilot immediately recognize the onset of the descent. In assessing his ability to do so, consideration must be given to the cues provided. During the takeoff roll until liftoff, the pilot flying the airplane uses visual references to maintain directional control, although he will periodically monitor his airspeed indicator and flight director for rotation to the takeoff climb attitude. He would probably transition to instrument flight as he established climb and certainly as he entered heavy precipitation. With visual cues obscured by the heavy precipitation, the pilot would have been totally reliant on his instrument presentation as a cue to the airplane attitude, airspeed, and flightpath.

Although an airplane may theoretically have the performance capability to penetrate a downburst or microburst without ground impact, success is contingent upon the ability of the pilot to recognize and react immediately to the hazard. From liftoff, the reaction of the pilot would have to include his perception of dynamic instrument presentations, evaluation of these readings, and finally control column force application. The added response time for the airplane to react to the control column movement is another factor that would further modify the airplane's theoretical performance capability.

In analyzing the pilot's performance during this accident, the Safety Board considered all the factors that could affect his reaction times and the implications of these reaction times on the airplane's attaining its theoretical performance capability. The Safety Board noted that the airplane entered heavy rain by the time of liftoff or immediately following, thus making the pilot totally dependent on his instruments to detect and react to the wind shear. The analysis showed that the airplane climbed for about 11 seconds after which the pitch attitude decreased from 13° to 5° and a descending flight path developed. The analysis also showed that the pilot reacted to the descent, and a nose-up pitching moment was developed within 6 seconds of the descent. However, the descent was not arrested until tree impact was inevitable. The Safety Board notes that a University of Southern California report indicates that a pilot already viewing an essential flight instrument would probably require a minimum of 4.25 seconds to respond, which includes recognition of the instrument deviation, perceiving its significance, and reacting with a force applied to the control column. 26/ The Safety Board believes that factors such as heavy precipitation, turbulence, the need to apply an abnormal force to the control column, and the need to achieve an unfamiliar pitch maneuver could adversely affect the pilot's recognition and responses; on the other hand, the onset of a ground proximity warning system (GPWS) alert could prompt a pilot to act more positively. The evidence in this accident indicates that the pilot probably had reacted and was applying corrective action when the GPWS alarmed. As described earlier, the performance analysis showed that the airplane theoretically could have maintained an altitude of 95 feet AGL. The physical evidence at the accident site showed that the pilot had been able to arrest the descent rate and place the airplane in a slight climb at or before the initial tree strike at about 50 ft AGL. Given the adverse factors which could have delayed the pilot's reactions, and given the fact that the altitude difference between the theoretical capability of the airplane to maintain level flight and the actual performance of the airplane was only about 45 feet, the Safety Board concludes that the pilot's actions to correct the airplane's nosedown pitching moment and descending flight path at least equalled the response which could be expected under the prevailing conditions.

While the Safety Board believes strongly that the most positive prevention of this type of accident is avoidance of critical microburst encounters, other actions must be taken to enhance the capability of flightcrews who may experience the hazard without warning to recover from the encounter. The airplane's flight instrumentation must be improved. In addition, the contents and scope of present simulator training must be broadened to increase the flightcrew's knowledge of the airplane's flight characteristics during varied wind shear encounters so that they can recognize the onset of the wind shear more quickly and also recognize the need to take rapid corrective action in order to prevent a critical loss of altitude. Both of these actions could effectively improve pilot response time and may mean the difference between a catastrophic accident and successful microburst penetration.

26/ Bond, Nicholas H., et. al., Aviation Psychology, University of Southern California, Los Angeles, California, March 1968.

Present generation flight directors provide the pilot pitch command guidance to either a fixed takeoff attitude, as is the case with most older jet transport airplanes such as the B727 involved in this accident, or an optimum climb airspeed, as is the case with the newer wide-body airplanes. In either system, the pitch command guidance is not programmed to account for the environmental wind condition experienced in a downburst or microburst. These flight directors will in fact provide takeoff and initial climb pitch commands which are likely to produce a descending flightpath as the airplane experiences a downdraft and loss of headwind. The Board believes that the FAA and industry should expedite the development and installation of a flight direction system such as MFD-delta-A which includes enhanced pitch guidance logic which responds to inertial speed/airspeed changes and ground proximity.

Although the Safety Board notes that most air carriers including Pan Am provide pilots with wind shear penetration demonstrations during their recurrent simulator training, there does not appear to be a consistent syllabus which encompasses microburst encounters during all critical phases of flight. Because of the differences in airplane configuration, performance margins, flight director logic, among others, the Board believes that flightcrews should be exposed to simulated microburst encounters during takeoff as well as approach phases of flight.

Effect of Heavy Rain on Airplane Airfoils.--The effects of heavy rain on airfoils still must be verified. The two most significant penalties postulated in the theory are the momentum penalty and the lift and drag penalties resulting from the formation of wing roughness. According to the senior research scientist, the momentum penalty becomes significant at rainfall rates approaching 500 mm/hr; the onset of "significant" roughness penalties would occur at about 150 mm/hr. The analysis of the meteorological data indicated that the maximum possible rainfall rates during Clipper 759's takeoff could have been 144 mm/hr in the area near the departure end of runway 10. This rate did not exceed the threshold rate of the momentum penalty; however, near the departure end of the runway, the rate was within 6 mm/hr of the rate at which the onset of "significant" roughness penalties occur. Given the present status of the theory, any calculations or computations designed either to demonstrate the effects a 144 mm/hr rainfall rate would have had on Clipper 759's lift and drag, or to calculate how much these penalties would change the amount of air mass motion required to account for a difference between theoretical performance and FDR measured performance would be speculative. Any values derived from this type of computation could not be used to support any findings or conclusions; therefore, the Safety Board has not pursued this course of action.

Although the effect of heavy rain on airplane airfoils has not been verified, one of the implications of the theory which is a matter of serious concern to the Safety Board is the effect of premature flow separation due to water film roughness. If this occurs, the flow separation would cause aerodynamic stall at a lower angle of attack than flow that is not affected by roughness. Since airplane stall warning systems are designed to operate on the basis of stall conditions for a smooth, or at worst, standard roughness airfoil, any significant roughness effects due to a water film might result in the true aerodynamic stall occurring before reaching the angle of attack that would cause the stall warning system to activate. It is not known if a natural warning (buffet onset) would occur with sudden entry into heavy rain.

The evidence developed at the public hearing indicated that research programs involving the necessary wind tunnel testing required to validate the heavy rain effect theory are being developed. Given the many detrimental effects on airplane performance postulated in the heavy rain theory, the Safety Board believes that the proposed research programs should be undertaken, and urges that this be done the earliest date possible.

2.4 Operational Factors

The final major area in the accident sequence which was analyzed by the Board was the captain's decision to take off. The Safety Board examined the guidelines concerning thunderstorm and wind shear avoidance provided in the Pan Am manuals, the weather information provided by the company, the ATC advisories issued before takeoff, and the use of the airplane's weather radar system.

Company Manuals.—The description of thunderstorms, wind shear, and the meteorological phenomena associated with them are adequately explained in the Pan Am company manuals. Although new data are now emerging from the JAWS project concerning microbursts and downbursts, the data provided in the Pan Am FOM and AOM represented an accurate portrayal of the low level wind shear as known on the date of the accident. The manuals emphasize that low level wind shears are associated with thunderstorms and that they can be in front of, to one side of, and behind the storm cell.

The Pan Am FOM states that in the event of "significant thunderstorm activity. . . . within 15 miles of the airport, the captain should consider conducting the departure or arrival from a different direction or delaying the takeoff or landing. Use all available information for this judgment including pireps, ground radar, aircraft radar, tower reported winds, and visual observations." Because of Clipper 759's takeoff gross weight, Clipper 759 was required to take off from runway 10; the captain did not have available the option of changing the direction of takeoff.

The Pan Am FOM contained a short description of the LLWSAS, its limitations, and the type information the flightcrew could expect to receive from the controllers at airports with a LLWSAS. The FOM states that LLWSAS wind information "is strictly informational, and no action is required unless deemed appropriate by the pilot."

The intent of the company manuals is straightforward. They describe the thunderstorm and wind shear phenomena, the possible consequences, and the necessity for avoiding them. They establish a distance standard -- 15 nmi -- at which the captain must exercise options to avoid the consequences of an encounter with the hazards associated with "significant thunderstorms activity." Thereafter, it is the captain's responsibility to evaluate and decide the severity of the weather with which he must contend, and based on this decision, to choose an appropriate course of action. The company manuals describe the available sources of the information on which this decision is to be based. The information and guidelines in the Pan Am manuals concerning this decision process are essentially the same as those contained in similar manuals of other air carriers. Thus, it is appropriate to examine the information provided to the captain of Clipper 759 and to ascertain its adequacy relevant to his decision to take off.

The flight folder provided to the captain of Clipper 759 at Miami contained the 0740, July 9, 1982, area forecast. This forecast was still valid at the time Clipper 759 departed New Orleans. The area forecast predicted thunderstorm activity near the New Orleans International Airport and also stated that the thunderstorms "imply possible. . . .low level windshear." Thus, the captain knew that thunderstorms with associated low level wind shear activity might affect his arrival and departure at New Orleans International.

ATC Dissemination of Weather Information.—At 1510, while Clipper 759 was at the gate at New Orleans, the Houston CWSU meteorologist called New Orleans tower on the FAA interphone and advised the controllers of VIP level 4 and 5 thunderstorms located south-southwest of the airport and moving toward the airport. However, the meteorologist did not provide the distance of the storm cells from the New Orleans International airport. The weather the meteorologist observed did not meet the criteria requiring a Convective SIGMET or CWA. The information was relayed from the tower cab to the TRACON facility below the tower cab.

The senior controller testified that the tower's BRITE IV display was set at the 20-nmi range and that he did not see the storms described by the meteorologist. In this connection, the radar equipment furnishing the BRITE IV display will depict precipitation returns; however, it does not determine and differentiate weather echo intensity.

The information concerning these storms was never relayed to any traffic at or near the airport nor was there any requirement to do so. However, the CWSU meteorologist relayed this information to the New Orleans tower because, based on their intensity and direction of movement, he considered them to be significant. The evidence showed that the storms did move toward the airport, and at about 1600, they were about 5 to 10 nmi south and southeast of the airport. The Safety Board recognizes that the storms reported by the meteorologist at 1510 did not, based on current criteria, require that either a SIGMET or CWA to be issued. However, the Safety Board believes that any convective weather advisory provided by a CWSU meteorologist to a terminal facility should be relayed by the facility to the pilots by inserting it into an ATIS message or as part of the opening communication between an arriving or departing airplane and the appropriate controller.

The evidence showed that the storms south of the airport did not affect Clipper 759's takeoff. The evidence also showed that the captain and first officer saw the storm south of the airport on the airplane's weather radar. The CVR showed that both pilots had agreed that they would turn left or to the north after takeoff. Since a right turn to the south would have been the shortest way to proceed on course to the west, the left turn suggests strongly that the decision to do so was based on weather radar information which depicted precipitation echoes to the south of the projected departure track. Thus, the only information concerning the storms which the captain did not have was the fact that at 1510 the precipitation echoes of these storms were VIP levels 4 and 5. Since the captain was aware of the storm to the south of his projected departure track, the Safety Board concludes that, in this instance, the failure to require the terminal facility to relay information provided by the CWSU meteorologist to the pilot was not a causal factor in this accident.

When Clipper 759 departed the gate at 1555, ATIS "F" was valid and contained the 1355 surface observation. When the 1455 surface weather observation was received, ATIS "F," in accordance with ATC procedures, should have been revised. It was not, and the ATC controller testified that the failure to do so was an "oversight." The significant difference between the 1355 and 1455 observations was the remark "cumulus buildup overhead east and south." The 1455 observation had been placed on the carousel on the desk in the Pan Am operations office and was available to Clipper 759's flightcrew. Examination of the company takeoff computation form completed by the captain and first officer showed that the 1455 weather observation data was used in the computation. Therefore, the Safety Board concludes that the pilots had read the 1455 observation. In addition, conversation between the captain and a member of the groundcrew personnel also indicated that the captain was well aware of the convective weather activity around the airport. He had seen it on his arrival at New Orleans, and based on its observed movement, he had expected it to move toward and impact upon the airport. The Safety Board concludes that since the captain had read and was aware of the contents of the 1455 surface weather observation, the fact that an ATIS message reflecting the 1455 observation was not issued was not a causal factor in this accident.

At 1555, another surface observation was received in the tower and in the Pan Am operations office. In addition to the recorded weather data, the observation noted that there were "heavy rain showers," and "cumulonimbus overhead." At 1603, a special weather observation was issued which, except for decreased visibility, was essentially the same as the 1555 observation. At 1604:45, ATIS "G" was issued. "G" contained the 1603 special observation, and in addition, contained the advisory remark "low level wind shear alert all quadrants." There is no requirement for ATC to broadcast on all frequencies that a new ATIS has been issued.

Clipper 759's flightcrew left the company's operations office before the 1555 and 1603 weather observations were received at that facility; therefore, the captain did not receive the information set forth in the two weather observations or ATIS "G". However, the evidence showed that the captain was to receive virtually all these data from other sources.

It was raining while Clipper 759 was taxiing from the gate to runway 10. After reaching the west end of runway 10 and while turning on the runway and toward the takeoff heading, the heavier rain at midfield and to the east would have been visually apparent to the captain. Given the weather data he already had and the type precipitation he was seeing, the Board concludes that it would have been apparent to the captain that the rain was emanating from cumulus type clouds over the airport. From the appearance of these clouds, as they were described by witnesses, it would have been equally apparent to him that they were cumulonimbus type clouds. He would have observed also that there was neither lightning nor thunder.

At 1603:37, ATC advised the captain that there were LLWSAS alerts "in all quadrants," that there was a "frontal (sic) passing overhead right now, we're right in the middle of everything." This advisory was incomplete since it did not include the wind direction and velocity at the peripheral sensors; however, the omission was not a causal factor in the accident. Despite the omitted data, the advisory gave the captain the pertinent weather data that was included in ATIS "G". He now knew of the low level wind shears in all quadrants. He also knew from the data in his flight folder that there was no front near the airport; therefore, he knew that whatever was producing the showers and wind shear was directly overheard. Since showers and wind shear are familiar by-products of cumulonimbus cloud formations, had the captain by chance not seen the cumulonimbus clouds, the advisory should have alerted the captain that such clouds were directly over the airport. Shortly after receiving the advisory, the captain advised the first officer to let his airspeed buildup on takeoff which was consistent with his having heard and understood the contents of the 1603:37 advisory concerning the presence of wind shears.

The wind sensor at the west end of runway 10 was inoperative. However, in this instance, the inoperative west sensor played no part in the accident sequence. Although the winds derived in the performance analysis indicated that there might have been a slight tailwind component during the initial segment of the takeoff roll, the wind switched rapidly to an increasing headwind. At liftoff, the headwind component was about 16 knots and was consistent with the winds noted at the centerfield sensor at this time.

Between 1600:13 and 1607:10, ATC transmitted nine wind shear advisories. An additional advisory was broadcast at 1609:03, 2 seconds after Clipper 759 hit the trees. The senior controller testified that wind shear alert advisories were issued whenever a LLWSAS alert was in progress and the information was operationally relevant to an airplane. The weight of the evidence confirmed this statement, and therefore, since Clipper 759 did not receive a wind shear alert advisory before takeoff, the Safety Board concludes that an operationally relevant wind shear alert was not in progress when Clipper 759 began its takeoff.

The Safety Board concludes that the captain had received adequate weather information from his company and from ATC to make an adequate assessment of the weather conditions at the airport.

Clipper 759's Weather Radar.--The captain had an operative weather radar which he could use to examine the weather along runway 10 and to the east of the airport. Based on the conversation on the CVR relating to a left turn after takeoff and on the fact that company procedures require that the weather radar system be used to check the departure area when possible thunderstorm activity is nearby, the Safety Board concludes that the captain did check the departure course with his weather radar.

The radar echoes seen on the weather radar systems of the air carrier airplanes and the Cessna Citation N31MT showed that there were level 3 echoes over the eastern part of the airport and just east of the airport. All these airplanes were at the eastern edge of the airport. Clipper 759 was about 1.5 nmi west of where these airplanes were located when these level 3 echoes were observed, and its weather radar antenna was "looking" at the area through rain. A properly functioning X-band weather radar would have indicated an area of precipitation over and to the east of runway 10. As stated earlier, the intensity of the weather echoes off the end of the runway 10 was greater than 40 dBZ and would have contoured on Clipper 759's weather radar, if it were operating properly. However, attenuation due to intervening rain along the axis of the radar beam could result in a contour not being displayed. At the time Clipper 759 lined up for takeoff, rain was falling near the departure end of the runway at a measured rate of about .5 in/hr; therefore, attenuation of the radar pulse would have occurred. The exact amount of this attenuation could not be determined. Considering the existing meteorological conditions, a 2-way attenuation on the order of several dBZ's was possible and would have been sufficient to prevent contouring of the cell activity along Clipper 759's takeoff path on its radar.

At the same time Clipper 759 began its takeoff, U.S. Air 404 was radar scanning the weather east of the airport. U.S. Air 404 was at the takeoff end of runway 10 and had a Bendix RDR-1-E radar system. The captain of U.S. Air 404 testified "I did see precipitation or an outline of rain. I did not see a contour." Based on the evidence, the Safety Board concludes that the weather radar echoes over and to the east of the airport did not contour on Clipper 759's radar.

The only information available concerning the intensity and location of the weather echo cells within 15 nmi of the New Orleans International Airport was the radar echoes shown on the airplane radars described earlier and on the Slidell, Louisiana, weather radar. The captain and pilot who observed level 3 weather echo cells on their radars did not relay this to ATC nor were they required to do so. The echo on the Slidell radar was a VIP level 2 cell; transmittal of this information to the captain by ATC, had it been available, would only have confirmed the captain's radar observations. Clipper 759's radar most probably showed level 1 to level 2 rain outlines; moreover, and of significant import, lightning and thunder were not occurring nor had these phenomena been reported on any weather observation. Based on the total data available to the captain concerning convective weather activity, it appeared that all that was occurring at the time was rain showers; company directives did not preclude the captain from taking off in these circumstances.

At the time the decision to take off was made, the last wind shear information was over 4 minutes old. Based on the evidence, wind shear relevant to his takeoff direction was not occurring. Company directives do not furnish flightcrews with any quantitative restrictions as to time intervals or severity for guidance in making the takeoff decision. In addition, Pan Am's FOM states that LLWSAS wind information "is strictly informational and no action is required unless deemed appropriate by the pilot."

The weight of the evidence showed that the winds which affected Clipper 759 were produced by a microburst which had occurred on the airport. The preliminary analysis of the JAWS data show that the microburst and downburst occurrences cannot be related to storm intensity. Therefore, neither the precise moment one will occur nor the numerical probability of such an occurrence can be forecast. The wind shear which affected Clipper 759 was not detected until after it began its takeoff. If meteorologists and current technology cannot predict the location, the frequency of occurrence, and severity of this type of wind shear, pilots cannot be expected to ordinarily or routinely predict where or when one will occur or to estimate its severity.

Operational Decisions.—In trying to assess whether the captain's decision to take off was reasonable, the Safety Board considered the guidelines contained in the Pan Am AOM and FOM concerning wind shear and thunderstorm avoidance, the weather information available to the flightcrew, the airplane's weather radar system, and the training and experience of the captain and the first officer.

The Safety Board believes that the wind shear information available to the industry does not provide sufficient guidance concerning wind shear avoidance. In particular, the data do not contain quantitative wind speed values which could be applied by pilots as a standard for refusing or delaying either a takeoff or an approach and landing. Consequently, the guidance contained in the Pan Am FOM, although generally considered the "state-of-the-art" information, did not contain any quantitative wind speed values which would indicate that the wind shear was of a magnitude that could approach or might exceed the capability of the airplane or pilot to fly through the phenomenon safely. Thus, the guidance in this area, unlike that concerning recommended minimum separation distances from thunderstorms, contain no quantitative wind speed parameters and no recommended courses of action for the pilot to follow should these parameters be approached or exceeded. Should quantitative wind speed parameters be established, the resultant parameters should be used to establish specific guidance or recommended courses of action for pilots to follow should the prescribed values contained therein be approached or exceeded.

The Safety Board believes that the LLWSAS could be used more efficiently and that more emphasis should be placed on its use in air carrier training programs. Pilots should be instructed that they can request wind direction and speed readouts from any remote sensor in the system and that the issuance of ATC LLWSAS wind shear advisories is dependent on the controller's higher priority traffic separation duties; therefore, when divergent wind flow conditions exist, it is incumbent on the pilot, in the absence of such an advisory, to request wind shear information from the controller before beginning the takeoff roll. In addition, pilots should be instructed that the wind speeds retrieved from any LLWSAS sensor may be lower than those existing at 75 to 200 feet AGL. Therefore, the sensor wind speed reading should be considered a conservative value for the purpose of estimating the magnitude of a wind shear. However, in evaluating the decision to take off, it is necessary to stress that the procedures noted above were not contained in any Pan Am manuals. According to the Pan Am FOM, the values derived from the LLWSAS were to be used for "informational purposes only." The Safety Board believes that the wind shear avoidance procedures based on LLWSAS information are essentially similar throughout the industry. Controller statements also show that pilots rarely delay takeoffs based solely on LLWSAS advisories.

The evidence also indicated that the flight simulator wind shear training exercises may tend to instill an unwarranted sense of security to the flightcrews rather than stressing wind shear avoidance. The exercises seem to indicate to the flightcrews that the wind shears may be flown through successfully by increasing the airspeed by 10 to 20 KIAS and then trading off the airspeed for altitude, if necessary, as the shear is penetrated. During the time Clipper 759 taxied from the gate toward runway 10, several wind shear advisories were received on its radio. Except for one advisory, none were directed to Clipper 759; however, the pilots were responsible for monitoring the radio for any information that would affect the conduct of the flight. Considering the weather conditions which existed at this time, the Safety Board believes that Clipper 759's pilots heard and were aware of the wind shear advisories received on their radio and had evaluated this data before beginning their takeoff. Although none of these advisories involved the east sensor, the magnitudes of the shears reflected in the advisories were about 10 to 15 knots; therefore, the captain, in his briefing, directed the first officer to "let your airspeed buildup on takeoff" allowing an airspeed increase above V2+10 KIAS in an effort to provide an airspeed margin to counteract the effects of a wind shear in the event one was encountered along the takeoff path. As a further precaution, he also briefed the flight engineer to turn off the air conditioning packs before takeoff and increase the thrust settings on engines Nos. 1 and 3.

The Pan Am FOM notes that wind shears and gust fronts can be associated with thunderstorms and that they are generally located within 5 to 10 miles of a thunderstorm. The FOM states that when "significant" thunderstorm activity is within 15 miles of the airport, the captain should take appropriate measures to avoid the storm. However, the determination of the severity of the thunderstorm and the measures to be used to avoid the thunderstorm and its associated hazards is vested in the captain, and that decision would be based on his training, experience, and judgment.

It was not possible to precisely determine how often the captain and first officer had encountered weather conditions similar to those which existed at takeoff on July 9, 1982. However, the captain and first officer were Miami-based and had flown National Airline's and Pan Am's southern routes since 1965 and 1976, respectively. From NOAA climatological data, thunderstorm occurrences during the 3 summer months in various cities served by the two airlines in Alabama, Florida, and Louisiana average about 45 days. Considering this, the Safety Board believes that the pilots were familiar with and had experience in dealing with the convective type weather occurring on July 9, 1982, and had successfully flown in such weather and evaluated its severity using their airplane weather radar systems.

The effect of rainfall on the capability of the X-band weather radar systems is well known and has been presented to flightcrews during their initial training in the use of the system, in operational bulletins, and in cautionary notes in the Pan Am FOM. Given the importance of the airplane's weather radar system in avoiding thunderstorms, the first officer's and captain's experience in flying in areas in which convective weather activity is predominant during the summer months, the Safety Board concludes that both pilots were competent in the use of their radar system, were familiar with its limitations, and would have considered the effects of these limitations in their evaluation of any convective returns they observed on their radarscope. The Safety Board has concluded that, due to the limitations of the X-band weather radar system, it was possible that the radar echoes east of the field would not have contoured on Clipper 759's radar. What the evidence does not show was the precise location of these echoes as portrayed on Clipper 759's radarscope.

From witness testimony, the captain's judgment and his ability to make timely and proper command decisions were rated excellent. His past record demonstrated that he had performed successfully under emergency conditions and in weather conditions similar to those which existed at New Orleans on July 9, 1982. His advice to his first officer to "let your speed build up on takeoff" showed that, based on the wind shear information known to him at that time, he was taking precautions to cope with a possible wind shear encounter. The direction to turn left after liftoff also showed that he had assessed the weather along his projected takeoff flightpath. His decision to take off indicated that, based on the portrayal shown on his radar, there were no thunderstorms directly over the takeoff runway and that the left turn after takeoff would place his airplane on a flightpath that would clear the radar echoes to the south and southeast of the airport in accordance with the parameters established in the Pan Am FOM. Given the captain's reputation for exercising superior judgment in the exercise of his command responsibilities, and given his performance record over the past 10 years as an airline captain, the Safety Board believes that it would be illogical to assume that he would decide to take off into thunderstorms which he had either observed visually or into contouring radar echoes which he had seen on his airplane's weather radar. Based on all of the factors cited above, the Safety Board concludes that the captain's decision to take off was reasonable.

2.5 Wind Shear Detection Systems

The Safety Board's investigation of this accident disclosed several matters which, although they were not causal to the accident, should be discussed. The New Orleans LLWSAS had been tested and evaluated with a functional west sensor. One week before commissioning the system, the west sensor was vandalized and rendered inoperative. The system, however, was commissioned without the west sensor. Since the system had been commissioned without the west sensor, and since the west sensor had never been repaired and commissioned, the manager of the FAA's Terminal Procedures Branch contended that it was never a component of the LLWSAS, and as a consequence, there was no requirement to insert this notification in the ATIS. Regardless of the FAA's contention, the Safety Board believes that the interests of safety demanded that pilots be aware that the west threshold of runway 28 -- an ILS runway -- was not protected by an LLWSAS sensor and that no LLWSAS wind data for that end of the runway was available. The Safety Board concludes that, given the continuing inoperative status of the west sensor, the FAA should have issued a NOTAM stating that the sensor was not in operation.

Until NEXRAD is in place and commissioned, the LLWSAS is likely to be the only system in existence which can and will, within its demonstrated limitations, inform pilots of the location and magnitude of an existing wind shear. Despite its potential benefits, the only data presently available to a pilot concerning a particular LLWSAS at a particular airport is a note on the airport's runway diagram that the airport has an LLWSAS in commission. There is no diagram or map depicting the location of the sensors described by the controller in an alert advisory. In addition, during the investigation, the Safety Board was not able to find any maps or charts depicting the New Orleans LLWSAS on display where it could be seen by the pilots. Also, the Safety Board has not discovered any data, to date, to indicate that this situation was peculiar solely to the New Orleans International Airport. The Safety Board believes that knowledge of the precise location of the LLWSAS's sensors relative to an airport's runways would enhance the pilot's ability to evaluate the LLWSAS information given by controllers.

The Safety Board also believes that the manner in which LLWSAS wind shear alert information is presented could be improved. The wind shear alert information would be more meaningful if it were presented to the pilots as either a head wind, a tailwind, or a crosswind shear relative to the runway being used. The direction of the shear should be accompanied by its magnitude. In cases where crosswind shears in excess of a specified minimum value are combined with either a headwind or tailwind, shear direction and magnitude of both components should be provided. The Safety Board believes that the LLWSAS computers could be modified to present LLWSAS wind data in this format, and that the issuing of advisories based on the revised format would not pose a serious burden to controllers.

Since the end of 1979, the FAA has not funded any research and development activities regarding airborne wind shear detection systems. Presently, airborne systems are available which are based on (1) groundspeed-airspeed comparison; (2) energy rate management; (3) a combination of features from the above systems combined with improved steering commands in modified flight director systems such as the MFD-delta-A. All improve pilot performance in the wind shear environment, and according to Report RD-117, the best results were obtained with the MFD-delta-A system. However, none of these systems are capable of "looking ahead" and informing the pilot of wind shear in front of his airplane.

During the JAWS project, a HS-125 with forward looking Doppler LIDAR radar was tested and evaluated. This system did detect wind shear in front of the airplane, but it only provided a 6-second lead time. Given the facts of this accident sequence, equipment such as the LIDAR system would not have provided sufficient lead time to avoid this wind shear encounter. The Safety Board believes the Task 2 data have demonstrated that airborne wind shear detection systems can improve pilot performance in wind shear, but they have not been perfected to predict the presence of wind shear sufficiently ahead of the airplane. Since the results of the AWLS Task 2 program show that there are realistic wind profiles in which even operation at the limit of airplane capability "is not enough to prevent ground contact," the Safety Board believes that programs must be pressed to develop airborne and ground systems with greater lead time predictive capabilities.

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 properly, and each crewmember had received the training and off-duty time prescribed by Federal regulations. There was no evidence of preexisting medical or physiological problems that might have affected their performance.

3. The ATC controllers on duty in the New Orleans tower were certificated properly, and each controller had received the training and off-duty time prescribed by FAA regulations.

4. The flight folders supplied to Clipper 759's flightcrew contained the required weather data. The forecasts therein were current and substantially correct.

5. Clipper 759's takeoff gross weight required the captain to use runway 10 for the takeoff.

6. At 1609, VIP level 3 weather echo were located over the eastern part of the airport and east of the departure end of runway 10. Lightning and thunder were not occurring either before or during Clipper 759's takeoff.

7. The most probable rainfall rates at the departure end of runway 10 and east of the departure end were .5 in/hr and 1.8 in/hr, respectively. The maximum possible rainfall rate near the departure end of the runway was in the area of 5.7 in/hr.

8. Between the time of liftoff and the time the airplane reached the tree line on Williams Boulevard, Clipper 759 experienced a decreasing headwind shear of about 38 knots and a 7 fps downdraft at 100 feet AGL. The wind shear was caused by diverging flow from a microburst which occurred on the New Orleans International Airport. The performance analysis indicated that, at 5.9 seconds before initial impact, had the pilot been able to increase the airplane's pitch attitude and maintain the indicated airspeed that existed at that time, Clipper 759 theoretically would have been able to maintain an altitude of 95 ft AGL. This theoretical evaluation is based on a static analysis of the airplane's instantaneous performance capability; the evaluation does not include any allowances for pilot recognition, perception, and reaction time.

9. The wind shear which affected Clipper 759's takeoff was not detected by the LLWSAS until after Clipper 759 began its takeoff.

10. The airplane was not equipped, nor was it required to be equipped, with flight instrument systems designed to sense wind shear and instantaneously provide information required to counter the effects of wind shear.

11. The first officer was not able to arrest the airplane's descent rate in sufficient time to prevent the accident.

12. The captain had received adequate weather information from his company and from ATC to make an adequate assessment of the weather conditions at the airport.

13. According to the Pan Am FOM and AOM, the captain is responsible for evaluating the severity of the weather and based on this appraisal, he is responsible for choosing the most appropriate course of action.

14. The ASR-8 radar at the New Orleans TRACON displays precipitation echoes; however, it does not incorporate equipment which can determine and differentiate weather echo intensity.

15. ATC did not issue an ATIS message reflecting the 1455 surface weather observation; however, the flightcrew of Clipper 759 had read the 1455 observation in Pan Am's Operations Office.

16. ATIS "G", which reflected the 1603 special weather observation, was issued before Clipper 759 took off, but Clipper 759's flightcrew did not see the 1603 special observation, nor did they receive ATIS "G". However, the flightcrew of Clipper 759 had received the pertinent information contained in the 1603 special observation and in ATIS "G".

17. The LLWSAS's west sensor had been vandalized and was inoperative; however, the inoperative west sensor was not a causal factor in the accident.

18. The captain was aware that LLWSAS alerts were occurring periodically around the airport.

19. According to the Pan Am AOM, LLWSAS wind information "is strictly informational, and no action is required unless deemed appropriate by the pilot."

20. The captain used his weather radar before takeoff to check the weather along his departure path. The rain falling along and east of runway 10 would have attenuated the radar pulse from Clipper 759's weather radar. The attenuation may have been sufficient to prevent contouring of the cell activity along Clipper 759's takeoff path.

21. The captain's decision to take off was reasonable in light of the information that was available to him.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the airplane's encounter during the liftoff and initial climb phase of flight with a microburst-induced wind shear which imposed a downdraft and a decreasing headwind, the effects of which the pilot would have had difficulty recognizing and reacting to in time for the airplane's descent to be arrested before its impact with trees.

Contributing to the accident was the limited capability of current ground based low level wind shear detection technology to provide definitive guidance for controllers and pilots for use in avoiding low level wind shear encounters.

4. RECOMMENDATIONS

As a result of problems experienced with flight data and cockpit voice recorders in this accident and several other accidents, the Safety Board issued the following six recommendations to the Federal Aviation Administration on July 13, 1982.

> Initiate a program involving all U.S. operators using United Control Corporation (Sundstrand) 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. (Class I, Urgent Action) (A-82-62)
>
> After a specified period of not more than 2 years, require the removal of all United Control Corporation (Sundstrand) V-557 cockpit voice recorders and installation of suitable replacements. (Class II, Priority Action) (A-82-63)
>
> Amend 14 CFR 121.343 so that, after a specified date, all turbojet aircraft manufactured before that date and type-certificated before September 30, 1969, be required to have installed a suitable digital recorder system capable of recording data from which the minimum following information may be determined as a function of time within the ranges, accuracies, and recording intervals specified in Table I-- altitude, airspeed, heading, radio transmitter keying, pitch attitude, roll attitude, vertical acceleration, longitudinal acceleration, stabilizer trim position, engine thrust, and pitch control position. (Class II, Priority Action) (A-82-64)
>
> At an early date and pending the effective date of the recommended amendment of 14 CFR 121.343 to require installation of digital flight data recorder systems capable of recording more extensive parameters, require that operators of all aircraft equipped with foil flight data recorders be required to replace the foil recorder with a compatible digital recorder. (Class I, Urgent Action) (A-82-65)
>
> Amend 14 CFR 121.343 so that, after a specified date, all aircraft manufactured after that date, regardless of the date of original type certificate, be equipped with one or more approved flight recorders that record data from which the information listed in Table I can be determined as a function of time. For newly type-certificated aircraft, any dedicated parameter which may be necessary because of unique features of the specific aircraft configuration and the type design should also be required. (Class II, Priority Action) (A-82-66)
>
> Amend 14 CFR 127, Subpart H, to require that all rotorcraft manufactured after a specified date, regardless of the date of original type certificate, be equipped with one or more approved

> flight recorders that record data from which the information listed in Table II can be determined as a function of time. For newly type-certificated rotorcraft, any dedicated parameter which may be necessary because of unique features of the specific configuration and type design should also be required. (Class II, Priority Action) (A-82-67)

As a result of its complete investigation of this accident, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Review all Low Level Wind Shear Alert System installations to identify possible deficiencies in coverage similar to the one resulting from the inoperable west sensor at New Orleans International Airport and correct such deficiencies without delay. (Class II, Priority Action) (A-83-13)

> Make appropriate distribution to the aviation community of information regarding (1) the location and designation of remote sensors of the Low Level Wind Shear Alert System (LLWSAS) at equipped airports, (2) the capabilities and limitations of the LLWSAS, and (3) the availability of current LLWSAS remote sensor information if requested from tower controllers. (Class II, Priority Action) (A-83-14)

> Record output data from all installed Low Level Wind Shear Alert System sensors and retain such data for an appropriate period for use in reconstructing pertinent wind shear events and as a basis for studies to effect system improvements. (Class II, Priority Action) (A-83-15)

> Emphasize to pilots on a continuing basis the importance of making prompt reports of wind shear in accordance with prescribed reporting guidelines, and assure that Air Traffic Control personnel transmit such reports to pilots promptly. (Class II, Priority Action) (A-83-16)

> Require that Automatic Terminal Information Service advisories be amended promptly to provide current wind shear information and other information pertinent to hazardous meteorological conditions in the terminal area as provided by Center Weather Service Unit meteorologists, and that all aircraft operating in the terminal area be advised by blind broadcast when a new Automatic Terminal Information Service advisory has been issued. (Class II, Priority Action) (A-83-17)

> Evaluate methods and procedures for the use of current weather information from sources such as radar, Low Level Wind Shear Alert Systems, and pilot reports as criteria for delaying approach and departure operations which would expose the flight to low altitude penetration of severe convective weather. (Class II, Priority Action) (A-83-18)

Study the feasibility of establishing aircraft operational limitations based on the data available from the Low Level Wind Shear Alert System. (Class II, Priority Action) (A-83-19)

Make the necessary changes to display Low Level Wind Shear Alert System wind output data as longitudinal and lateral components to the runway centerline. (Class II, Priority Action) (A-83-20)

Use the data obtained from the Joint Airport Weather Studies (JAWS) Project and other relevant data as a basis to (1) quantify the low-level wind shear hazard in terms of effect on airplane performance, (2) evaluate the effectiveness of the Low Level Wind Shear Alert System and improvements which are needed to enhance performance as a wind shear detection and warning system, and (3) evaluate the aerodynamic penalties of precipitation on airplane performance. (Class II, Priority Action) (A-83-21)

As the data obtained from the Joint Airport Weather Studies (JAWS) Project become available (1) develop training aids for pilots and controllers to emphasize the hazards to flight from convective weather activity, (2) develop realistic microburst wind models for incorporation into pilot flight simulator training programs, and (3) promote the development of airborne wind shear detection devices. (Class II, Priority Action) (A-83-22)

Expedite the development, testing, and installation of advanced Doppler weather radar to detect hazardous wind shears in airport terminal areas and expedite the installation of more immediately available equipment such as add-on Doppler to provide for detection and quantification of wind shear in high risk airport terminal areas. (Class II, Priority Action) (A-83-23)

Encourage industry to expedite the development of flight director systems such as MFD-delta-A and head-up type displays which provide enhanced pitch guidance logic which responds to inertial speed/airspeed changes and ground proximity and encourage operators to install these systems. (Class III, Longer Term Action) (A-83-24)

Recommend to air carriers that they modify pilot training on simulators capable of reproducing wind shear models so as to include microburst penetration demonstrations during takeoff, approach, and other critical phases of flight. (Class II, Priority Action) (A-83-25)

Advise air carriers to increase the emphasis in their training programs on the effective use of all available sources of weather information, such as preflight meteorological briefings, ATIS broadcasts, controller-provided information, PIREPS, airborne weather radar, and visual observations, and provide added guidance to pilots regarding operational (i.e., "go/no go") decisions involving takeoff and landing operations which could expose a flight to weather conditions which could be hazardous. (Class II, Priority Action) (A-83-26)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ G. H. PATRICK BURSLEY
Member

/s/ DONALD D. ENGEN
Member

March 21, 1983

5. APPENDIXES

APPENDIX A

INVESTIGATION AND PUBLIC HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident about 1800 e.d.t., on July 9, 1982, and immediately dispatched an investigative team to the scene from its Washington, D.C., headquarters. Investigative groups were formed for operations, air traffic control, witnesses, human factors, human performance, structures, powerplants, systems, flight data recorder, maintenance records, cockpit voice recorder, and airplane performance.

Parties to the investigation were the Federal Aviation Administration, Pan American World Airways, Inc., Boeing Airplane Company, Air Line Pilots Association, Flight Engineers International Association, United Technologies Corporation, and the International Union of Flight Attendants.

2. Public Hearing

A 4-day public hearing was held in Kenner, Louisiana, beginning September 14, 1982. Parties represented at the hearing were the Federal Aviation Administration, Pan American World Airways, Inc., Boeing Airplane Company, Air Line Pilots Association, Flight Engineers International Association, and the National Weather Service.

One deposition was taken on March 2, 1983.

APPENDIX B

PERSONNEL INFORMATION

Captain McCullers

Captain Kenneth L. McCullers, 45, was 6 feet 1 inch tall and weighed about 190 pounds. The captain was employed by National Airlines, Inc., on August 16, 1965. He held Airline Transport Pilot Certificate No. 1570394 with an airplane multiengine land rating and commercial privileges in airplane single engine land. He was type rated in B-727 airplanes. His last first class medical certificate was issued April 12, 1982, and he was required to "wear lenses that correct for distant vision and possess glasses that correct for near vision while exercising the privileges of his airman certificate." On June 24, 1980, he had been issued a Statement of Demonstrated Ability, No. 40D68015, for defective vision in his left eye (20/50 corrected to 20/30). His medical examinations were otherwise unremarkable.

Captain McCullers qualified as captain in the B-727 on January 20, 1972. He passed his last proficiency check on January 13, 1982; his last line check on January 23, 1982; and he completed recurrency training on July 24, 1981. The captain had flown 11,727 hours, 10,595 of which were in the B-727. During the last 90 days, 30 days, and 24 hours before the accident, he had flown 212 hours, 47 hours, and 1 hour, respectively. At the time of the accident, the captain had been on duty about 3 hours 45 minutes, 1 hour of which was flight time.

During the 90 days before the accident, the captain had made five arrivals and departures at the New Orleans International Airport.

First Officer Pierce

First Officer Donald G. Pierce, 32, was 6 feet 2 inches tall and weighed about 225 pounds. The first officer was employed by National Airlines, Inc., on December 20, 1976. He held Commercial Pilot Certificate No. 276807536 with airplane multiengine land and instrument ratings. He was type rated in the Lockheed L-300 airplane. His first class medical certificate was issued December 29, 1981, and contained no limitations. The first officer had suffered a kidney stone problem which was corrected in December 1978. His medical examinations were otherwise unremarkable.

First Officer Pierce qualified as first officer in the B-727 on January 21, 1977. He passed his last proficiency check on February 13, 1982, and completed recurrency training on July 7, 1982. The first officer had flown 6,127 hours, 3,914 of which were in the B-727. During the last 90 days, 30 days, and 24 hours before the accident, he had flown 186 hours, 84 hours, and 1 hour, respectively. At the time of the accident, the first officer's duty hours were the same as the captain's.

Flight Engineer Noone

Flight Engineer (Second Officer) Leo B. Noone, 60, was employed by National Airlines, Inc., on June 19, 1967. He held Flight Engineer Certificate No. 1233362 with reciprocating engine and turbojet engine power airplane ratings. His second class medical certificate was issued on April 21, 1982, and required him to wear glasses which corrected for near and distant vision while exercising the privileges of his airman certificate. No waivers were issued and all medical examinations were unremarkable.

Flight Engineer Noone qualified in the B-727 on July 30, 1968. He passed his last proficiency check on July 29, 1981, and completed recurrency training January 18, 1982. The first engineer had flown 19,904 hours, 10,508 of which were in the B-727. During the last 90 days, 30 days, and 24 hours before the accident, he had flown 226 hours, 83 hours, and 1 hour, respectively. At the time of the accident, the flight engineer's duty hours were the same as the captain's.

Cabin personnel were also trained and qualified in accordance with current regulations.

ATC personnel were trained and qualified in accordance with current regulations.

APPENDIX C

AIRPLANE INFORMATION

Boeing 727-235, N4737

The airplane, manufacturer's serial No. 19457, was delivered to National Airlines, Inc., on January 3, 1968, and had been operated by the airline continuously since that time. A review of the airplane's flight logs and 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 engines rated at 14,000 lbs of thrust at 84 F.

The following is pertinent statistical data:

Airplane

Total Aircraft Time	-	39,253 hours
Total Airframe Cycles	-	35,643
Last Base Check	-	6/18/82
Last "B" Check	-	4/26/82
Last Heavy Service	-	12/8/80

Powerplants

Engine	No. 1	No. 2	No. 3
Serial Number	654851	655137	653683
Date Installed	12/2/80	11/15/81	6/8/82
Time Since Installation	4,191 hours	1,658 hours	210 hours
Cycles Since Installation	2,257	887	129
Total Time	29,900 hours	25,581 hours	31,337 hours
Total Cycles	27,499	22,245	30,034

APPENDIX D

TRANSCRIPT OF A MODEL V-557 COCKPIT VOICE RECORDER, S/N 1832 REMOVED FROM A PAN AMERICAN B-727 WHICH WAS INVOLVED IN AN ACCIDENT AT KENNER, LOUISIANA, ON JULY 9, 1982

LEGEND

CAM	Cockpit area microphone voice or sound source
RDO	Radio transmission from accident aircraft
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Flight Engineer
-4	Voice identified as jump seat rider
-5	Voice identified as female Flight Attendant
-6	Voice identified as male Flight Attendant
-7	Voice identified as Ground employee
-?	Voice unidentified
UNK	Unknown
ATIS	New Orleans Automatic Terminal Information Service
INT SI	Ground crewmember
INT1	Captain on interphone
CO	Pan American Operations (PAN OP) New Orleans
PA	Public address announcement
CD	New Orleans Clearance Delivery
LC	New Orleans Tower
GC	New Orleans Ground Control
N1MT	Other aircraft
NO3B	Other aircraft
SW 860	Other aircraft
EA 956	Other aircraft
PHM 66K	Other aircraft
TI 794	Other aircraft
AL 404	Other aircraft
RAY 433	Other aircraft
N5MR	Other aircraft
N58RD	Other aircraft
N58 EV	Other aircraft
*	Unintelligible word
#	Non pertinent word
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause

Note: All times are expressed in Greenwich Mean Time. Duplication of some transmissions made on RDO-1, RDO-2, and RDO-3 are heard on CAM. However, for clarity, they are omitted from this transcript.

INTRA-COCKPIT

TIME & SOURCE	CONTENT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2048:02 N58 EV	Okay sir cleared out of the TCA climb and maintain four thousand five hundred feet, departure one two three point eight five and squawking oh four five six, thank ya
2048:09 TI 794	Clearance (Texas) seven ninety four clearance to Houston
2048:13 CD	Baron eight echo victor roger ground one twenty one nine
2048:15 CD	Ah clipper seven fifty nine Moisant clearance
2048:18 RDO-2	Go ahead
2048:20 CD	Clipper seven fifty nine cleared to the Las Vegas Airport as filed, maintain five thousand, expect flight level two eight zero one zero minutes after departure, departure frequency will be one two three point eight five squawk seven four two seven
2048:37 RDO-2	Clipper seven fifty nine cleared to Las Vegas as filed, maintain five thousand, expect two eight oh in ten minutes, departure one two three eight five, squawk seven four two seven

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2052:06 CAM-2	Cleared as filed
2052:09 CAM-?	Roger
2052:11 CAM-?	•

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2048:46 CD	Clipper seven fifty nine roger, good day
2048:50 CD	Texas seven ninety four
2048:53 GC	(Delta) sixteen twenty one, Moisant ground taxi to runway one nine foxtrot is current, hold short of the east west runway
2051:40 INT SI	Cockpit this is ground
2051:42 INT-3	Yep
2051:43 INT SI	Would you like me to raise the rear air-stairs or have the flight attendants do it
INT-3	No we'll have them raise them up here
2051:48 INT SI	Ah roger
2051:58 PA-3	Raise the aft stairs please

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2052:13 CAM-?	(Cabin)
2052:15 CAM-2	Leo
2052:19 CAM-2	No smoking, seatbelts
2052:20 CAM-1	On
2052:22 CAM-2	Windows
2052:23 CAM-1	Closed, heat set
2052:24 CAM-2	Closed on the right
2052:36 CAM-2	Altimeters
2052:37 CAM-1	Set, cross checked *
2052:40 CAM-2	Engineer's preflight

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2052:24 INT SI	Dagone catering truck had been finished, I'd beat this rain we got coming
2052:29 INT-1	Yeah I figured it ah that it would be here before now from the looks of the radar when we came in here
2052:35 INT SI	I can see it movin across the ramp alot heavier ah

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
2052:41 CAM-3	Complete		
2052:42 CAM-2	Fluid service		
2052:43 CAM-3	Forty four five hundred oil and hydraulics		
2052:45 CAM-2	Takeoff bugs ninety ninety two, one thirty eight, one fifty (one)		
2052:50 CAM-1	One sixty nine five		
2052:51 CAM-?	(One seventy)		
2052:54 CAM-2	Four eight oh four		
2052:54 CAM-1	A hundred and seventy thousand pounds		
2052:56 CAM-2	Eight hundred		
2053:01 CAM	((Sound of stabilizer being set))		
2053:04 CAM-2	Set		
2053:06 CAM-2	Shoulder harnesses		

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
2053:07 CAM-1	Fastened		
2053:08 CAM-2	Fastened right		
2053:10 CAM-2	ATIS and ATC clearance		
CAM-?	Thank you		
2053:12 CAM-1	* direct to ah		
CAM-3	I thought you'd never ask		
2053:14 CAM-1	Alexandria * ((pronounciation of word extended))		
CAM-5	(You guys like some water?)		
2053:17 CAM-2	Start checklist next		
CAM-?	((Unintelligible conversation C3, C5, C6))		
2053:28 CAM-5	(Huh?)		
CAM-?	*		
2053:31 CAM-6	Fourteen one twenty two		
CAM-?	*		

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
2053:33 CAM-6	Fourteen and one twenty two captain over here		
2053:34 CAM-3	Okay		
2053:47 CAM-1	Last ah July taking off (from) Las Vegas, we threw a tire cap out and off this thing, went back and on the way back, it separated just at liftoff, and ah went back and hit the top of the ah		
CAM-?	●		
2054:10 CAM-1	Hit the * fairing		
2054:12 CAM-7	What's your last name		
2054:13 CAM-1	McCullers		
2054:14 CAM-7	McCullers?		
2054:15 CAM-1	McCullers, uh huh		
CAM-?	* *		
CAM-?	* *		
		2054:17 RDO-2	Clipper seven fifty nine to push out of seven

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
		2054:21 GC	Clipper seven fifty nine Moisant ground ah roger on the push, traffic is a pushed back ah southwest seven thirty seven
2054:22 CAM-1	Went back and knocked the ah fairing off the ah jackscrew ah left jackscrew, went on back from there and hit the number three engine, left a big --- dent in (the) leading edge		
CAM-?	* *		
CAM-2	*		
		2054:28 RDO-2	Okay
2054:38 CAM-1	And when I think about how close it was to injesting that # thing and ninety eight degree temperature out (there), no way		
2054:55 CAM-1	I thought we had gotten a compressor stall		
2055:00 CAM-3	(Pump)		
2055:03 CAM-1	So I don't do any more five degrees of flap slow rotation ah at high temperatures *	2055:03 GC	Texas seven ninety four hold
		2055:04 TI 794	Roger Texas seven ninety four holding short of two eight

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2055:12 CAM-?	No
2055:40 CAM-2	(With this) thing, any more than one knot of tailwind and we wouldn't be legal for fifteen
2055:45 CAM-1	No #

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2055:06 GC	Roger Texas seven ninety four thank you
2055:17 SW 860	Southwest eight sixty taxi with foxtrot
2055:23 GC	Southwest eight sixty Moisant ground, taxi to runway one niner, ah foxtrot is current ah hold short of the east west runway
2055:30 SW 860	Southwest eight sixty any chance of two eight?
2055:34 GC	Ah southwest eight sixty, that's ah, negative, unable at this time due to inbound traffic to ten
2055:40 AL 404	Ah ground U.S. Air four on four, we're still at the gate ah any chance of one
2055:41 INT SI	Well they're finally backin out now okay cleared for push back, brakes off

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2055:47 CAM-2	With this thing
2055:51 CAM	((Three mechanical clicks))
2056:07 CAM-1	Door lights out now
CAM-3	Yeah
2056:20 CAM-3	What do you want to call the time (Kenny) ((Sound of whistling))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2055:49 GC	U.S. Air four oh four, runway one is noise sensitive ah for departures, advise your intentions
2055:51 INT-1	I'm trying to get 'em okay there they are, brakes released
2055:56 INT SI	Ah roger
2055:57 AL 404	Roger we'll have to look at the weather
2056:11 INT SI	And we're gonna let southwest squeeze out behind us now since he already started his swing around
2056:14 INT-1	Okay
2056:23 AL 404	And Ground U.S. Air four oh four push back

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2056:28 CAM-1	Whatever it is I guess, about ah (fifty five fifty seven)
2056:36 CAM-(7)	We've got fourteen one twenty two cabin secure
2056:54 CAM-3	Start pressure (*) forty pounds, pumps on

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2056:25 GC	U.S. Air four oh four Moisant ground roger on the push
2056:34 GC	Southwest eight sixty hold short abeam the wind sock ah you'll be ah it'll be for sequencing
2056:37 INT SI	Engines one two and three cleared to start
2056:40 INT-1	Okay
2056:41 SW 860	Sixty
2056:41 INT SI	Is it okay if I give you a kind of a fast wave off out there, I didn't have a chance to get any rain gear on me
2056:46 INT-1	Sure enough, yeah as soon as you get us out there you can cut out, if we have problems we can call you
2056:53 INT SI	Ah roger, thank you

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2057:00 CAM	((Sound of click))
2057:00 CAM-1	(Start check)
2057:01 CAM-2	Start check, parking brake
2057:01 CAM-1	(The parking) brake's off
2057:02 CAM-2	Beacon's on, engineer's start check
2057:03 CAM-3	Complete
2057:06 CAM-2	Start checklist is completed
2057:07 CAM-3	Turning one
2057:07 CAM	*((Irrelevant conversation between captain and unidentified male flight attendant))*

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2057:08 UNK	*
2057:17 GC	Texas seven ninety four continue holding short landing traffic
2057:20 TI 794	Roger
2057:24 RAY 433	**And Royale four thirty three to the gate**

INTRA-COCKPIT

TIME & SOURCE		CONTENT
2057:30	CAM-1	Normal fuel and light
2057:38	CAM	((Tap tap sound))
2057:40	CAM-3	Valve closed
2057:40	CAM-3	Turn two
2057:43	CAM-3	Valve open
2057:59	CAM	((Electronic sound identified as an engine ignitor))
	CAM	((Tap tap sound))
2058:06	CAM-1	(Normal fuel and a light)
	CAM	((Tap tap sound))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE		CONTENT
2057:27	GC	Royale four thirty three Moisant ground taxi to the gate
2057:31	RAY 433	Okay
2057:33	INT SI	Set brakes
2057:36	INT-1	Okay the brakes are set
2057:40	INT-1	Turning two
2057:40	INT SI	Roger
2058:05	GC	Texas seven ninety four cross the east west runway
2058:07	TI 794	Seven ninety four

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
2058:10 CAM	((Tap tap sound))		
2058:11 CAM-3	Valve closed		
CAM	((Tap tap sound))		
2058:16 CAM-3	Valve open		
2058:19 CAM-1	Temperature ah causes the ah •		
		2058:21 INT SI	Okay all ground equipment's removed, torsion links connected, clearing off head set and I'll see you all out front
		2058:28 INT-1	So long now ((sound of mike being keyed twice))
		2058:34 N5MR	Ground five mike romeo is clear of one zero
2058:36 CAM	((Tap tap sound))		
		2058:38 GC	Five mike romeo Moisant Ground hold your position ah outbound traffic is a Citation
2058:39 CAM-3	Valve closed		
2058:40 CAM-?	Roger		
2058:44 CAM-2	Clear right	2058:44 N5MR	Okay we got him
2058:47 CAM	((Tap sound))		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2059:15 CAM-2	Pretaxi check cabin report
2059:17 CAM-3	Secure
2059:19 CAM-2	Door lights
2059:20 CAM-3	They're (off)
2059:21 CAM-2	Anti-ice

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2058:48 RDO-2	Clipper seven fifty nine taxi and we need runway ten
2058:52 GC	Clipper seven fifty nine, roger ah taxi to runway one zero amend initial altitude four thousand ah departure frequency will be one two zero point six
2059:03 RDO-2	Twenty point six and four thousand clipper seven fifty nine what is your wind now
2059:09 GC	Wind zero four zero at eight
2059:16 AL 404	Ah U.S. Air four oh four taxi
2059:20 GC	U.S. Air four oh four Moisant ground taxi to runway one niner, hold short of the east west runway, five mike romeo taxi to the west ramp

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2059:23 CAM-2	Wing closed, engine closed, pitot's on and checked, pretaxi check's complete
2059:34 CAM	((Mechanical sound attributed to positioning of flap control lever))
2059:38 CAM-1	(Can't see anything now right there)
CAM-2	(Yes sir)
2059:52 CAM	((Mechanical sound attributed to windshield wipers))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2059:26 RDO-3	* Pan Ops clipper seven (fifty) nine (any) corrections?
2059:30 N5MR	Five mike
2059:33 CO	Okay ah are you ready to copy sir?
RDO-3	Okay go ahead
2059:38 CO	Eh zero fuel weight one two five point five, M.A.C. twenty five point four, takeoff weight one sixty nine point five, twenty one point two and you have a total of a hundred and thirty six on board
2059:43 AL 404	U.S. Air ah four oh four the wind sock is straight (out) and down runway nineteen, we (wanta) go to ten
2059:55 RDO-3	Okay seven fifty nine and eh we were off the blocks at five five

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2059:58 CAM-2	(Wipers aren't too hot)
2100:04 CAM-1	Checklist
2100:11 CAM-2	Taxi check, wing flaps
2100:13 CAM-1	Fifteen, fifteen, green
2100:17 CAM-2	Yaw dampers and instruments
CAM	((Sound of cough))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2059:56 GC	U.S. Air ah four oh four wind zero three zero degrees at one zero, say your intentions
2100:01 CO	Five five thank you sir
2100:03 UNK	* request runway one
2100:04 RDO-3	Okay we'll see ya
2100:06 AL 404	Runway ten for ah four oh four
2100:12 GC	U.S. Air four oh four taxi to runway one zero amend your initial altitude to read climb and maintain four thousand departure frequency now one two zero point six rest of your clearance remains the same

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2100:21 CAM-1	Checked
2100:25 CAM-2	Checked on the right side, controls
CAM-1	Right (turn)
2100:30 CAM-2	Weight and balance finals
2100:32 CAM-1	Watch yourself
2100:33 CAM-1	Left turn (looks like) a right
2100:38 CAM-1	We do have the right of way here, don't we?
2100:39 CAM-2	Yes
2100:44 CAM-3	One sixty nine five hundred
2100:51 CAM-2	No significant change(s)
2100:53 CAM-3	Twenty one point two on the stabilizer

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2100:21 AL 404	Four thousand one twenty point six
2100:23 GC	One mike tango taxi continue taxiing straight ahead pull up behind the er southwest there and er keep the Pan Am clipper off to your right
2100:32 GC	U.S. Air four oh four follow the Pan Am clipper and clipper keep off to the left, you have opposite direction Citation
2100:37 AL 404	Four oh four follow Pan Am
2100:39 GC	Clear the intersection inbound that er heavy

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2100:53 CAM-2	Set
2101:00 CAM-2	Engineer's taxi check
2101:04 CAM-3	Complete
2101:08 CAM-2	Takeoff and departure briefing
2101:10 CAM-1	It'll be a heavy ah takeoff (at the present time here) so ah if we have to take ah, if we have to abort for any reason, you'll have the throttles, get all we can out of 'em now so if we bust one (before) vee one, we'll stop and we'll ah stand on the brakes Don
2101:34 CAM-2	Yes sir
2101:39 CAM-1	If it's ah past vee one, go ahead and starting dumping Leo

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2101:21 N58RD	And Ground eight RD heavy is off one zero going to the west ramp
2101:26 GC	Five seven RD Moisant ground ah for the west ramp give way the aircraft ah DC nine and the seven twenty seven
2101:32 N58RD	All right sir, we're giving way

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
2101:42 CAM-3	Okay		
2101:45 CAM-1	Depending on the ah		
2101:48 CAM-3	Want the fueling panel (open)		
2101:50 CAM-1	If it's climbing okay *		
2101:52 CAM-3	Verified		
CAM	((Sound of two mechanical clicks))		
2101:57 CAM-2	Taxi checklist complete		
		2102:03 GC	Citation one mike tango taxi ah taxi around the southwest he's holding for flow control
		2102:08 NIMT	Mike tango roger
		2102:12 GC	Five seven RD taxi (to) west ramp
		2102:14 N58RD	Five eight RD roger
2102:16 CAM-?	* B four *	2102:16 GC	Five eight RD
2102:17 CAM-?	*		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
2102:25 CAM-1	How did your (B four check) go		
2102:30 CAM-2	Pretty good, he asked us about this, he said what's the first thing you do on a rejected takeoff? that the FAA has been askin	2102:30 N1MT	And mike tango what's that wind doing now please?
		2102:34 GC	Wind ah zero six zero degrees at one five, peak gusts two five, low level wind shear alert at, at northeast quadrant three three zero degrees at one zero northwest quadrant one three zero degrees at three
2102:39 CAM-1	As for after the abort?		
2102:41 CAM-2	No, no, during the abort, as soon, if you see the need to abort what's the first thing you do?		
		2102:47 N1MT	Okay, thank you
2102:48 CAM-1	Pull the ((tap)) throttles off, ((tap)) speed brake, ((tap)) reverse, steppin on the brakes all at the same time, what's the (answer supposed to be on it?)		
2102:54 CAM-2	Brakes	2102:54 N1MT	Is mike tango cleared to cross the east west?
2102:55 CAM-1	Brakes?		
2102:56 CAM-2	Brakes		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2102:57 CAM-1	The thing, the thing is to bear in mind ((tap)) this is what so many guys forget
2103:02 CAM-2	Yeah
2103:03 CAM-1	In any abort, now I've had quite a few aborts and ah this is the big item right here
CAM-?	• • (putting it) out (here) ((the two unintelligible words are superimposed on words "big item right here" by C1))
2103:14 CAM-?	(Wait)
2103:26 CAM-1	Now we might have to turn around and come back

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2103:00 GC	One three mike ah correction, three one mike tango, cross the east west runway
2103:03 N1MT	Mike tango
2103:09 SWA 860	Ground southwest eight sixty with the present wind conditions we're request-ing two eight for departure
2103:19 GC	Southwest weight sixty roger see what we can work for you
2103:24 N1MT	And ah ground thirty one mike tango is also requesting two eight

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2103:30 CAM-2	Yeah
2103:31 CAM	((Sound of click))
2103:32 CAM-?	((Sound of cough))
2103:56 CAM-?	* *
2103:57 CAM-1	Let your airspeed build up on takeoff, takeoff
2104:08 CAM	((Tap tap tap sound))
CAM	((Electronic buzz sound))
2104:23 CAM-1	Leo, you want to (do) a no packs takeoff on this thing
2104:25 CAM-?	((Sound of whistling))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2103:29 GC	One mike tango roger stand by
2103:33 RDO-2	What are you winds now
2103:37 GC	Winds now zero seven zero degreees at one seven and ah peak gust that was ah two three and we have ah low level wind shear alerts all quadrants appears the frontal passing overhead right now we're right in the middle of everything

INTRA-COCKPIT	
TIME & SOURCE	**CONTENT**
2104:26 CAM-3	No packs, okay
2104:29 CAM-3	I'll get (it) lined up (for) you
2104:46 CAM-1	The (winds) going to be off to the left (too)
2104:53 CAM-1	Not much
2104:58 CAM-1	I don't understand why these guys are requesting runway twenty eight
2105:03 CAM-2	I don't either
2105:06 CAM-2	(Must be sittin there) lookin at a windsock

AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	**CONTENT**
2104:34 GC	November one mike tango unable runway two eight due to the overhead traffic and inbound traffic, wind now zero six zero degrees at one seven
2104:43 N1MT	Okay we'll go on down
2104:46 GC	One mike tango cross the east west
2104:59 RDO-?	Hey Tex ya still there?
2105:02 RDO-?	(Click - click)
2105:05 RDO-?	A stewardess said a ah lady (with glasses) and grey hair, in first class (was) coming over from Houston

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2105:58 CAM-2	Want to put the EPR corrections up there
2106:02 CAM-1	For the packs?
2106:02 CAM-2	Packs off
2106:03 CAM-1	Yeah what, what, what'll we get on (them)

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2105:14 RDO-?	Well I guess that's where she's (at)
2105:20 PA-1	Ah good afternoon ladies and gentlemen, we would like to welcome our New Orleans passengers aboard the continua- of, the continuation of flight seven fifty nine to Las Vegas and San Diego, we'll be ready for takeoff momentarily, we'd like to ask you to please ensure that your seatbelts are all buckled up, we'll be cruising at thirty one thousand feet to Las Vegas and estimated flying time is three hours and ten minutes after takeoff we'll be maneuvering around, circumnavigating some ah some little thundershowers out there so we would like to ask you folks to please remain in your seats, we thank you flight attendant please secure the cabin

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2106:07 CAM-3	Pick up ah, three (more) we got one ninety, gonna go to max
2106:14 CAM-2	One ninety (and) three on the outboards
2106:35 CAM-1	Okay we have the pretaxi and the taxi checklist complete?
2106:39 CAM-?	Yes

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2106:08 LC	Zero three bravo proceed direct to the ah west pad remain south of the east west runway
2106:13 N03B	Zero three bravo roger
2106:22 RDO-2	Clipper seven fifty nine is ready
2106:24 LC	Clipper seven fifty nine maintain two thousand, fly runway heading, cleared for takeoff runway one zero
2106:30 RDO-2	Maintain two thousand, runway heading, cleared for takeoff runway one zero clipper seven fifty nine

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
2106:40 CAM-1	Takeoff checklist		
2106:41 CAM-2	Takeoff check, transponders and DME on, cabin notification and lights		
2106:45 CAM-1	We got 'em		
2106:48 CAM-2	Engineer's check		
2106:49 CAM-3	Complete		
2106:50 CAM-2	Configuration check		
2106:53 CAM-3	Anti-skid		
2106:54 CAM-1	Skid is on		
2106:56 CAM-3	Speed brake		
2106:57 CAM-1	Forward	2106:57 EA 956	And Eastern ah nine fifty six is by the marker
2106:58 CAM-3	Stabilizer trim		
2106:59 CAM-1	It's set		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2107:00 CAM-2	Twenty one three
2107:03 CAM-3	Wing flaps, vee speeds
2107:05 CAM-2	Okay
CAM-1	Okay we've got (ah)
2107:06 CAM-2	Thirty eight (fifty one)
2107:06 CAM-1	Fifteen indicate fifteen green
2107:07 CAM-2	Fifteen fifteen green light
2107:09 CAM-3	Compasses
2107:11 CAM	((Click, click sound))
2107:18 CAM-1	Now we're going out this way
2107:20 CAM-2	All right

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2107:02 LC	Eastern nine fifty six Moisant tower cleared to land runway one zero
2107:06 EA 956	Roger
2107:08 LC	And ah Eastern the wind zero seven zero one seven heavy DC eight er ah heavy Boeing just landed said a ten knot wind shear at about a hundred feet on the final
2107:18 EA 956	Thanks very much

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
2107:25 CAM-3	Takeoff check complete		
2107:27 CAM-1	(Okay spoolin up)		
2107:33 CAM	((Two clicks))		
2107:33 CAM-1	Lights are on		
2107:35 CAM-1	Engines spoolin up Leo		
2107:44 CAM-2	Right turn or left turn after we get out of here?	2107:44 AL 404	Ah tower U.S. Air four oh four is ah ready to go whenever Pan Am is ready to go
2107:48 CAM-1	(A little) north		
2107:50 CAM-2	We're cleared for takeoff		
		2107:51 LC	*U.S. Air four oh four*
		2107:51 PHM 66K	Moisant tower six six kilo
2107:52 CAM-1	I would (suggest) ---		
2107:52 CAM-3	*Looking good*		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2107:53 CAM-1	A slight turn over to the left
2107:56 CAM-2	Okay
2107:56 CAM-3	Takeoff (checks all done)
2107:59 CAM-2	Takeoff thrust
2108:04 CAM-2	(Need the) wipers
2108:06 CAM	((Sound of windshield wipers begins and continues to end of tape))
2108:16 CAM	((Thump sound similar to runway bump))
2108:16 CAM-?	(Eighty knots)

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2108:00 PHM 66K	Moisant tower six six kilo
2108:02 LC	Six six kilo traffic is a helicopter landing at the west pad
2108:06 PHM 66K	This is petroleum six six kilo lifting the ah west pad on a special VFR
2108:14 LC	Zero three bravo traffic is departing the west pad, do you have him in sight
2108:16 N03B	I got him in sight, I'll turn inside of him
2108:19 LC	Okay thank you

INTRA-COCKPIT

TIME & SOURCE	CONTENT
2108:27 CAM	((Click)) ((Windshield wiper speed increases))
2108:28 CAM	((Thump sound similar to runway bump))
2108:33 CAM-1	(Vee R)
2108:34 CAM	((Clunk sound attributed to nose strut topping))
2108:41 CAM-1	Positive climb
2108:42 CAM-2	Gear up
2108:43 CAM-1	(Vee two)

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2108:20 RDO-2	Sixty * is ready on number one
2108:25 N1MT	And ah thirty one mike tango is ready
2108:28 LC	Thirty one mike tango hold short
2108:30 AL 404	And U.S. four oh four is ready
2108:33 LC	U.S. Air four oh four roger

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
2108:45 CAM-1	(Come on back you're sinking Don --- come on back)		
2108:48 CAM	((Thump sound attributed to nose gear striking up locks))		
		2108:51 LC	Clipper seven fifty nine contact departure one two zero point six so long
2108:56 CAM	((Thump))		
2108:57 CAM	((Sound of GPWS)) -- "Whoop whoop pull up whoop		
2109:00 CAM	((Sound identified as first impact))		
2109:02 CAM-?	#		
2109:03 CAM	((Click))		
2109:04 CAM	((Sound of impact))		
2109:05 CAM	((Sound of final impact))		
2109:05	((Sound attributed to end of tape))		

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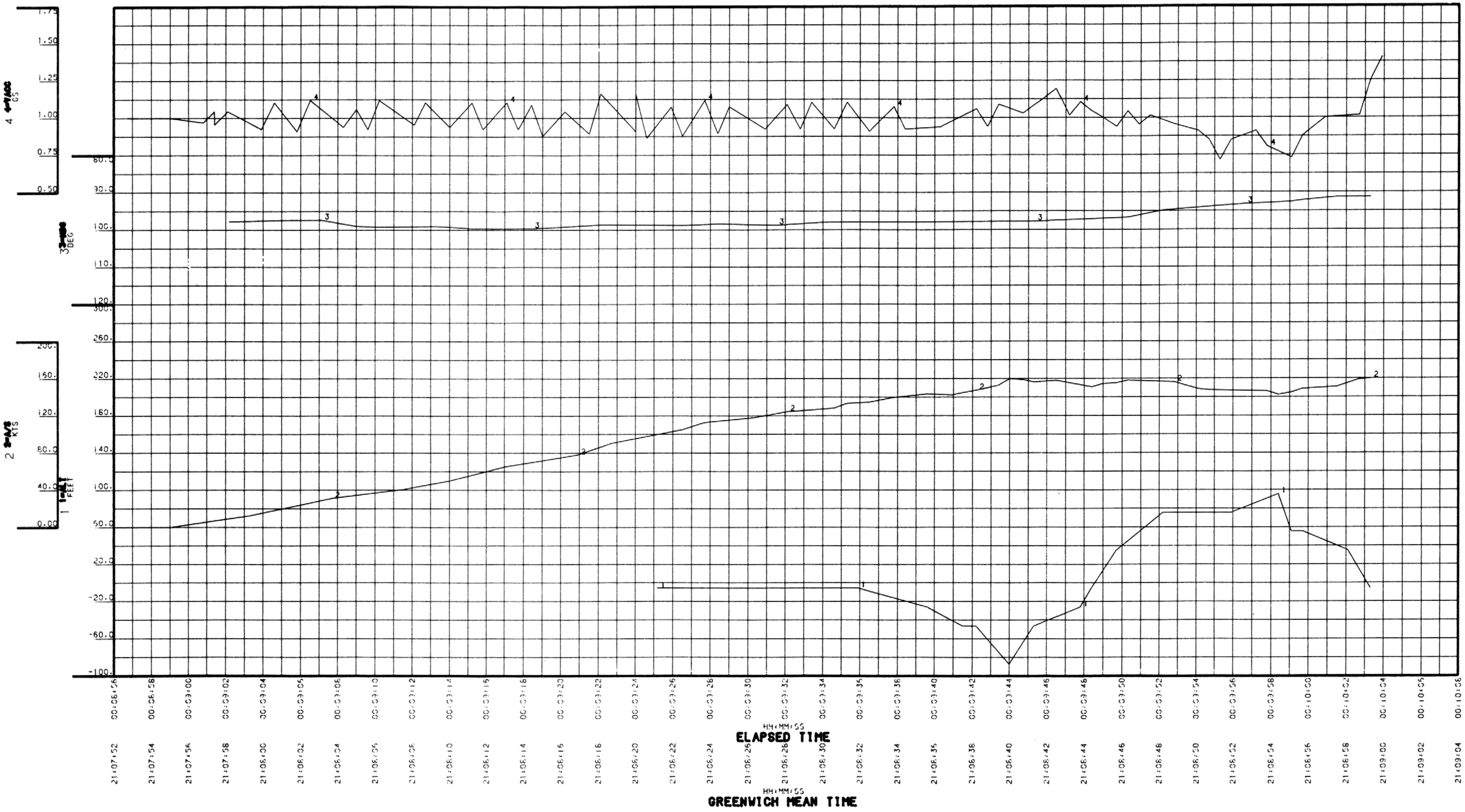
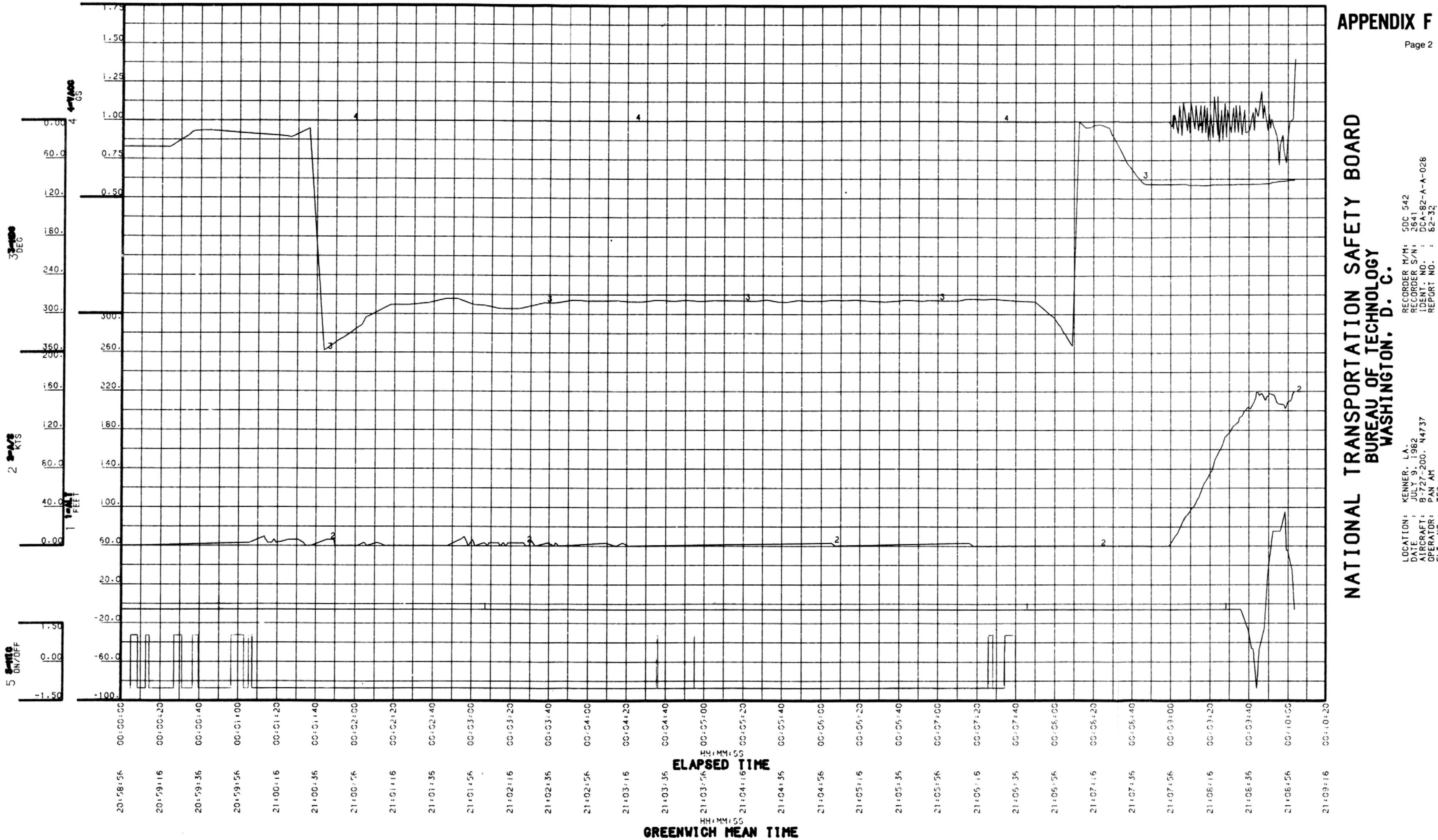


NATIONAL TRANSPORTATION SAFETY BOARD
BUREAU OF TECHNOLOGY
WASHINGTON, D. C.

LOCATION: KENNER, LA.
DATE : JULY 9, 1982
AIRCRAFT: B-727-20C, N4737
OPERATOR: PAN AM
FLT. NO.: 759

RECORDER M/M: SDC 542
RECORDER S/N: 2641
IDENT. NO. : DCA-82-A-A-028
REPORT NO. : 82-32

APPENDIX F



4 ACC GS
3 HDG DEG
2 A/S KTS
1 ALT FEET
5 HIC ON/OFF
HH:MM:SS
ELAPSED TIME
HH:MM:SS
GREENWICH MEAN TIME
NATIONAL TRANSPORTATION SAFETY BOARD
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